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A high-$\delta^{18}O$ mantle origin for the Phalaborwa Complex, South Africa

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The 2060 ± 2 Ma Phalaborwa Complex is an ultramafic to carbonatite intrusion formed from multiple magma pulses. These produced a main pipe consisting of clinopyroxenite, pegmatoids, carbonatite and foskorite (olivine-apatite-magnetite-calcite) and many smaller syenite plugs. The range in mineral $\delta^{18}O$ values for all rock types in the Phalaborwa Complex is 2.2 to 18.3‰, but most mineral $\delta^{18}O$ values are within a 1.1‰ range. In most $\delta^{18}O$ versus $\delta^{18}O$ plots for different mineral pairs, differences are consistent with O-isotope equilibrium at magmatic temperatures. Alkali feldspar and micas have more variable $\delta^{18}O$ values, consistent with limited subsolidus exchange or alteration.

Magma $\delta^{18}O$ values estimated from constituent minerals for pyroxenites (~6.8 to 8.3‰) and foskorite are generally higher than normal mantle magma. Despite evidence for fluid-rock interaction in the carbonatite-foskorite rocks, carbonatite $\delta^{13}C$ and $\delta^{18}O$ values overlap with the primary igneous carbonatite field. Local basement rocks have average bulk $\delta^{18}O$ values of 8.6‰, and realistic proportions of assimilation could not have produced the $\delta^{18}O$ values in the mafic rocks. We propose that the high-$\delta^{18}O$ values of Phalaborwa Complex magmas reflect that of the mantle source. The similar-aged Rustenburg Layered Suite of the Bushveld Complex (2060 to 2055 Ma) also has 'high' $\delta^{18}O$ values, as do the much younger Karoo LIP picrites (183 Ma). These data support previous proposals for a long-lived, high-$\delta^{18}O$ mantle beneath southern Africa. The $\delta^{18}O$ value of syenite magma estimated from aegirine is ~8.8 to 10.3‰ and is consistent with an origin by partial melting of metasomatised country rock.