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Development of modal layering in granites: a case study from the Carna Pluton, Connemara, Ireland

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Modal layering in igneous rocks uniquely record dynamic processes operating in magma chambers and also host a large proportion of Earth's strategic mineral deposits. This research investigates the origin of biotite modal layering and primary pseudo-sedimentary structures in felsic magmas, by using a combination of Crystal Size Distribution (CSD) analysis and Electron Probe Microanalysis (EPMA) to determine the mechanisms responsible for the development of these structures in the Carna Pluton, Connemara, Ireland.

The Carna Pluton is a composite granodiorite intrusion and is one of five plutons comprising the Galway Granite Complex (425 – 380 Ma). Prominent 30 cm thick modal layers are defined by sharp basal contacts to a biotite-rich (20%) granite, which grades upward over 10 cm into biotite-poor, alkali-feldspar megacrystic granite. The layering strikes parallel to, and dips 30-60˚N toward the external pluton contact. Pseudo-sedimentary structures (cross-bedding, flame structures, slumping and crystal graded bedding) are observed within these layers. Petrographic observations indicate the layers contain euhedral biotite and fresh undeformed quartz and feldspar. Throughout the pluton, alkali-feldspar phenocrysts define a foliation that is sub-parallel to the strike of biotite modal layers. Together these observations indicate that the intrusion's concentric foliation, biotite layers and associated structures formed in the magmatic state and due to a complex interaction between magma flow and crystallisation processes. Biotite CSDs (>250 crystals per sample) were determined for nine samples across three biotite-rich layers in a single unit. Preliminary CSD results suggest biotite within basal contacts accumulated via fractional crystallisation within an upward-growing crystal pile, likely reflecting the yield strength of the magma as a limiting factor to gravitational settling of biotite. This is supported by the abrupt decrease in mean biotite crystal size across the contact, compared to the biotite crystals in the megacrystic granite below. CSD results provide additional evidence for in-situ textural coarsening of biotite.

This study proposes a new model for the crystallisation dynamics of the Carna Pluton. During emplacement, 2 – 5 cm alkali-feldspar megacrysts were aligned and fractional crystallisation was the primary mechanism driving the formation of biotite modal layers. Pseudo-sedimentary structures are interpreted to have formed due to the entrainment of biotite crystals within a necessarily highly fluid magma chamber. However, this interpretation is difficult to reconcile with the high viscosities commonly associated with granitic melts. To test this hypothesis, ongoing EPMA analysis on biotite F content and Fe/(Fe+Mg) ratios will assess whether the magma viscosity could have been low enough to produce these features via flow processes; or whether expansion of the pluton and tilting of planar primary magmatic layers, prior to solidification, could be responsible.