Geophysical Research Abstracts
Vol. 18, EGU2016-4152, 2016
EGU General Assembly 2016
© Author(s) 2016. CC Attribution 3.0 License.

Microstructural indicators of convection in sills and dykes

Marian Holness (1), Jerome Neufeld (1,2,3), Andrew Gilbert (1,2)

(1) Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK (marian@esc.cam.ac.uk), (2) BP Institute for Multiphase Flow, University of Cambridge, Madingley Road, Cambridge, CB3 0EZ, UK, (3) Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Centre for Mathematical Sciences, Wilberforce Road, Cambridge , CB3 0WA, UK

The question of whether or not magma convects is a vexed one, with some advocating vigorous convection in crustal magma chambers while others suggest that convection is weak and short-lived. From a detailed microstructural study of a range of tabular mafic intrusions, we argue that it is possible to determine whether crystallization took place predominantly in solidification fronts (i.e. the magma was essentially crystal-free) or whether crystals grew suspended in a convecting magma.

The 168m thick Shiant Isles Main Sill is a composite body, dominated by a 140m thick unit with a 45m thick base rich in olivine phenocrysts (picrodolerite). The remainder of the unit contains only interstitial olivine. The average olivine grain size in the picrodolerite decreases upwards in the lowermost 10m, but then increases upwards. The coarsening-upwards sequence is marked by the onset of clustering of olivine grains. The extent to which these clusters are sintered, and the average cluster size, increase upwards. The coarsening-upwards sequence and the clustering are mirrored in a thinner (<10m) sequence at the roof. The fining-upwards sequence of non-clustered olivine formed by the rapid settling of incoming cargo crystals, while the coarsening-upwards sequence of clustered olivine represents post-emplacement growth of grains suspended in a convecting magma. The clusters grew by synneusis, with the extensive sintering pointing to the retention of the clusters in the convecting magma for a considerable time. The presence of large clusters at the intrusion roof can be reconciled with their high Stokes settling velocity if they were brought up in rapidly moving convective currents and entangled in the downwards-propagating solidification front.

A further indication of convection is provided by plagioclase grain shape. During interface-controlled growth, plagioclase grows as well-facetted compact grains: these grains are platy in rapidly-cooled rocks and blocky in slowly-cooled rocks. In mafic sills, the average apparent aspect ratio (AR), as measured in thin-section, varies smoothly with model crystallization times (calculated assuming diffusive heat loss), consistent with in situ growth in solidification fronts. However, AR is invariant across individual mafic dykes, with decreasing values (i.e. more blocky grains) as the dyke width increases. This difference can be accounted for by the plagioclase in dykes growing as individual grains and clusters suspended in a convecting magma. Cooling at a vertical wall, as is the case for dykes, will always result in a gravitational convective instability, and therefore crystal-poor magma in dykes will always convect. As solidification proceeds, the increasing volume fraction of suspended crystals will eventually damp convection: the final stages of solidification occur in static crystal-rich magma, containing a well-mixed grain population.

That the Shiant Isles Main Sill exhibits evidence for prolonged convection of sufficient vigour to suspend 5 mm olivine clusters, while other sills of comparable thickness contain plagioclase with grain shapes indicative of growth predominantly in solidification fronts, is most likely due to the composite nature of the Shiant. The 140m unit is underlain by 23m of picrite which intruded shortly before – this heat source would have acted as a strong driver for convection.