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The significance of late-stage processes in lava flow emplacement: squeeze-ups in the 2001 Etna flow field

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The general processes associated with the formation and activity of ephemeral boccas in lava flow fields are well documented (e.g. Pinkerton & Sparks 1976; Polacci & Papale 1997). The importance of studying such behaviour is illustrated by observations of the emplacement of a basaltic andesite flow at Parícutin during the 1940s. Following a pause in advance of one month, this 8 km long flow was reactivated by the resumption of supply from the vent, which forced the rapid drainage of stagnant material in the flow front region. The material extruded during drainage was in a highly plastic state (Krauskopf 1948), and its displacement allowed hot fluid lava from the vent to be transported in a tube to the original flow front, from where it covered an area of 350,000 m2 in one night (Luhr & Simkin 1993). Determining when a flow has stopped advancing, and cannot be drained in such a manner, is therefore highly important in hazard assessment and flow modelling, and our ability to do this may be improved through the examination of relatively small-scale secondary extrusions and boccas.

The 2001 flank eruption of Mt. Etna, Sicily, resulted in the emplacement of a 7 km long compound ‘a‘ā flow field over a period of 23 days. During emplacement, many ephemeral boccas were observed in the flow field, which were active for between two and at least nine days. The longer-lived examples initially fed well-established flows that channelled fresh material from the main vent. With time, as activity waned, the nature of the extruded material changed. The latest stages of development of all boccas involved the very slow extrusion of material that was either draining from higher parts of the flow or being forced out of the flow interior as changing local flow conditions pressurised parts of the flow that had been stagnant for some time. Here we describe this late-stage activity of the ephemeral boccas, which resulted in the formation of ‘squeeze-ups’ of lava with a markedly different texture to that of the surrounding ‘a‘ā flow surface. The appearance of the squeeze-up material in this flow is similar to that of the plastic lava forcibly drained from the front of the Parícutin flow.

The squeeze-up features demonstrate marked morphological variation, which was found to reflect the rheology of the material being extruded, the volume of material being extruded, the extrusion rate and the geometry of the source bocca. We describe the final morphology of squeeze-ups from the 2001 flow field, which ranges from relatively fluid flows to extrusions of high-strength material that accumulated above the source bocca, forming features more akin to tumuli. Although tumulus-like in overall shape and dimensions, the morphology and inferred growth mechanisms for these structures leads to them being dubbed ‘exogenous tumuli’, to distinguish them from the more familiar tumuli resulting from inflation processes, which are described elsewhere (e.g. Macdonald 1972; Walker 1991; Duncan et al. 2004).

The morphological data are then used together with observations of lava surface textures and squeeze-up locations to build up a picture of flow structure and flow dynamics at the time of squeeze-up formation. The structure of the crust underlying the clinker cover can be elucidated by examining the locations in which squeeze-ups occur, as extrusions exploit zones of crustal weakness. It is found that the flow crust plays an increasingly important role in determining the locus of squeeze-ups as the flow evolves.

Squeeze-ups that clearly had a high strength upon extrusion formed as a result of high overpressures in the flow interior. The extrusion of such material may represent the latter stages of activity of a long-lived bocca, or the new development of a bocca in a part of the flow that had been stagnant for some time. Examination of squeeze-up textures may help determine whether the material was transported to the extrusion site in an open or closed system, or if it was stored for a significant length of time before extrusion. Information may also be gleaned concerning the maximum crystallinity at which lava can flow, which is an important parameter in flow modelling. Evidence for a mechanism by which sufficient overpressure can be generated to extrude such material is presented.