THE 1984 MAUNA LOA ERUPTION AND PLANETARY LAVA FLOWS

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Lava flows on the Moon and Mars are commonly treated as fairly simple systems whereas observations of terrestrial lava flows indicate that they are often complex. For example, the main flow system of the 1984 Mauna Loa eruption [1] developed in four distinct stages that overlap in time [2]: (A) rapid advance of a narrow aa sheet; (B) development of a channel within the aa sheet that conducted lava from the vents to the lower reaches; (C) development of blockages and obstructions in the channel that produced ebbing and surging flow, overflows, levees, and lava ponds on the aa sheet; and (D) onset of waning stages during which the lava channels drained and distal parts of the flow thinned and spread. Significant variations occurred in the lava flowing in the channel from the vent toward the toe: (1) densities of samples from the flowing lava increased from less than 530 to more than 2,400 kg/m^3; (2) temperatures of the most fluid lava decreased from 1140 °C to as low as 1086 °C; (3) concentrations and sizes of warm to incandescent objects increased; (4) apparent viscosity increased dramatically; (5) flow changed from Newtonian to pseudoplastic; and (6) the volume flow rates decreased.

Apparent viscosities of the lava were calculated from observed velocities, assumed densities based on samples from the flowing lava, and flow dimensions along the main flow. On any given day, apparent viscosities increased downstream. On April 2, they were about 10^2 Pa•s at the vents, 10^3 Pa•s at 3 km from the vents, 10^5 Pa•s at 15 km from the vents, and near 10^7 Pa•s at the toe. Apparent viscosity at the vents increased to about 2×10^3 Pa•s by April 13. These increases in apparent viscosity were probably related to (A) increase in the concentrations of solid debris, crystals, and plastic clots; (B) reduction in gas and bubble content; (C) decrease in temperature; and (D) reduction of stresses and shear rates.

The character of flow probably varied along the length of the flow from Newtonian, through Bingham, to pseudoplastic. Other fluid models may also apply [3,4]. Estimated stresses and shear rates for the lava compare favorably with laboratory data at similar temperatures (1120-1140 °C) [5].

Volume flow rates at the vents on April 3 were about 560 m^3/s, about 12 times higher than at 15 km downstream. Mass flow rates, calculated with the densities used in calculations of apparent viscosities, indicated a mass loss along the flow that could not be accounted for by ponding, overflows, or gas loss. With certain assumptions, conservation of mass requires a lava density at the vents of about 220 kg/m^3, implying a mass flow rate about 1.2×10^5 kg/s. If these masses were deposited with an average bulk density of 2,200 kg/m^3, the volume flow rate would appear to be 56 m^3/s.

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The implications of the above results for planetary geology are clear. Lava flows cannot necessarily be modeled as simple flow units because they may develop in time-dependent stages and their rheological properties vary with time. Volume flow rates during an eruption depend, in part, on the volatile content of the lava. These volume flow rates differ from the volume flow rates calculated from post-eruption flow dimensions and the duration of the eruption [6,7] and also from those calculated using models that assume a constant density [8,9,10]. Estimation of mass flow rates might be more realistic than volume flow rates because the masses of volatiles in lavas are usually small, but the variable and sometimes unknown densities also impose severe limitations on mass estimates.

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