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Titanium isotopic fractionation during tholeiitic magmatic differentiation from the Bushveld Complex

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Titanium isotopes have shown two distinct trends between calc-alkaline and tholeiitic magma series, making them a powerful tool for tracing magma differentiation processes and tectonic settings [1, 2], although the reasons for these two trends remain unclear. The Rustenberg Layered Suite (RLS) of the Bushveld Complex in South Africa is the world's largest layered mafic intrusion and an excellent example of the tholeiitic series [3]. Notably, the upper main zone and upper zone (UUMZ) of the RLS, characterized by uniform whole rock Sr isotope compositions, is thought to be derived from a single parent magma without significant additional input [4]. Its relative isolated nature and well-characterized mineral evolution make it an ideal site for investigating Ti isotopic fractionation during tholeiitic differentiation. Furthermore, it has been suggested that a small amount of evolved magma escaped from the magma chamber and became part of the overlying felsic rocks, a hypothesis that can be further examined by Ti isotopes [5].

We measured whole rock δ^{49}Ti on samples from the UUMZ in the Eastern Bushveld and its overlying felsic rocks. Our results show that the whole rock δ^{49}Ti of gabbronorites at the base of the UUMZ are around +0.13‰. Whole rock δ^{49}Ti decreases sharply to -0.20‰ coincident with the onset of cumulus magnetite crystallization and then gradually increases to +0.34‰ with increasing stratigraphic height in UUMZ. We employed a closed-system fractional crystallization model to simulate Ti isotopic evolution, incorporating a scenario where approximately 15-25% of the mass was expelled from the magma chamber at the end. This model successfully replicates the observed Ti isotopic signatures and predicts an escaped felsic liquid with a δ^{49}Ti similar to the range of data we measured on samples of the overlying Rooiberg Group lavas. Our work shows that Ti isotopes could provide valuable information on reconstructing the liquid line of descent and tracing complex magmatic differentiation processes.

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