

Stable isotopes constraints on crystal mush processes in layered intrusions: crystal growth vs. diffusion?

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Mafic layered intrusions such as the Bushveld Complex provide a track record of how basaltic magmas crystallize and differentiate within the crust. Layered intrusions are classically interpreted as resulting from fractional crystallization of one or more parent magmas or their mixtures, with changes in mineral assemblages and composition being broadly consistent with a single liquid line of descent. However, a growing body of observations including the presence of intra- and inter-grain isotopic heterogeneity [1] as well as evidence for diffusive re-equilibration at various scales [2, 3] suggests that these rocks have undergone extensive re-equilibration within the crystal mush. Compositional mineral zoning in igneous rocks can be used to retrieve precious information on their magmatic evolution. Alternatively, chemical profiles associated with intra-grain diffusive modification are commonly used for geospeedometry [4]. However, distinguishing crystal growth from chemical diffusion is challenging, because both processes can impart similar chemical profiles.

Metal stable isotopes may provide a solution to this challenge. As light isotopes diffuse faster than heavier ones, diffusion-driven chemical zoning is associated with large kinetic isotope fractionation. Fe-Mg isotopes have successfully been used to reveal processes and time scales of magmatic evolution in volcanic rocks [5], but have seldom been used in slowly cooled rocks. Here we present Fe and Mg isotope data combined with trace elements data to evaluate the extent of diffusive modification in the Critical Zone of the Bushveld Complex. Our results reveal complex mineral heterogeneities, reaction textures and mineral compositions which do not conform to liquidus phase equilibria and do not reflect original mineralogy and texture, but highlight instead the importance of post-depositional modification that occur in the crystal mush.

[1] Chutas et al. (2012) *CMP* **163** 653-668; [2] Tanner et al. (2014) *J Pet* **55** 859-882; [3] Veksler et al. (2015) *J Pet* **56** 1229-1250; [4] Shea et al. (2015) *Geology* **43** 935-938; [5] Sio et al. (2013) *GCA* **123** 302-321