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Fractional crystallization and mush emplacement are working in tandem in the generation of a stratiform anorthosite: The MG3 anorthosite marker layer of the lower-upper critical zone boundary of the Bushveld complex

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In this study, we provide a field, textural and geochemical characterization of the MG3 anorthosite in order to understand the nature of magma replenishment at the Lower-Upper Critical Zone (LCZ-UCZ) boundary of the Rustenburg Layered Suite. This boundary takes place between the Middle Group (MG2 and MG3) chromitites and is marked by the appearance of the first layer of plagioclase cumulates, known as the MG3 anorthosite (1.5 m thick). Based on the erosional features at the contact between the MG3 anorthosite and its footwall pyroxenite, magma replenishment at the LCZ-UCZ boundary is a consensus. However, it is not known if the replenishing magma was a plagioclase slurry or a superheated aphyric magma that then crystallized in-situ. The MG3 anorthosite is characterized by non-cotectic proportions of plagioclase and chromite as well as a well-developed foliation. Nodules and lens-shaped inclusions of chromitite are also conspicuous in the anorthosite layer. In the lower half of the MG3 anorthosite, the concentrations of LREEs in plagioclase increase upward ($\sum$LREEs 0.796-1.0 ppm) as the An content of plagioclase shows a light but systematic decrease ($\sim$78.5-78.4 mole%). Midway through the layer, there is a compositional break that divides the MG3 anorthosite into a lower and upper part. This also corresponds to an increase in chromites and a change in the foliation orientation in the middle of the layer. The upper part of the anorthosite displays an upward decrease in LREE concentrations (1.285-0.985 ppm) while the An content of plagioclase slightly increases ($\sim$77.8-78.0 mole %).

Based on the textural features and the geochemical trends, we envisage a solidification model whereby there was an initial pulse of plagioclase-saturated liquid at the cumulate-mush interface. This magma intruded as a basal flow and crystallized in-situ by fractional crystallization. The nature of magma emplacement is revealed by the in situ strontium isotope compositions in plagioclase. There is a lack of strontium isotope heterogeneity (0.7056-0.7057) in the basal part of the MG3 anorthosite. In addition there is an upward increase in the LREE concentrations of plagioclase laths while the An content of plagioclase slightly decreases. Hybrid melts produced at the interface between the resident melt and the crystallizing first pulse of magma led to the precipitation of chromite. In the upper part of the anorthosite layer, strontium isotopes record the existence of multiple, isotopically distinct populations of plagioclase. We argue that the isotopic diversity in plagioclase is partly the product of the influx of a new plagioclase-bearing magma above the crystallizing base of the MG3 anorthosite. Plagioclase laths brought in with this magma were isotopically distinct compared to those in the resident mush, explaining the juxtaposition of isotopically variable plagioclase laths. Moreover, the hybrid magma was produced again at the new interface between the inflowing second magma and the resident magma that kick started chromite precipitation to form the overlying MG3 chromitite layer. Therefore, two successive pulses of magma are required to explain the formation of the MG3 anorthosite layer at the LCZ-UCZ boundary and both in-situ crystallization and slurries were involved.