Inflation structures and dynamics of pahoehoe lava flows

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Fluidal basaltic lava on a gentle slope to a flat field forms pahoehoe flow lobes at low extrusion rates, and sheet flows at high extrusion rates. Inflation of flow lobes is common to these flows. Flow lobes consist of upper crust, core and lower crust in descending order. Both crusts are formed upon emplacement and during the inflation of the flow lobe, while the core solidified after the injection of lava to the lobe stopped. The rate of lava supply and the volume of flow lobes are linearly correlated, which are mainly controlled by cooling of lava. Flow lobes stop advancement due to heat loss to the environment, when brittle crust thickens and hinders the lobe from deforming freely.

Pahoehoe lava flowing as interconnected small flow lobes at a low extrusion rate often forms inflation structures such as tumuli. Recent studies have shown that the inflation of compound flow lobes is common to fluidal basaltic flows on a gentle slope to a flat field and an important mechanism of forming vast sheet-like lava flows. Columbia River Basalts and some sheet flows on mid-ocean ridges, which were once thought to be formed by rapid extrusion of copious lava, are now interpreted to be formed by gentle extrusion of lava at very low to moderate rates. We can deduce the rate of lava supply and the period of lava extrusion by examining such inflation-related structures. We describe the subaerial and subaqueous flow lobes from Hawaii, Mt. Fuji and the Oman Ophiolite, and discuss the controlling factors of flow-lobe formation.

On 1990-91 flow of Kilauea secondary flows leaked out from cracks on the surface form tumuli a few meters to several tens of meters across. 1843 flow of Mauna Loa has the largest tumuli in Hawaii, which exceeds 100 m in length. The Hawaiian tumuli are composed of coalesced flow lobes and have many outflows through inflation cracks.

A.D. 864 Aokigahara lava of Fuji volcano has subaqueous tumuli on the terminal ends along the coasts of Motosuko and Shyojiko. Unlike Hawaiian tumuli, they lack outflows through inflation cracks and the banding on the crack walls has textures indicating larger degrees of undercooling, which are consistent with their formation under water.

The south rift zone of Loihi seamount has abundant small conical lava cones with flat tops up to 2 km in diameter. Steep slopes of these cones are covered with elongate pillows flowing downslope, however, the flat tops are overlain by lobate sheet flows and pahoehoe flows. Pahoehoe lobes are generally inflated with fractures displacing the surface crust, and hollow lobes are common among the lobate sheets.

The Oman Ophiolite is the world largest and best preserved and was formed at a fast spreading ridge in the Tethys ocean. Low relief is inferred for the paleovolcanic edifices from scarcity of volcaniclastic materials, and abundant sheet flows among pahoehoe lobes. A flow field mainly consisted of pahoehoe flows has many hollow lobes with empty upper third of the cores, which were drained out after inflation of the lobes.

Time for emplacement of inflated flow lobes can be estimated by the thickness of brittle crust, which may be seen on the crack surfaces through inflation of the lobes. Duration of inflation is given by the thickness of the crust of hollow lobes, which solidified before drainage of lava inside, and by banding on the inflation cracks of tumuli as summing the time for cooling of individual bands either below the solidus or the glass transition temperature.

Analyses of Graetz numbers for the above flow lobes and tumuli show that the lateral extension of the lobes is cooling limited, which results in the linear relationship between the rate of lava supply and the volume of lobes. Flow lobes stop advancement due to heat loss to the environment, when brittle crust thickens and hinders the lobes from deforming freely.