Similarities in basalt and rhyolite lava flow emplacement processes

Nathan Magnall[a], Mike R. James[b], Hugh Tuffen[b], Charlotte Vye-Brown[c]

[a,b]Lancaster University, [c]BGS, [a]n.magnall@lancaster.ac.uk

1. Introduction

Here we use field observations of rhyolite and basalt lava flows to show similarities in flow processes that span a large compositional range.
The 2011-2012 eruption of Cordón Caulle, Chile, provided some of the first quantitative observations of the emplacement of a rhyolite lava flow[1,2]. The flow advanced and eventually halted due to the formation of a cooled crust, breakouts (secondary flows) then formed from the flow front and margins[1].

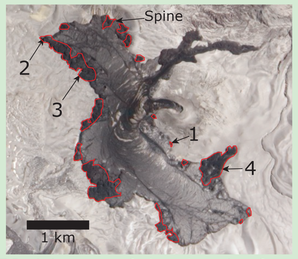
This cooling-limited rather than volume-limited behaviour is common in basaltic lava flows but had never previously been observed in rhyolite lava flows.

	Cordón Caulle Rhyolite	2001 Etna Basalt
Flow width	1500 m	90-300 m
Flow length	4900 m	6869 m [3]
Eruption duration	285 days	23 days [3]
Viscosity	$4x10^{10}$ Pa s [4]	10^5 Pa s [5]
Erupted volume	0.4 km^3 [1]	0.0214 Km^3 [3]
Breakout lengths	30 – 450 m	15 – 250 m
Breakout widths	30 – 150 m	10 – 50 m
Breakout thickness	15 – 30 m	2 – 6 m

Comparison table of flow properties for the 2011-2012 Cordón Caulle rhyolite and 2001 Etna basalt.

2. Cordón Caulle rhyolite flow features

Overview

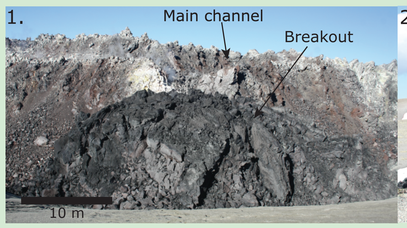


EO-1 image of the rhyolite flow, numbers correspond to the field photos. Red lines highlight clusters of breakouts.

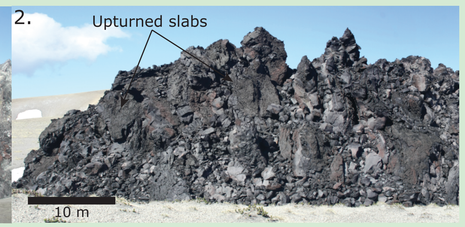
As breakouts extrude they inflate[1,4] due to vesiculation of the decompressed lava and continued lava supply.

As they grow the surface becomes increasingly brecciated. Eventually large surface fractures form and secondary breakouts can form. The field photos show part of the continuum through breakout evolution.

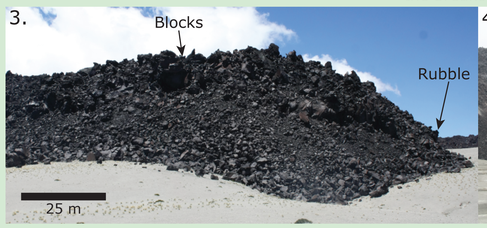
Breakouts



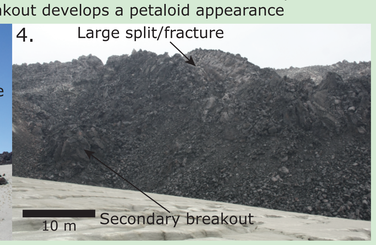
1. Domed breakout with a surface crust



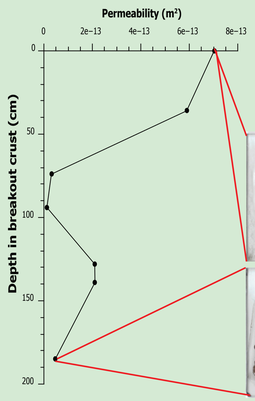
2. Inflation of the breakout causes slabs to upturn and the breakout develops a petaloid appearance



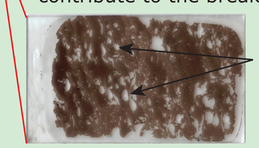
3. Continued advance of the breakout leads to full breakup of the carapace, creating a blocky/rubbly surface texture



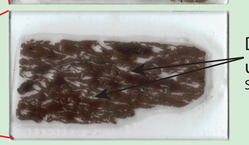
4. As the breakouts inflate a large lateral fracture can form, with secondary breakouts generated



TinyPerm permeability measurements through a breakout slab. The higher permeability at the surface may relate to decompression and vesiculation of the surface crust. This could contribute to the breakout inflation.



Top of breakout, greater number of more open undeformed vesicles.
Section 48 mm long.



Deeper in breakout, fewer undeformed vesicles.
Section 48 mm long.

Squeeze-ups

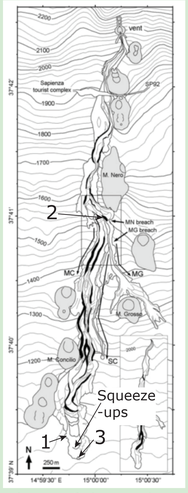
Spine-like squeeze-ups are found on the surface of the rhyolite flow. They have a core of dense crystalline rhyolite and a brecciated margin.

Spines form due to ramping of material along inclined shear planes behind a stalled flow front[5,6].

The distribution of squeeze-ups on the flow surface is currently unknown.

3. 2001 Mt Etna basalt flow features

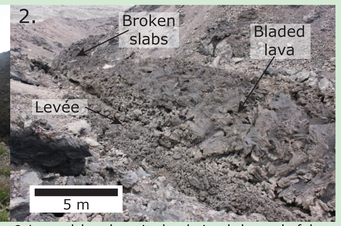
Overview



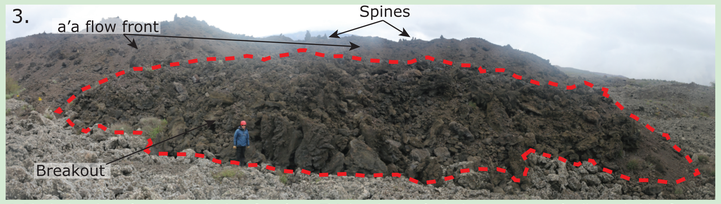
Flow map[6] showing the location of the field photos.

Breakouts

1. Breakouts of blade topped lava from the western margin of the 2001 Mt Etna flow.



2. Leveed breakout in the drained channel of the an earlier flow



3. Blocky breakout from the stalled a'a flow front. This breakout rafted a large amount of collapsed older flow material.

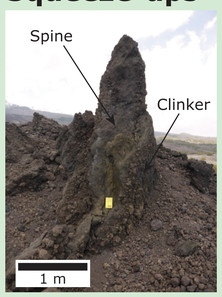
Breakouts form from the stalled flow front, margins and in areas of drained channel.

Initially the breakout comprises a'a clinker, this forms levées. As the flow front cools and slows the surface buckles forming ogives and areas of crust become fragmented. The breakout takes on a blocky appearance.

The last effused material is more viscous toothpaste extrusions of bladed lava. Such a transition could relate to a slowing effusion rate at the breakout source.

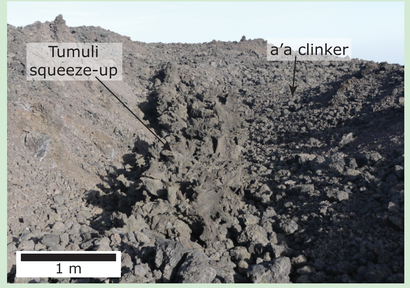
Unlike the rhyolite, in the basalt there is no obvious systematic variation in vesicularity through the breakouts, but inflation is prevalent.

Squeeze-ups



Spine squeeze-ups are found on the surface of the 2001 Etna flow. Several are found near the flow front.

These spines form due to the ramping of material to the surface behind a stalled flow front[5,6].



Linear squeeze-up on the 2001 Mt Etna flow. These are found near the flow front in the main channel and between the levee and main channel.

The squeeze-ups are formed of striated tumuli that likely formed as toothpaste extrusions[7].

4. Summary

- Breakout formation suggests the role of a strong crust that significantly influences the development of the flows.
- The morphological differences in both rhyolitic and basaltic breakouts relates to their evolution over time. Factors such as effusion rate and duration, cooling, and strain rate will all impact on breakout morphology.
- The presence of squeeze-ups on both flows suggests the upwards ramping of material behind a stalled flow front, or internal pressure forming a toothpaste extrusion.
- The sizes of spines on the flow surfaces are similar, suggesting a similar controlling factor (such as yield strength) on their maximum size.
- Despite the differences in morphologies the processes that form these features are similar across compositions, suggesting a more universal model for lava emplacement.

References

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