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LAVA CRUSTS AND FLOW DYNAMICS. C.R.J. Kilburn, Environmental Science Division, Lancaster University, Lancaster, LA1 4YQ, U.K, and Osservatorio Vesuviano, Napoli, Italy.

Lava flows can be considered as hot viscous cores within thinner, solidified crusts. Interaction between crust and core determines a flow's morphological and dynamical evolution. When the lava core dominates, flow advance approaches a steady state. When crusts are the limiting factor, advance is more irregular. These two conditions can be distinguished by a timescale ratio comparing rates of core deformation and crustal formation. Aa and budding pahoehoe lavas are used as examples of core- and crustal-dominated flows respectively. A simple model describes the transition between pahoehoe and aa flow in terms of lava discharge rate, underlying slope and either the thickness or velocity of the flow front. The model shows that aa morphologies are characterized by higher discharge rates and frontal velocities and yields good quantitative agreement with empirical relations distinguishing pahoehoe and aa emplacement on Hawaii.

Interaction between the core and crust of a lava produces a variety of surface morphologies [1,2], cooling regimes [3] and modes of flow advance [4,5]. Such variations are especially evident comparing the main categories of subaerial basaltic lava, *pahoehoe* and *aa* [6]. Pahoehoe lavas have smooth crusts, typically thicker than 1-3 cm, which break locally across a flow front; advance occurs unevenly by the extension of numerous small tongues [6,7,8]. Aa lavas have irregular surfaces, usually hidden beneath loose debris; crustal failure is widespread and fronts tend to advance steadily as single units [8,9,10]. The clearest quantitative data distinguishing pahoehoe and aa emplacement concern flow discharge rate (Q), higher values of Q being associated with aa morphology [7,11].

It is proposed that such a discharge-rate control reflects a critical condition for lava crusting. Lava crusts are important because of their high tensile strength [8,9]. Nevertheless, it is normal for crusts to be disrupted during the early stages of flow growth. Crustal restraint thus depends on how quickly broken crust can heal compared with how quickly it continues to be deformed by movement of the lava interior. When healing is slow, emplacement is governed by the lava core; when healing is fast, emplacement is dominated by crustal resistance. Transitional conditions occur when the rates of core deformation and of crustal healing are comparable. In terms of process timescales, core-dominated flow occurs when the timescale of core deformation (t_{def}) is smaller than the timescale of crustal healing (t_h); crustal-dominated flow is described by $t_h/t_{def} < 1$; and transitional conditions coincide with $t_h/t_{def} = 1$.

A recent model which treats lava fronts as newtonian fluids within brittle crusts [9], and which accounts for the final planimetric shapes of aa flow fields [9], as well as the positive dependence of aa flow length on discharge rate [8], indicates that, for core-dominated advance: (a) the mean frontal velocity u depends on Q and slope angle ß through the relation $u^3 = (Q \sin\beta)(t_h/t_{def})^2/(3\,t_h^2)$, and (b) Q and mean frontal thickness h are linked by $Q = 3h^3 (t_h/t_{def})/(t_h \sin\beta)$. Observed minimum thicknesses of pahoehoe crust are consistent with values of $t_h \sim t_{ch}$, the timescale of initial surface chilling [3,8,9; nominally 200 s for basalt]. Since $(t_h/t_{def}) < 1$ for crustal-dominated flow, the equations above yield for the emplacement of pahoehoe lavas ($t_h = t_{ch}$):

$$u^3 < (Q \sin\beta)/(3\,t_{ch}^2) \qquad (1)$$

and

$$Q < 3h^3/(t_{ch} \sin\beta) \qquad (2)$$

Core-dominated, aa lavas are thus expected when equations (1) and (2) are not satisfied. Knowing the slope angle and flow front thickness (a surrogate measure for the lava's physical properties [8]), equations (1) and (2) can be used to describe conditions for aa and pahoehoe development in terms of Q and u. Using Hawaiian lavas as an example (ß between 3^o and 5^o; maximum transitional values of h between 3 and 5 m [8]), equations (1) and (2) suggest that (a) pahoehoe must occur for $Q < 4\ m^3s^{-1}$ and $u < 0.01\ ms^{-1}$, and (b) aa must occur for $Q > 40\ m^3s^{-1}$ and $u > 0.03\ ms^{-1}$; at intermediate values of Q and u, the preferred flow morphology depends on the specific combination of ß and h. These limits compare extremely well with those determined empirically for historical lavas on Mauna Loa and Kilauea [7]: pahoehoe exclusively when $Q < 5\ m^3s^{-1}$ and $u < 0.007\ ms^{-1}$, and aa exclusively when $Q > 20\ m^3s^{-1}$ and $u > 0.02\ ms^{-1}$. Such agreement confirms the importance of crusts on lava flow development. It also suggests that equations (3) and (4) may be used to place upper limits on the mean discharge rate and frontal velocity of a pahoehoe lava once its frontal thickness and the mean underlying slope are known.

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