THE INFLUENCE OF DEGASSING ON THE EMPLACEMENT OF LAVA FLOWS: IMPLICATIONS FOR PLANETARY MODELING STUDIES. Matthew N. Peitersen[1], Stephen M. Baloga[1] , Lori S. Glaze[1], and Joy A. Crisp[2], [1]Proxemy Research, 20528 Farcroft Lane, Laytonsville, MD 20882, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

Introduction: Morphological analyses of lava flows are frequently used to study planetary volcanology. In the absence of returned samples, the morphology derived from spacecraft images may be the only data available to constrain volcanic processes on other planets. One modeling approach uses morphometry to estimate rheologic parameters. While estimations of yield strength [e.g. 1-4] are most common, both Newtonian (following the method of Nichols [5]) and Bingham plastic (following [6-7]) viscosities have also been calculated [e.g., 8-10] often by assuming conservation of volumetric flow rate (Q) along the path. Relative downflow changes in viscosity and other rheologic parameters have also been addressed by the method of Baloga et al. [11] in several studies [12-13]. The estimated rheologic properties are then used to make inferences about the eruption characteristics, styles of volcanism, and plausible compositions. However, the assumption of a conserved Q clearly conflicts with numerous field observations of terrestrial flows [e.g. 14]. Thus, rheologic estimates based on this assumption may be significantly in error. Using the model of Baloga et al. [11], previous research [12-13] has already considered the effect of volume loss to inactive margins of the flow. We here address one additional mechanism for volume loss; namely, degassing of the emplacing lava flow.

The Degassing Model: We modify a standard flow volume conservation statement to account for the effects of volume loss due to degassing. We assume a Newtonian flow of constant width and slope; the rate of volume loss by degassing is assumed to be proportional to the remaining volume. The governing partial differential equation is then

$$\frac{\partial h(x,t)}{\partial t} + \frac{g\sin\theta}{3}\frac{\partial}{\partial x}\left[\frac{h^3(x,t)}{\nu(x,t)}\right] = -\lambda(h(x,t) - h_\infty)$$

This equation determines the thickness profile of a flow as a function of space and time in the presence of a loss of volatiles, a viscosity that changes with distance along the path of the flow, and a time-dependent depth of flow at the vent.

By assuming steady-state conditions, we derive a simple stepwise numerical solution for thickness:

$$h(x+\Delta x) = \left[\frac{\nu(x+\Delta x)}{\nu(x)}\right]^{1/3}\left[h(x) + \left(\frac{\Delta x \lambda \nu(x)}{g\sin\theta h(x)}\right)\left(\frac{h_\infty}{h(x)} - 1\right)\right]$$

We use this numerical solution to explore how simultaneous changes in viscosity and degassing affect the profile of a lava flow for different sets of parameters. To apply the algorithm, we need values for average slopes (θ), viscosities (ν), and initial thicknesses (h_0), as well as parameters that describe the rate (λ) and magnitude (h) of degassing. The model has been formulated so that the degassing process can be characterized by limited field data.

Results for Mauna Loa: We use field data from the 1984 eruption of Mauna Loa as a terrestrial analog to realistically constrain the model for planetary flows. Flow dimensions (h_0=5 m, length=13 km from breakout to toe), underlying slope (θ=4°), and time of emplacement (t=7.2 days) were taken from the 1A lobe; λ and h_∞ were derived from estimates of degassing based on downflow changes in density of quenched field samples [15]. A number of viscosity scenarios (constant, linearly, and exponentially increasing) were assumed. Model results for an exponentially increasing viscosity (three order of magnitude change) are illustrated in Figure 1.

Conclusions: The presence of even moderate degassing can have a profound influence on the flow profile. In the illustrated case (Figure 1), an increase in bulk density from 2200 to 2600 kg/m3, representing only a 15% volume loss, can decrease the final flow thickness by over an order of magnitude with relatively rapid rates of degassing ($1/\lambda$ =0.9 days). Since, for Newtonian rheology, flow velocity increases by the square of the thickness, the effect on emplacement times can be substantial. For the examined flow in Figure 1, arrival time is more than doubled for even slow rates of degassing ($1/\lambda$=12.5 days), when compared to the no degassing case. For higher rates, emplacement time increases by over an order of magnitude.

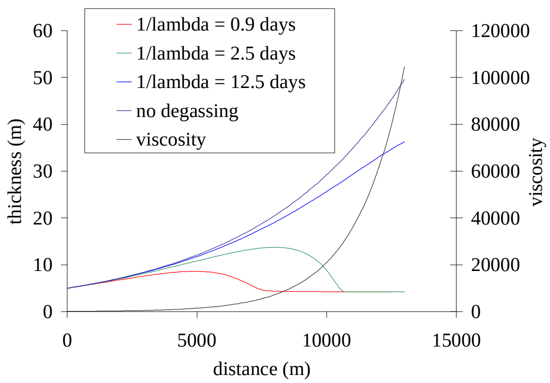

Figure 1. Thickness (h(x)) as function of distance of an analog Mauna Loa 1984 1A flow, for exponentially increasing kinematic viscosity (100 - 100000 m^2/s) and ρ_0 = 2200 kg/m^3. Examples shown are for $1/\lambda$ =0.9 days (red), 2.5 days (green), and 12.5 days (blue). No degassing case (indigo) and viscosity (black) are shown for reference. Note substantial effect of degassing on flow profile, and "rollovers" (decreasing thickness) for high rate (red, green) cases.

Implications for planetary studies: When applied to thickness data from a planetary flow, the degassing model may result in viscosity estimates that are substantially different from those obtained by other models that do not account for this process. For a given flow thickness profile, the degassing model will estimate higher viscosities. Given flows of approximately constant thickness such as those Ascraeus Mons [Figure 2], previous models would estimate more or less constant viscosity. If degassing is present, however, the same profiles can be generated with viscosities increasing downflow. The expected increase in thickness resulting from this is removed by volatile loss. Estimates of effusion rates and emplacement times may be similarly affected.

Constraining the rates and amounts of degassing, or the corresponding lava density changes, emerges as an important issue for understanding the emplacement of terrestrial analog flows. Further investigation of this process is likely to lead to significant revisions of the rheologic estimates for planetary flows and the quantitative aspects of planetary eruptions.

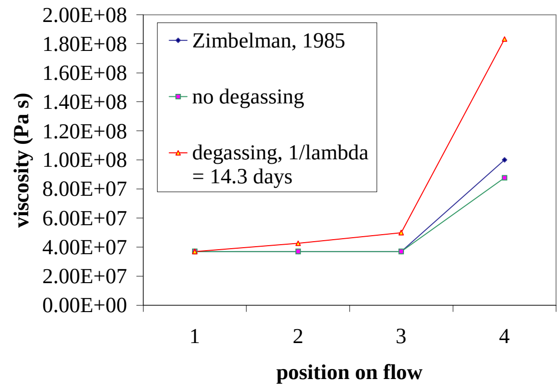

Figure 2. Viscosity estimates for Ascraeus Mons flow A [data from Zimbelman, 1985]. If we assume with no degassing is present, our model's results (green) agree well with Bingham viscosities calculated by Zimbelman [1985] (blue); relatively constant viscosities are predicted. By assuming a moderate density change similar to that found at the Mauna Loa 1A flow (i.e. from 2200 to 2600 kg/m^3 over the emplacement time of 100 days (from Zimbelman), and a relatively fast rate ($1/\lambda$=14.35 days) of degassing, we can generate the same profile using viscosities which are up to 50% higher, and increase downflow. Greater amounts of degassing, or faster emplacement rates, have still greater effect.

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