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The significance of slab-crusted lava flows for understanding controls on flow emplacement at Mount Etna, Sicily

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Abstract

Slab-crusted flows on Mount Etna, Sicily are defined here as those whose crust has ridden on the flow core without significant disruption or deformation and have a high length to width ratio. They typically erupt from ephemeral boccas as late-stage products on dominantly aa flow fields, such as that of the 1983 eruption on Mount Etna. Slab-crusted flows tend to inflate mainly as they approach and after they reach the maximum length of slab-crust formation, the flow interior acting as a preferential pathway for injecting lava under a stable crust. Coalescence of vesicles under successive crusts causes separation between core and crust giving a new cooling surface within the flow, on which ropy surfaces (and occasionally aa textures) of limited areal extent may develop. Slab-crusted flows tend to form at ephemeral boccas together with other surface textural types including toes, ropy pahoehoe sheets and aa flows. This suggests that, on Etna, slab-crusted flows form from lava of the same rheological properties as both aa and pahoehoe textured flows. They do not represent a transition between aa and pahoehoe as argued for toothpaste flows in Hawaii. We conclude that slab-crusted flows on Etna owe their morphology to a relatively high critical ratio of effusion rate to advance rate, related to vent cross-sectional area and the slope over which the flow forms.

Keywords: Mount Etna; lava morphology; lava flow emplacement; lava inflation; toothpaste lava; slab-crusted lava

1. Introduction

There is a specific morphology of lava flow, which we term *slab-crusted flow*, here described from the Mount Etna volcano, Sicily. Such flows have a continuous, level, slab-like pahoehoe crust, normally about 1–2 m wide, and a length on the order of metres to tens of metres (Fig. 1). These flows typically erupt from ephemeral boccas (short-lived secondary vents on the surface of an active flow) formed at a late stage in aa flow field development. Aspects of the most typical form of this type of flow have been described by Polacci and Papale (1997, 1999) who termed them *toothpaste lava*, following Rowland and Walker (1987) from their Hawaiian studies on flows that have some characteristics in common with these flows

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Fig. 1. Photograph of the surface of a slab-crusted flow showing some of the typical features. This flow erupted from an ephemeral vent in the foreground. Hammer for scale.

on Etna. The Hawaiian toothpaste flows differ from the Etnean slab-crusted flows, in their larger size and marginal characteristics. In addition, flows on Etna with this slab-crusted form range from those with a similar width to thickness cross section, as described by Polacci and Papale (1997), to those that are thin compared to their width. We therefore distinguish the Etnean flows by giving them a different name, indicting the slab-like nature of the surface crust.

Slab-crusted flows are particularly well displayed on the flow field of the 1983 eruption of Etna where Polacci and Papale (1997, 1999) carried out part of their study. They explained the slabby crust as having formed by riding, generally undisrupted, on a plug of lava. They interpret the quadrant cross section as the result of inflation, but, based on studies of vesicle distribution, they argue that the interior of the flow was like a lava tube with changing lava levels within it.

Here, we examine this type of flow further, using mainly the 1983 flow field examples together with observations of active flows. We investigate in more detail why these flows have this specific morphology and their significance in terms of the factors that control how different lava textures and morphologies develop.

2. Characteristic features of Etnean slab-crusted flows

2.1. Size and shape

We measured the characteristics of 20 slab-crusted flows on the 1983 flow of Etna. The slab-crusted flows on Etna have a high length to width ratio (Fig. 2). The surface consists of a relatively smooth level slab of crust that is largely intact. The crustal slab is typically 1 to 2 m across and tends to retain much the same width along the length of the flow. The continuous 'road' of crust may be from a few to tens of metres long. A plot of the length vs. width for 20 slab-crusted flows measured on the 1983 flow illustrates that the width only increases slightly with increased length of flow (Fig. 3).

The thickness of slab-crusted flows varies and is not usually easy to determine. Some slab-crusted flows have surfaces flush with the surrounding surface (Fig. 4A), and thus an unknown thickness. We interpret most of these flows to be relatively thin. When the crust stands well above, the flows can be seen to be at least as thick as they are wide (Fig. 4B). These flows tend to have a box-like cross section (termed sarcophagus-shaped by Polacci and Papale, 1997), where the sides are steep and often overhanging as a result of outward collapse of the original margin (Fig. 2). In addition, it is common for the upper surfaces of the raised slab-crusted flows to be inclined towards one side.

2.2. Surface texture and crust

The crustal slabs consist of an upper crust (Fig. 5) that is 4–10 cm thick, usually vesicular. Such a crust would be expected to form in about 15–30 min following calculation for lava crust growth by Fink and Griffiths (1990). As Polacci and Papale (1997) noted, the crust does not thicken significantly downflow. The upper approximately 2.5 cm normally has fewer, smaller vesicles and is glass-rich. The crust