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Magma deformation and emplacement in rhyolitic dykes

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Silicic eruption mechanisms are determined by the rheological and degassing behaviour of highly-viscous magma ascending within shallow dykes and conduits. However, we have little knowledge of how magmatic behaviour shifts during eruptions as dykes and conduits evolve. To address this we have analysed the micro- to macro-scale textures in shallow, dissected rhyolitic dykes at the Tertiary Húsafell central volcano in west Iceland. Dyke intrusion at $\sim$3 Ma was associated with the emplacement of subaerial rhyolitic pyroclastic deposits following caldera formation[1].

The dykes are dissected to $\sim$500 m depth, 2-3 m wide, and crop out in two stream valleys with 5-30 m-long exposures. Dykes intrude diverse country rock types, including a welded ignimbrite, basaltic lavas, and glacial conglomerate. Each of the six studied dykes is broadly similar, exhibiting obsidian margins and microcrystalline cores. Dykes within pre-fractured lava are surrounded by external tuffisite vein networks, which are absent from dykes within conglomerate, whereas dykes failed to penetrate the ignimbrite. Obsidian at dyke margins comprises layers of discrete colour. These display dramatic thickness variations and collapsed bubble structures, and are locally separated by zones of welded, brecciated and flow-banded obsidian.

We use textural associations to present a detailed model of dyke emplacement and evolution. Dykes initially propagated with the passage of fragmented, gas-charged magma and generation of external tuffisite veins, whose distribution was strongly influenced by pre-existing fractures in the country rock. External tuffisites retained permeability throughout dyke emplacement due to their high lithic content. The geochemically homogenous dykes then evolved via incremental magma emplacement, with shear deformation localised along emplacement boundary layers. Shear zones migrated between different boundary layers, and bubble deformation promoted magma mobility. Brittle-ductile microtextures and bubble populations point towards multi-step and multi-rate magma decompression, and we propose that gas overpressure in bubbles created tensile micro-cracks, whose coalescence culminated in macroscopic fragmentation. Finally, we infer that bubble collapse was associated with both localised brittle magma failure at shallow levels and macroscopic magma fragmentation deeper within the magmatic system.

Processes recorded by the Húsafell dyke exposures appear akin to those occurring in the shallow conduits of Chaitén and Cordón Caulle during recent rhyolitic eruptions[2,3]. The field evidence presented here therefore bridges the gap between eruption observations and the deeper geological record, and so provides new insight into conduit evolution during explosive-hybrid-effusive eruptive phases[2,3] and the influence of country rock. The parallels between intrusive dyke textures and those found in extruded silicic lavas suggest that processes recorded in the dykes, including bubble collapse, volatile resorption, thermally-induced vesiculation and the formation of brittle-ductile shear zones, also occur within extrusive flows, contributing to their extreme textural heterogeneity[4].

[1] Saemundsson K & Noll H (1974) Jökull 24, 40-59.
[2] Schipper CI et al. (2013) JVGR, 262, 25-37.
[3] Castro JC et al. (2014) EPSL, 405, 52-61.
[4] Shields JK et al. (2016) JVGR, 310, 137–158.