



Emplacement of mafic lava flows: role of insulated transport and inflation

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Pahoehoe lava flow fields consist of numerous smooth surfaced lobes and feature surface flow structures such as, tumuli, lava-rises and lava-rise pits. Their key constituents are pahoehoe sheet lobes with typical aspect ratios (a.r.) of ~ 0.15 (range, 0.05-0.25). These lobes exhibit a three-part structural division of vesicular basal crust, crystalline lava core, and vesicular upper crust that correspond to the bottom crust, molten core and the surface crust of an actively inflating sheet lobe. Furthermore, adjacent lobes that inflated concurrently feature lava-rise sutures at their margins. These flow structures are a testimony of insulated transport and inflation, processes that govern the emplacement of pahoehoe. The lava is transported beneath a coherent stationary crust reducing cooling during transport to $< 1^\circ\text{C}/\text{km}$. This crust grows in thickness during emplacement and is held up by a lower horizon of viscous lava. Lava tubes and tumuli form as the result of localization of flow along preferred internal pathways and lobe inflation. Eventually, the flow is restricted to a few preferred pathways that feed lava to the steadily advancing flow front, where it breaks out to form new inflating lobes. In due course, the flow of lava is confined to a new extension of the lava pathway. It is by this step-wise mechanism of forming lobe after lobe, pahoehoe flows gradually make their way across the landscape without much cooling of the flow interior. In doing so they have formed $> 300\text{-km}$ -long flow fields, which represent some of the longest lava flows known on Earth.

A'ā lava flows are characterized by a coherent core floored and topped by horizons of scoriaceous clinker breccia. The lava is transported from source to active flow fronts in open channels where heat loss is uninhibited. In the channel, the flow velocity is highest at the surface and induces tearing of viscous lava forming the flow top

breccia that is dumped at the front of the flow, creating the basal breccia that the coherent liquid core advances over. Therefore, a'a lavas are cooling limited flows and the flow length (size) is controlled by rate of effusion. Accordingly, a'a rarely reaches the lengths obtained by pahoehoe as is illustrated by the ongoing Pu'u O'o eruption at Kilauea, Hawaii.

The mechanisms of flow inflation and insulated transport are by and large not considered to feature in the emplacement of a'a. However, our recent studies on the ~1150AD Kapelluhraun a'a flow field in SW-Iceland tell a different story. Kapelluhraun is an archetypical a'a flow with a distinct central channel by which the lava was delivered to the then active flow fronts. The lava of the flow fronts is compound in that they consists of multiple meters-thick a'a lobes, characterized by sheet-like geometry (a.r., ~0.32; range, 0.11-0.58) and less commonly tumulus-like profile. Lava-rise sutures mark the margins of adjacent lobes. In vertical sections, the coherent lobe interiors are enclosed in decimeter-thick flow breccia consisting of spiny scoriaceous clinker clasts. Upper and lower surfaces of the coherent interior contain bulbous spiny clinker-like protrusion frozen in place during the process of viscous tearing. Distinct vertical arrangement of internal structures are present in the coherent part, defining a decimeters-thick hypocrySTALLINE upper and lower vesicular horizon separated by meters-thick holocrySTALLINE and non-vesicular lava core. Thus, a five-fold vertical division into a basal breccia, lower vesicular horizon, dense lava core, upper vesicular horizon and flow top breccia is apparent in the Kapelluhraun sheet lobes. We interpret the breccia horizons to be equivalent to the brittle part of the crust on pahoehoe sheet lobes, whereas the vesicular horizons of the coherent section correspond to the viscous portion of the crust. The dense lava core represents the part filled with fluid lava during emplacement. These observations indicate that flow inflation occurs in a'a flows and may play an important role in lobe emplacement at active flow fronts.

When assessing hazards and risks from mafic lava flows, it is important to account for the mechanics of endogenous growth (i.e. insulating emplacement and inflation). Although these lavas do not travel at life-threatening speed, they grow as long as lava is supplied from the source vents and destroy anything in their path. Flow inflation makes it easy for the lava to overcome any obstacles in their path, whether they are natural or manufactured barriers.