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Eddy flow and associated particle dynamics during magma intrusion: the Basement Sill, Antarctica

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The McMurdo Dry Valleys magmatic system Antarctica forms part of the Ferrar dolerite Large Igneous Province. The intrusions comprise a vertical stack of four interconnected sills linked to surface flows of the Kirkpatrick flood basalts. Together the complex provides a world-class example of pervasive lateral flow of magma on a continental scale. In addition the Basement Sill offers unprecedented two and three dimensional sections through the now frozen particle macrostructure of a congested magma slurry. Using image-based numerical modelling (the intrusion geometry defines its unique finite element mesh) it is possible to simulate aspects of the flow regime and rheology that have bearing on the formation of mesostructures including compositional layering. A distinction between structures formed during flow, where the shearing regime dominates, and post-emplacement features due to local crystal-melt segregation constrained by thermal modeling, is made. In the former regime we describe a potentially novel crystal-liquid segregation that may have been overlooked because it is so simple. The critical boundary condition is an undulating base or roof in the intrusion where magma eddies can develop during low Reynolds Number flow. Numerical particle tracing is used to show that wall eddies can either trap (and ultimately freeze) crystals in-situ or retain and eject them back into the flow at a later time according to their mass density. The mechanism has potential to develop local variations in magma chemistry and structure that would not otherwise arise where the contact between magma and country rock is linear. We refer to this local fluid dynamical effect as 'slingshot' fractionation and are not aware of any previous quantitative description of this effect in igneous rocks.