LAVA FLOW RHEOLOGY: A COMPARISON OF DATA AND THEORY; B.C. Bruno[1], S.M. Baloga[2], G.J. Taylor[1] and M.J. Tatsumura[1] ([1]Planetary Geosciences, Dept. of Geology and Geophysics, University of Hawaii, Honolulu, HI 96822; [2]Jet Propulsion Laboratory, California Institute of Technology, MS 183-601, Pasadena, CA 91109).

This work involves testing a fluid dynamic model of lava flow emplacement by comparing its predictions against measurements obtained from field and photographic studies of terrestrial flows. This model determines changes in flow thickness and width with distance from the source of the flow for different rheological characteristics based on known or assumed initial parameters. Consequently, these results may be used to infer downstream changes in rheology of unconfined flows from the width and/or thickness of the deposits. Thus, this work can be useful in the study of planetary lavas from photographs and other images.

Theory: The Model & The Solution.

In [1], we find an exact analytic solution for unconfined flows with an arbitrary power-law rheology advancing on an inclined plane. Based on earlier work [2,3], we consider flow movement to be the result of both gravitational transport and hydrostatic pressure, and we examine how these forces combine to drive flow movement in the downstream (x) and cross-stream (y) directions by adopting a volume conservation approach. Simplifying assumptions reduce the equation to the dimensionless form:

$$\frac{\partial}{\partial x}(\alpha h^m) = \frac{\partial}{\partial y}\left(\alpha h^m \frac{\partial h}{\partial y}\right)$$

where h is flow thickness, and $\alpha = \alpha(x)$ and m are prescribed by the rheology of the fluid. Smith [4] solved this equation analytically for a Newtonian fluid (m=3) with a constant rheology ($\alpha=1/3\upsilon$, where υ=viscosity) using a similarity transformation. By invoking additional transformations of the dependent and independent variables, we use this same approach to obtain an analytic solution for flows of arbitrary rheology (i.e., arbitrary m and α). The parameter α is unknown and must be modeled; endmember approximations include constant α, linearly decreasing α, and exponentially decreasing α. These choices for α are somewhat arbitrary, but based on our knowledge that, at least for Newtonian flows, α is inversely related to υ.

Data.

We conducted field studies of 5 basaltic flows on Kilauea volcano. We measured longitudinal profiles of flow thickness and width. Flows are individual pahoehoe breakouts, with lengths ranging from 0.6 - 5 m from the point of breakout. Over this length, υ (and thus α) is assumed constant. We also measured longitudinal width profiles of 4 basaltic flows (alkali basalt to basaltic andesite) from aerial photographs and other images. As flow lengths ranged from 2 - 8 km, we can not assume constant υ.

Results: Data vs. Theory.

1) *Basaltic lava flows have m ~ 1 - 2.* Fig. 1 shows a comparison of longitudinal width profiles of sample field data and model predictions, assuming constant rheology. These field data are well approximated by the constant viscosity model, for m between 1 and 2.

2) *Model predicts downstream viscosity increases of 2 - 3 orders of magnitude.* Using m values of 1 and 2, we ran the model for endmember approximations of α. The best fits of the model to sample photographic data are shown for constant α (Fig. 2), linear α (Fig. 3) and exponential α (Fig. 4). In Fig. 2, the data are inconsistent with the model's predictions, indicating non-constant α. Instead, the data are better approximated by linearly or exponentially decreasing α. The downstream υ increases corresponding to the model predictions shown in Fig. 3 and 4 are two and three orders of magnitude, respectively, over a distance of 4 km. The reasonableness of these values [e.g., 5] attests to the validity of this model.

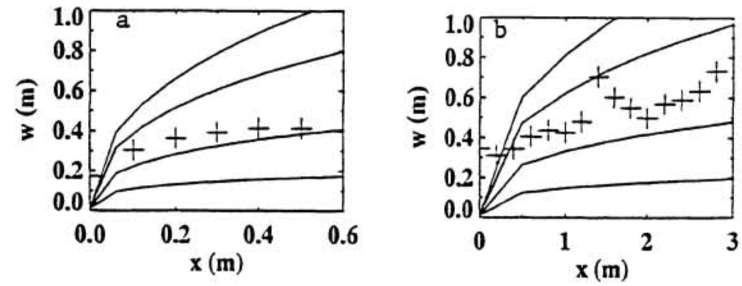

Fig. 1. Plots of half-width w(x), based on field data (+) of (a) ropy pahoehoe and (b) pahoehoe toe. Also shown are the model's predictions for constant α for m=1/2, 1, 2, 3 (bottom to top). The data in (a) and (b) both lie between m=1 and m=2.

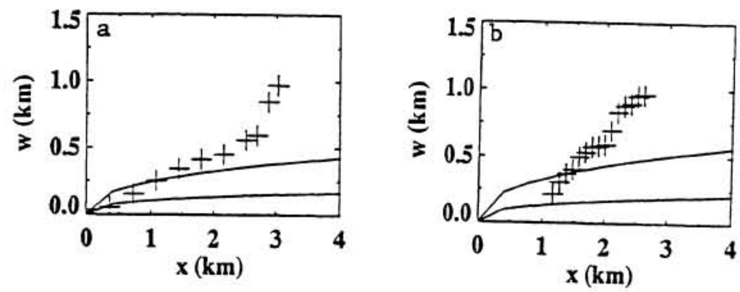

Fig. 2. Plots of half-width w(x), based on photo data (+) of (a) basaltic andesite and (b) alkali basalt. Also shown are the model's predictions for constant α for m=1 (bottom curve) and m=2 (top curve). This constant α model does not appear to fit the data well.

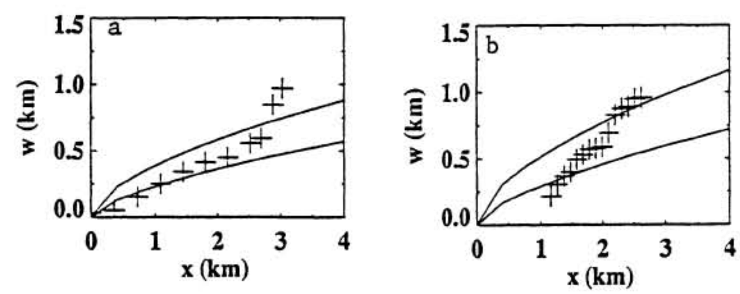

Fig. 3. Plots of half-width w(x), based on photo data (+) of (a) basaltic andesite and (b) alkali basalt. Also shown are the model's predictions for linear α for m=1 (bottom curve) and m=2 (top curve). The corresponding downstream υ increase is approximately 2 orders of magnitude.

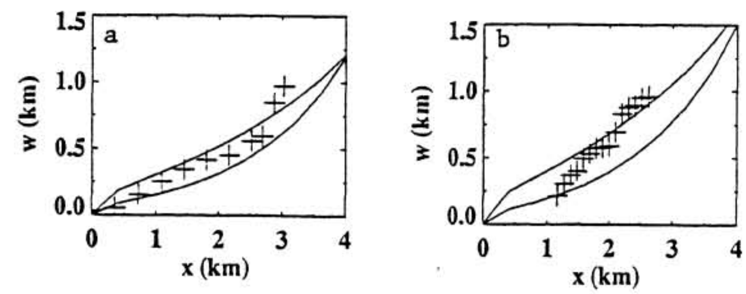

Fig. 4. Plots of half-width w(x), based on photo data (+) of (a) basaltic andesite and (b) alkali basalt. Also shown are the model's predictions for exponential α for m=1 (bottom curve) and m=2 (top curve). The corresponding downstream υ increase is approximately 3 orders of magnitude.

References. (1) Bruno, B.C. *et al.* (1993), *IAVCEI Abstracts 1993*, pp.13. (2) Baloga, S. and D. Pieri (1986), *JGR* **91**, 9543-52. (3) Baloga, S. (1987), *JGR* **92**, 9271-79. (4) Smith, P. (1973), *JFM* **58**, 275-88. (5) Fink, J. and J. Zimbelman (1990), In *Lava flows and domes. Emplacement mechanisms and hazard implications* (J. Fink, ed.), pp. 157-173.