Geophysical Research Abstracts
Vol. 21, EGU2019-416, 2019
EGU General Assembly 2019
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Emergence of Finger-Like Channels from Planar Intrusions: New Insights from 3D Analogue Experiments

Uchitha Nissanka Arachchige, Alexander Cruden, and Roberto Weinberg

School of Earth, Atmosphere and Environment, Monash University, Melbourne, Australia
(uchitha.nissankaarachchige@monash.edu)

The geometries of planar igneous intrusions such as dykes, sills and inclined sheets have often been used to delineate emplacement mechanisms, magma flow pathways, and melt source locations in crustal magma plumbing systems. It is known that dykes and sills do not always propagate with uniform margins but instead break down into finger-like and/or lobate segments. The morphology and propagation mechanism of these segments and how they connect are still debated and mostly explained by brittle-elastic instabilities, where tensile brittle fracture leads to the formation of segment connectors such as steps and broken bridges. However, non-brittle emplacement mechanisms such as ductile flow processes and heat-induced fluidisation also show the development of such segments. Recent studies have also suggested that magma cooling and solidification can contribute to formation of segments.

Here we present an experimental approach to model segmented sill margins and to analyse their propagation mechanisms. Paraffin oil (magma analogue) is injected into horizontal interfaces between two layers of Laponite RD gels (a visco-elastic-plastic host rock analogue) at constant flux and propagation of the resulting sill is monitored. Rheological analysis show that Laponite RD gel is in the linear visco-elastic (LVE) region for strain amplitudes < 3.2 % and its shear strength increases with increasing time and concentration, with plastic failure occurring at strain values in between 15.2% and 20.2%. Preliminary results indicate that intrusion structure and propagation are largely controlled by the rheology of the host rock analogue, whereby ascending bulbous and saucer shaped sills form when the host analogue is either of low or high stiffness, respectively. The experiments reveal that cracks initially propagate along the interface as an inner flat sill and then transitions into an inclined sheet to define an overall saucer shaped intrusion morphology. Saucer shaped sills form in the experiments when the inner sill diameter to overburden thickness ratio is > 1.5. The dip of the inclined sheets varies from 11.5° to 35.5° and this angle is shallower at the onset of the inclined sheet formation and becomes steeper as it approaches the surface of the experiments. In experiments using stiff Laponite RD analogue host rocks, segmented fingers and lobes develop at the leading edges of both inner sills and inclined sheets, and these structures remerge by forming steps and broken bridge structures. Our results are consistent with previous field and experimental observations of formation of sheet intrusion segments and provide new insights on how offset lobate intrusive segments and magma fingers emerge from initially planar fractures in layered viscoelastic host rocks.