

Connate brine incorporation into the Bushveld magmas as evidenced by hydrogen and triple oxygen isotopes in phlogopite from the UG2 chromitite

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The Bushveld Complex is the largest layered mafic intrusion on earth and also the leading resource for platinum group elements (PGE). There are major gaps in understanding the modal layering and the concentration of PGE into certain layers of the Critical Zone (e.g., the Merensky Reef and the UG2 chromitite), but evidence suggests that hydrous melts and/or fluids played a role. Crystallized melt inclusions with hydrous, Cl-bearing phases occur in both the Merensky Reef and UG2, and both layers also contain interstitial phlogopitic mica. While the existence of late-stage hydrated melts and their effects on phase relations and element redistribution in the cumulate layers have been described, the source of water remains an open question: is it internal, concentrated by fractional crystallization, or is it external?

To address this, we analyzed the hydrogen and triple-oxygen isotope composition of interstitial, late-magmatic phlogopite separated from UG2 drillcores at three widely-separated localities. All three localities yielded similar compositions. The triple oxygen isotope values ($\Delta^{17}\text{O}_{0.5305}$) average $-0.06 \pm 0.01\%$ ($\delta^{18}\text{O} = 5.6$ to 6.2%), which are consistent with previous models of 30–40% contamination of mantle-derived magmas by Archean rocks in the lower to middle crust. However, the phlogopite δD values average $-31 \pm 5\%$, which is about 30‰ higher than previously-reported, near-mantle values of Bushveld rocks ($-70 \pm 20\%$). The new values reported here ($n = 27$) are close to the estimated seawater composition of $0 \pm 20\%$ at the ca. 2050 Ma intrusion of Bushveld magmas into marine sediments of the Transvaal basin. We argue that the high δD signature of UG2 requires a second step of magma contamination by incorporation of connate seawater at the emplacement level. A modified seawater source is supported by the well-known Cl abundance in interstitial hydrous phases (apatite, amphibole, phlogopite).