Topographic and stochastic influences on pāhoehoe lava lobe emplacement

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Basalt is the most common rock type on the surface of terrestrial bodies throughout the Solar System and—by total volume and areal coverage—pāhoehoe flows are the most abundant form of basaltic lava on Earth. Models of flow field development are important for understanding the hazards imposed by terrestrial lava flows and for interpreting the significance of lava morphologies on Earth and other planetary surfaces. However, at present, such models are limited by the availability of dynamic dimensional measurements of active flows and the characterization of random influences on flow emplacement. This study addresses this issue by characterizing topographic and stochastic influences on active pāhoehoe lobes from Pu‘u ‘Ō‘ō on Kīlauea, Hawai‘i, during 21–26 February 2006 using oblique time-lapse stereo-photogrammetry and differential global positioning system (DGPS) measurements. At this time, the local discharge rate supplying lava to a distal lobe was 0.0061 $\pm$0.0019 m^3/s. This rate was generally constant during the period of observation, but every 4.13 $\pm$0.64 minutes there was a 2- to 6-fold increase in the areal coverage rate. This periodicity is attributed to the time required for the pressure within the liquid lava core to exceed the cooling-induced strength of its margins. The pāhoehoe flow advanced through a series of down-slope and cross-slope breakouts, which began as 0.2 m-thick units (i.e., toes) that coalesced and inflated to become approximately meter-thick lobes. The lobes were thickest above the lowest points of the initial topography and above shallow to reverse-facing slopes, defined relative to the local flow direction. The flow path was typically controlled by high-standing topography, with the zone directly adjacent to the final lobe margin having an average relief that was a few centimeters higher than the lava-inundated region. This suggests that microtopography (i.e., cm-scale relief) can exert strong controls on pāhoehoe flow paths by impeding peripheral toes and confining the interior portions of flow. This study also develops models to explore the effects of random and correlated growth processes during the emplacement of pāhoehoe lobes. Results show that cycles of enhanced areal spreading and inflation can be reproduced by simulating the preferential growth of lava lobes in the direction of new breakouts using a probability distribution that governs the possibility of the correlated emplacement of lava parcels from the flow margins. These examples demonstrate the value of time-series observations of active pāhoehoe emplacement processes. It further clarifies the need for future observations of dynamic topography coupled with surface temperature distributions to determine how thermo-rheological parameters affect the location and frequency of new breakouts as well as the balance between areal spreading and inflation.