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Hydrogen isotopes in phlogopite indicate crustal fluids in the UG2 chromitite layer, Bushveld Complex

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The Upper Group 2 (UG2) chromitite layer in the upper Critical Zone of the Bushveld Complex, South Africa, is the world's largest PGE orebody. The UG2 is typically 0.5 to 1.5 m thick and it consists of 75–90 modal % chromite with interstitial silicate and sulfide minerals. Although a minor component, phlogopite is important because it is a hydrous phase. It has been noted that the UG2 chromitite contains more abundant phlogopite (locally > 1 modal %) than the surrounding pyroxenite layers (Mathez and Mey, 2005). More and more studies suggest that water plays an important role in the UG2 chromite formation and in PGE enrichment or remobilization (e.g., Li et al., 2004; Mathez and Mey, 2005; Schannor et al., 2018). The source of the water is controversial, and this motivated our ongoing study of hydrous minerals in the UG2.

We determined the chemical composition and hydrogen isotope ratio of phlogopite from the chromitite layer and from the surrounding pyroxenite in drill cores from two sites the eastern and western Bushveld (Nkwe and Khuseleka, respectively). The δD values of phlogopite in chromitite from the eastern site are -38.2 to -25.5‰ (mean = -29.7‰, n = 6). The corresponding values from the western site are similar, with -34.6 to -31.6‰ (mean = -33.2‰, n = 6). The δD values of phlogopite from pyroxenite are more variable, ranging from -43.1 to -26.1‰ for the eastern site (mean = -32.9‰, n = 4) and from -38.7 to -26.1‰ for the western site (mean = -31.7‰, n = 3).

Published whole-rock δD values for silicate cumulate rocks in the upper Critical Zone are -93 to -55‰ (Mathez et al., 1994), which are similar to mantle values (-70±10%; Boettcher and O'neil, 1980) and are interpreted as magmatic. In comparison, our δD values of phlogopite from UG2 are much higher and suggest a significant contribution of crustal fluids. Harris and Chaumba (2001) estimated a δD value of -22‰ for paleo-meteoric water in the Bushveld Complex. Given the relative homogeneity of the phlogopite δD data in both sites of the complex, and the primary appearance of the grains in thin section, we argue that the crustal fluids were incorporated in the magma before the crystallization of the UG2 layer. Triple oxygen isotopes will test our hypothesis further.

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