EGU25-7393, updated on 28 Nov 2025
https://doi.org/10.5194/egusphere-egu25-7393
EGU General Assembly 2025
© Author(s) 2025. This work is distributed under
the Creative Commons Attribution 4.0 License.

Numerical modelling of melt-solid separation in layered intrusions

Catherine Booth, Haiyang Hu, and Matthew Jackson
Department of Earth Science and Engineering, Imperial College London, London, UK (c.booth17@imperial.ac.uk)

Many conceptual models of layered intrusions are based on the idea of a long-lived, melt-dominated magma chamber, within which chemical differentiation occurs through fractional crystallisation and assimilation of the surrounding crust. These models typically assume magma is delivered in a single large batch or a few large pulses. However, recent studies have suggested that melt-dominated chambers are transient. Intrusions are constructed incrementally from smaller magma batches. Melt-dominated layers may form in response to new intrusions or melt-solid separation, but most of the intrusion comprises crystal-rich mush or solid rock. Chemical differentiation occurs by assimilation and fractional crystallisation, as well as reactive percolative melt flow within the mush.

The origin of layering is closely linked to fluid-dynamical processes occurring in intrusions: conceptual models ubiquitously invoke flow, whether of low crystallinity magma driven by thermal or compositional convection, or of melt or fluids percolating through high crystallinity mush. Yet, despite the importance of these processes, few models have attempted to model them using well-established physical conservation laws, constitutive equations and numerical methods. Our aim is to explore the coupled processes of heat and mass transfer in layered intrusions. We develop a two-phase (melt and crystals) numerical model that is applicable to layered intrusions constructed incrementally or by a single large batch of magma. The numerical model captures (i) separation of melt and crystals by crystal settling at high melt fraction and percolative flow at low melt fraction, (ii) transfer of heat by conduction and advection and (iii) solid-melt mass exchange and chemical differentiation. We report a chemical model, used to track chemical differentiation, which is built for layered intrusions. The chemical model can match the end-members of equilibrium and fractional crystallisation, depending upon the efficiency of melt-solid separation calculated by the numerical model. The chemical model also calculates the proportion of four major rock-forming minerals in layered intrusions: olivine, orthopyroxene, clinopyroxene and feldspar.

Preliminary results suggest layering in these intrusions can form by melt-crystal separation at high and low melt fraction, coupled with reactive percolative flow at low melt fraction. Reversals in the characteristic upwards decrease in MgO can also arise by these processes. Incrementally built complexes may contain multiple magma chambers at different depths, separated by crystal-rich mush or solid rock, rather than a single chamber. Although the chemical model is the same, we observe differences in layering style and composition depending on the cooling time and intrusion style. Ongoing research continues to investigate the parameter space.

Current work is focussed on coupling the chemical model reported here with a three-dimensional code for simulating heat and mass transport and chemical reaction. This will allow us to test determine the style of convection, and the impact of convection on layering. Second, our model assumes local thermal and chemical equilibrium. It does not allow crystal zonation or undercooling of a pure melt prior to crystallisation. Current research is focussed on extending the chemical model to allow undercooling, so we can test the prevalence of pervasive versus in-situ nucleation and growth of crystals.