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Microstructural indicators of convection: insights from the Little Minch Sill Complex, Scotland

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The fluid dynamic behaviour of crystal-bearing magmas is a key parameter to understand the formation of magmatic bodies. There are two opposite views on the subject: Some argue that solidification in intrusive bodies is affected by convection whereas others claim solidification happens in a static environment. A consensus on the question may be reached by carefully studying the grain size distribution in the settled accumulations of cargo crystals.

In the absence of significant crystal growth or particle coarsening by agglomeration, settling of a polydisperse crystal load will always result in a fining-upwards sequence in static magmas as well as in convecting environments. If we assume the particle concentration is always sufficiently low to prevent hindered settling, gravitational settling in a static magma leads to the settling of individual crystals at a constant rate determined by their Stokes' velocity. Each size class is deposited at a constant rate, until all the grains of that size class have fallen out of suspension, leading to a well-stratified sequence and the complete disappearance of progressively smaller size classes upwards in the accumulation.

In contrast, in a vigorously convecting magma crystals settle when they enter the stagnant basal boundary layer. In a system containing a polydisperse crystal population most of the bigger particles are removed rapidly from the bulk magma, leading to the creation of a fining-upwards sequence on the floor. However, in detail the structure of this fining-upwards sequence is critically different from that created by settling from a stagnant magma, with the gradual phasing out of each size class instead of the abrupt termination of size classes seen in static systems. This provides us with the opportunity to distinguish between settling from static or convecting magma using the spatial variation of grain size in settled accumulations.

We focus on the Little Minch Sill Complex in Scotland, which formed from olivine-phyric magma and is characterised by both composite and single-injection bodies with significant accumulation of olivine on their lower margins. Comparison of the fining-upwards sequences in the picrodolerite/crinanite unit of the composite Shiant Isles Main Sill,and related single-injection sills on the Trotternish Peninsula, Skye, illustrate the ability of this method to distinguish between convecting and non-convecting magma bodies.