

**RECONSTRUCTION OF THE DYNAMICS OF THE 1800-1801 HUALALAI ERUPTION:
IMPLICATIONS FOR PLANETARY LAVA FLOWS** Stephen Baloga¹ and Paul Spudis² 1. Code SLC,
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The 1800-1801 eruption of alkalic basalt from the Hualalai volcano, Hawaii provides a unique opportunity for investigating the dynamics of lava flow emplacement with eruption rates and compositions comparable to those that have been suggested for planetary eruptions. Field observations [1] suggest new considerations must be used to reconstruct the emplacement of these lava flows. These observations are: 1) The flow traversed the 15 km from the vent to the sea so rapidly that no significant crust formed and an observation of the eruption reported that the flow reach the sea from the vent in approximately 1 hour; 2) The drainage of beds of xenolith nodules indicates a highly fluid, low viscosity lava; 3) Overspills and other morphologic evidence for a very low viscosity host fluid; 4) No significant longitudinal increase in flow thickness that might be associated with an increase in the rheological properties of the lava; and 5) the relatively large size of channels associated with the flow, up to 80 meters across and several km long [1].

Models for many geologic mass movements and fast moving fluids with various loadings and suspensions approximate the flow velocity by

$$u = \sqrt{\frac{hg \sin \theta}{C_f}} \quad (1)$$

where g is gravity, θ is the slope, and C_f is a *dimensionless* friction factor that has to be determined empirically. The velocity u , the friction factor, and the original depth of the flow are all unknown so additional considerations must be used to develop inferences about the dynamics of the eruption. There are four zones identified where the slope and width are roughly constant in each reach. These values are shown in Table 1. Requiring the model to be applicable in each zone allows the unknown quantities to be estimated for the early flooding stage of eruption before a channel network developed.

For the early stage of emplacement, we assume that the volumetric flowrate $Q (= u h w)$ is a quantity that is approximately conserved along the flow path. In the steady state, this flowrate has a single value, Q_0 , that is the same in each zone, i.e.,

$$Q_0 = u_i h_i w_i \quad (2)$$

where the subscript i refers to a particular zone. By using eq. (1) in eq. (2), we get a constraint on the ratio of the thickness of the flow in each section given by :

$$\frac{h_i}{h_r} = \left(\frac{w_r}{w_i}\right)^{2/3} \left(\frac{\sin \theta_r}{\sin \theta_i}\right)^{1/3} \quad (3)$$

where the thickness of the flow in a particular zone is given relative to a reference value that must be determined by field observation. The reference values are taken as those in zone 1 although any zone could be chosen. Table 1 shows the thickness of the flow in each of the zones based on the measured values of the flow widths and slopes and a field estimate of 5 m for the depth in zone 1. Although it is difficult to establish flow thicknesses from post-emplacement conditions, we consider the values in the Table to be consistent with field observations.

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TABLE 1

Zone	L (km)	W(m)	Slope	u(m/s)	h (m)
1	3.5	1400	12.5°	10 ¹	5
2	4	1150	9.5°	9.8	6
3	5	1200	3.8°	7.1	7.9
4	2.5	2500	1.2°	3.8	7.2

The continuity of the volumetric flowrate along the path of the flow and eq. (4) can be used to express the velocity in each of the zones as

$$u_i = u_r \left(\frac{w_r \sin \theta_r}{w_i \sin \theta_i} \right)^{1/3} \quad (4)$$

The velocity in each of the zones can be reconstructed by knowing one velocity in a particular zone. Guest *et al.* [1] have estimated a minimum local flow velocity in zone 1 to be 10 m/s. Using this result as the reference value, Table 1 gives the zonal flow velocities. This set of velocities indicates that the transit time from the crater to the ocean was about 35 minutes.

This type of model produces a longitudinal thickness profile that is relatively flat in spite of the dramatic changes in slope and flow width. In contrast, the 1A flow of the Mauna Loa eruption increased in thickness along the flow path from a few meters or less to more than 25 m near the front. This flow required between 4-5 days to attain its full extent and was accompanied by a significant increase in the rheological parameters of the magma during transit.

Two significant characteristics of the emplacement can be computed from the values reconstructed above, namely, the volumetric flowrate and the friction coefficient. From the definition of flowrate, we find that the flow rate must have been $7 \times 10^4 \text{ m}^3/\text{s}$ and the uncertainties in the estimates suggest that the flowrate could be even higher. This is almost two orders of magnitude higher than the 1950 Mauna Loa eruption, which attained a peak of $3000 \text{ m}^3/\text{s}$ [2].

As a check of the consistency of the model, we have examined the flow conditions in the deepest channels. The largest channel is approximately rectangular in shape with a width of 80m and a depth of 18m. The parameters derived above give a depth of 37m for this channel geometry. This channel must have been completely filled at some point during the eruption and the reconstructed eruption conditions easily fulfill this requirement.

Conclusions The overall dimensions of the flow are consistently reproduced by a dynamic model taken from turbulent, mass movements, and sedimentation theory produces results consistent with measured dimensions and field observations. The eruption rate must have been approximately $10^5 \text{ m}^3/\text{sec}$, roughly two orders of magnitude higher than the 1950 Mauna Loa flow, and comparable to eruption rates cited for large lava flows on Mars and the Moon. The 1800-1801 eruption of the Hualalai volcano is a better analog for planetary eruptions with the high effusion rates than other terrestrial eruptions.

REFERENCES [1] Guest J.E. *et al.* (1993) *Geology*, submitted [2] Malin M. (1980) *Geology* 8, 306