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SPECIAL COLLECTION: PERSPECTIVES ON ORIGINS AND EVOLUTION OF CRUSTAL MAGMAS

Field and model constraints on silicic melt segregation by compaction/hindered settling: The role of water and its effect on latent heat release†

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Abstract

To investigate how large volumes of silicic melts segregate to form granitic plutons, we conducted a case study of a zoned pluton, in which SiO_2 increases from intermediate (69 wt%) to highly silicic compositions (74 wt%) toward the contact with metasedimentary wallrock in the outer 25 m of the pluton. All other major, minor, and trace elements vary systematically with SiO_2 and indicate that outward increasing SiO_2 is due to a decrease in mafic elements and minerals. Whole-rock oxygen isotopes and elemental variation diagrams do not support mixing with wallrock as an explanation for the Si-rich boundary layer. Instead, mafic enclaves, which are common in the pluton, also decrease in abundance in the outer 25 m of the pluton, suggesting a mechanical origin for the Si-rich boundary layer. The coupling of mechanical and geochemical boundary layers, combined with geochemical modeling, indicate that the silica-rich, enclave-poor boundary layer formed by hindered settling or compaction of a crystal-rich (crystal fractions >60%) magmatic mush. Segregation of melts at high crystal fraction is known to be a slow process. However, petrography and Zr-based thermometry indicate that the residual Si-rich liquids were water-saturated. Water decreases melt viscosity, which helps expulsion, but equally importantly, water also delays much of the latent heat release to late in the thermal and crystallization history of a cooling magma. We show that the higher the water content, the longer the time interval over which a magma chamber resides at the stage when water-saturated, high-silica liquids form, allowing sufficient time for exfiltration of silicic liquids before the magma body freezes.

Keywords: Granite, rhyolite, batholith, pluton, cumulate, compaction, settling, xenolith