

GRAVITATIONAL SCALING OF KILAUEA ERUPTIONS; S. Baloga
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The detailed documentation of recent Kilauea eruptions and recent theoretical models permit us to examine analog eruptions scaled for the value of gravity on the surface of Mars. The influence of gravity is summarized below for the dimensions of lava flows on the surface and the depth of the magma chamber.

The Figure below shows the result of scaling an emplacement model [Baloga and Pieri, 1986; Baloga, 1987] for episode 4 of the 1983-1984 Puu Oo eruption sequence [Baloga and Crisp; 1988]. For this flow, there is enough information available to compare the predictions of the model with field observations. The agreement is generally very good, which gives us confidence in scaling the model for Mars gravity. In performing this scaling, only the value of gravity was changed; other parameters such as topography, flow rate, and eruption rate were retained at their terrestrial values. The gravity-scaled results show that the corresponding flows on Mars would be thicker than their terrestrial counterparts and advance more slowly. The rate of flow thickening with distance from the vent is also higher on Mars because the additional cooling time during emplacement allows more of a viscosity increase at any station along the flow path.

Wadge [1981], Hardee [1986, 1987], and others have used a simple open pipe model for the transport of magma from the chamber to the surface for terrestrial eruptions. By slightly modifying Poiseuille's formula for the flow of a viscous fluid in a pipe, we obtain the formula

$$P_0 = \rho g L + 8 \mu Q L / \pi R^4$$

where P_0 is the excess magmatic pressure in the chamber, ρ is density, μ is the viscosity, L is the depth of the chamber, Q is the eruption rate, and R is the radius of the conduit to the surface. This formula clearly shows the pressure above hydrostatic required to produce a given eruption rate. With the assumption that the driving pressure is the same on Mars, we obtain the scaling relationship for the depth of the magma chamber,

$$L_m / L_e = (g_e + g^*) / (g_m + g^*)$$

where $g^* = 8 \mu Q / \rho \pi R^4$, and the "e" and "m" subscripts refer to Earth and Mars. Depending on the size of g^* , the relative depth can range from 1 to about 2.6. The table below shows the relative depths (L_m/L_e) of the Kilauea magma chamber scaled for Mars gravity using data on three episodes of the Puu Oo eruption and a viscosity of 100 Pa·s. Values for the conduit radius for these episodes have been given by Hardee [1987]. The conduit radii computed by Hardee range from about 3 to 3.5 m for the episodes shown below. For radii above 3 m, the g^* terms are inconsequential and the relative depth of the chamber on Mars is about 2.6. However, such radii are in excess of commonly observed dike dimensions. If the conduit radius is set at a more modest 1 meter, then the relative depth of the magma chamber on Mars is about twice its terrestrial value, as shown in the Table.

TABLE: RELATIVE DEPTH OF MAGMA CHAMBER ON MARS
 FOR Puu Oo ERUPTIONS AND 1 m CONDUIT

EPISODE	ERUPTION RATE (m ³ /s)	RELATIVE DEPTH (L_m/L_e)
2	15	2.2
10	52	1.7
18	56	1.7

REFERENCES: Baloga, S., 1987, JGR, 92, 9271-9279; Baloga, S. and D. Pieri, 1986, 91, 9543-9552; Baloga, S. and J. Crisp, 1988, Simulations of lava flows on Mars, NASA MEVTV Program Working Meeting; Volcanism on Mars, Oahu, Hawaii.; Hardee, H.C., 1987, Chap 54. U.S.G.S Professional Paper 1350; Hardee, H.C., 1986, J.V.G.R., 28, 275-296; Wadge, G., 1981, J.V.G.R., 11, 139-168.

FIGURE CAPTION : Computed flow thickness of a gravity-scaled model for Puu Oo eruption, episode 4. X's indicate depth with Mars gravity, filled O's denote depth with Earth gravity, and open O's are field measurements.

