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Lava flow superposition: the reactivation of flow units in compound flow fields

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Long-lived basaltic eruptions often produce compound ‘a‘ā lava flow fields that are constructed of many juxtaposed and superposed flow units. We have examined the processes that result from superposition when the underlying flows are sufficiently young to have immature crusts and deformable cores. It has previously been recognised that the time elapsed between the emplacement of two units determines the fate of the underlying flow[1], because it controls the rheological contrast between the units. If the time interval is long, the underlying flow is able to cool, degas and develop a rigid crust, so that it shows no significant response to loading, and the two units are easily discernable stratigraphically. If the interval is short, the underlying flow has little time to cool, so the two units may merge and cool as a single unit, forming a ‘multiple’ flow[1]. In this case, the individual units are more difficult to distinguish post-eruption. The effects of superposition in intermediate cases, when underlying flows have immature roofs, are less well understood, and have received relatively little attention in the literature, possibly due to the scarcity of observations. However, the lateral and vertical coalescence of lava tubes has been described on Mt. Etna, Sicily[2], suggesting that earlier tubes can be reactivated and lengthened as a result of superposition.

Through our recent analysis of images taken by INGV Catania during the 2001 eruption of Mt. Etna (Sicily), we have observed that the emplacement of new surface flows can reactivate underlying units by squeezing the still-hot flow core away from the site of loading. We have identified three different styles of reactivation that took place during that eruption, which depend on the time interval separating the emplacement of the two flows, and hence the rheological contrast between them. For relatively long time intervals (> 2 days), hence high rheological contrasts, superposition can cause an overpressure to develop in the underlying flow front that leads to crustal rupture, and the subsequent extrusion of a small volume of high yield strength lava. Following shorter intervals (1 to 2 days), the overpressure caused by superposition can result in resumed, slow advance of the immature flow front. On timescales of < 1 day, where there is little rheological contrast between the two units, the thin intervening crust can be disrupted during superposition, allowing mixing of the flow cores, large-scale reactivation of both flows, and widespread channel drainage. Because the remobilisation of previously stagnant lava can occur swiftly and unexpectedly[3], it may pose a significant hazard during the emplacement of compound flow fields. Constant monitoring of flow field development to identify areas where superposition is occurring is therefore recommended, as this may allow potentially hazardous rapid drainage events to be forecast.

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