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Coupled S and Pb isotopic systematics of the ~2.06 Ga Phalaborwa phoscorite-carbonatite complex: sulphur sources and age of sulphide mineralization

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The Palaeoproterozoic Phalaborwa Complex in the Limpopo Province of South Africa represents a unique Cu deposit, comprising as main rock types phoscorites (magnetite-, forsterite-, apatite-, calcite-bearing peridotites), carbonatites and pyroxenites [1]. The main intrusive bodies were emplaced into Archaean basement rocks of the Kaapvaal Craton synchronously at 2060 Ma [2].

All major rock types contain Cu-rich sulfides (bornite, chalcopyrite, minor pyrite, pyrrhotite, cubanite, and valleriite), with an average modal abundance of 2-3 % [2]. Among three major stages of sulphide mineralization, the main stage affected mostly the transgressive carbonatite, which also hosts the highest abundance of sulphides. Their formation occurred under late-magmatic to hydrothermal conditions, inferred from textural observations (interstitial filling, occurrence within fractures in rock-forming minerals, and exsolution textures), phase assemblages, and thermometry, at temperatures of 500-100°C [3].

We report high-spatial resolution SIMS measurements of Pb and multiple sulphur isotope ratios for different sulphide types from phoscorite, and banded and transgressive carbonatites.

Lead isotopic compositions for all sulphide types are highly variable and radiogenic ($^{206}\text{Pb}/^{204}\text{Pb}$: 10-110, $^{207}\text{Pb}/^{204}\text{Pb}$: 16-26). Robust regression line yields an apparent date of 2108 \pm 110/-100 Ma (95% conf.), which corresponds with the established age of emplacement. Therefore, re-equilibration between sulphides and whole rock during tectono-thermal events significantly post-

dating magmatic emplacement appears unlikely. Comparison of least radiogenic Pb isotope ratios with hypothetical MORB-mantle and upper continental crustal reservoirs at 2.1 Ga [4] appears to require that sulphide melts incorporated significant quantities of evolved crust, either prior to or during emplacement.

Multiple S isotope measurements (within the same sulphide domains that were previously analyzed for Pb) reveal large variations in $\delta^{34}\text{S}_{\text{CDT}}$ values (-15 to +13 ‰). Different sulphide types from all rock types also preserve evidence for significant mass-independent isotopic fractionation ($\delta^{33}\text{S}_{\text{CDT}} = -0.5$ to +2.5 ‰). Large, anomalous $\delta^{33}\text{S}_{\text{CDT}}$ values cannot be generated by magmatic processes characterized by mass-dependent fractionation, and require assimilation of a sedimentary component that had incorporated sulphur cycled through a pre-2.45 Ga oxygen-poor atmosphere [5].

References:

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