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Conditions for dyke emplacement at Birsay (Orkney, Scotland)

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Intrusions such as igneous dykes and sills form the key conduits for the transport of magma from the mantle to the crust and surface. Our current understanding of dyke and sill emplacement is built upon a combination of analogue models, field observations and theories based on fracture mechanics, fluid dynamics, heat flow, and elasticity. However, despite their computational power, most numerical models of fluid-filled fractures are greatly simplified in comparison to natural geological fractures. For example, dykes are typically modelled as a fluid-filled fractures on a two-dimensional vertical plane within an infinite isotropic and homogenous elastic solid. There are many basic field observations that contradict both the configuration of these models, and their predictions.

We present a combination of field and laboratory data including geochemical, geothermobarometry and micro-textural analysis, along with numerical modelling including viscosity and density. Comparing the geological data to the predictions of various numerical models, we aim to assess the discrepancies in order to isolate and evaluate the key controlling variables. At Birsay in Orkney (Scotland, UK) there is a set of segmented dykes which were emplaced into previously jointed and uniformly dipping Devonian host rocks. These dykes lie within the alkaline basic series and are part of the Carboniferous-late Permian dyke swarm of the Scottish Highlands. The magma intruded at high temperature with the chilled margin crystalizing at $\sim$965°C with a density of approximately 2.65 g/cm3 and a log(viscosity) of 1.5-1.85 Pa S. These dyke segments show no significant lateral variation, have shallow dipping floor and roof contacts, and display no evidence of segments merging downwards.

Understanding the mode of magma emplacement is critical to our understanding of magmatism particularly in large igneous provinces, and more widely of crustal evolution processes such as continental rifting and plate divergence. Our current focus is on investigating the conditions of emplacement at Birsay and the role of common geological heterogeneities such as pre-existing joint sets and bedding, to re-direct numerical models away from assumptions of homogeneity and isotropy, and towards the attributes of natural systems.