MARTIAN AND TERRESTRIAL LAVA FLOWS

H. J. Moore, U. S. Geological Survey, Menlo Park, CA 94025
J. A. Ackerman, North Dakota State Univ., Fargo, ND 58105

We assume that lava flows can be treated as Bingham fluids, and then, we calculate yield strengths and viscosities for mafic to felsic flows on Earth, near the summit of Ascraeus Mons and Alba Patera on Mars. The calculations require estimates of: effusion rates, flow dimensions, and topographic gradients.

Three models for effusion rates are considered: (1) mixed cooling [1,2], (2) unmixed cooling [1,2], and Graetz number [3,4]. The unmixed cooling model parameters are calibrated with two terrestrial aa flows [5,6,7] and then applied to other flows on Earth and Mars. Effusion rates calculated with the mixed cooling model are about ten times larger than those of the unmixed cooling model; those of the Graetz number model are much lower than those of the unmixed model [see also 8].

To calculate yield strengths and Bingham viscosities, we use: (A) a wide flow model [9], (B) Hulme's model [3], and (C) model 1 of Baloga and Crisp [10]. Model C fulfills kinematic requirements by depositing moving lava from the channel to form stationary levees [10]. All calculations require estimates of effusion rate, topographic gradient, lava density, and acceleration of gravity. In addition, estimates of rest thickness and flow depth are used in Model A, channel and levee widths in Model B, and levee height and channel and flow widths in Model C.

For the Puu Kiai flow in Hawaii [6], we find that both the yield strength and viscosity tend to increase with distance from the vent when the lava density is constant. This trend is similar to previous results [11,12] for Hawaiian flows. No strong trend is found for the 1984 Mauna Loa, other terrestrial, or martian flows when the lava density is taken as constant.

Yield strengths from the three models are more or less the same. Bingham viscosities calculated with the mixed cooling model are about ten times larger than those of the unmixed cooling model; those calculated with the Graetz number model are lower than the unmixed cooling model. Comparison of yield strengths and viscosities suggest that there is a relation between the two (e.g., Fig. 1).

Estimates of compositions of martian flows are subject to many uncertainties [13]. One of these uncertainties is that yield strength and viscosity may vary along the length of the flow. If yield strengths and viscosities are compared using a given set of models, it is found that felsic flows tend to have larger yield strengths and viscosities than mafic flows (e.g., Fig. 1), but the magnitudes of the strengths and viscosities differ among the model sets. Our results suggest that the martian lavas are more akin to mafic and intermediate lavas, such as basalt and basaltic andesite, than felsic lavas, such as rhyolite and trachyte (Fig. 2) [see also 14].

REFERENCES

[1] Pieri, D.C. and Baloga, S.M., 1986, J. Volc. Geotherm. Res., v. 30, p. 29-45.

[2] Harrison, C.G.A. and Rooth, C. 1976, in Aoki, H. and Iizuka, S., eds., Volcanoes and Tectosphere: Tokyo Tokai Univ. Press, p. 103-113.
[3] Hulme, G., 1974, Geophys. J. Roy. Astron. Soc., v. 39, p. 361-383.
[4] Hulme, G. and Fielder, G., 1977, Phil. Trans. Roy. Soc., Lond., ser. A, v. 285, p. 227-234.
[5] Moore, R. B., et al., 1980, J. Volc. Geotherm. Res., v.7, p. 189-210.
[6] Lipman, P. W. and Banks, N.G., 1987, U.S. Geol. Survey Prof. Paper 1350, p. 1527-1567.
[7] Moore, H. J., 1987, U.S. Geol. Survey Prof. Paper 1350, p. 1569-1588.
[8] Cattermole, P., 1987, J. Geophys. Res., v. 92, #B4, p. E553-E560.
[9] Moore, H.J. and Schaber, G.G., 1975, Proc. 6th Lunar Sci. Conf., p. 101-118.
[10] Baloga, S.M. and Crisp, J., 1988, unpublished report, 35p., 5 figs.
[11] Moore, H.J., et al., 1988, Repts. Planet. Geol. Prog.- 1980-1981, NASA TM 82385, p. 269-271.
[12] Fink, J.H. and Zimbelman, J.R., 1986, Bull. Volcan., v.48, p. 87-96.
[13] Moore, et al., 1978, Proc. 9th Lunar Planet. Sci. Conf., p. 3351-3378
[14] Zimbelman, J.R., 1985, J. Geophys. Res., v. 90, Suppl. D, p. D157-D162.

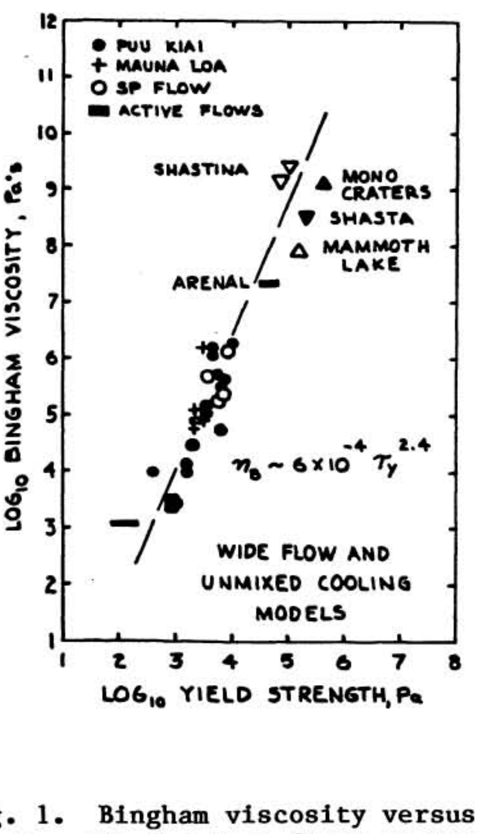

Fig. 1. Bingham viscosity versus yield strength for lava flows on Earth.

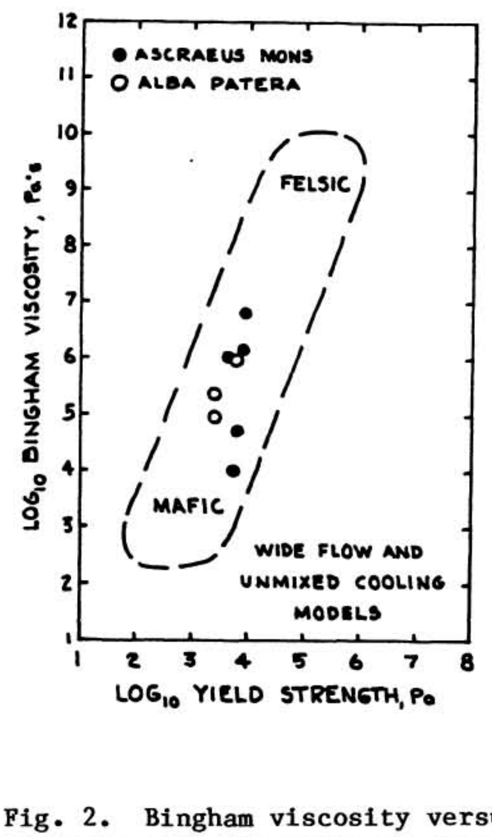

Fig. 2. Bingham viscosity versus yield strength showing martian flows and composition fields.