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Extreme crustal fractionation in a Proterozoic chemical hotspot

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Proterozoic basement rocks in Australia host major mineral systems, some of which are amongst the largest ore deposits in the world. The spatial clustering and episodicity of mineral systems have long been recognized, and have been interpreted to reflect tectonic setting and geodynamic processes. Understanding geodynamic controls on mineral systems can provide insights on crustal fractionation and magmatic processes through time and has important implications for reducing exploration risk.

We present new K-feldspar and whole-rock Pb isotopic data and apatite U-Pb ages from a suite of (meta-) igneous rocks collected across the Curnamona Province, southeastern Australia, which hosts the world's largest Pb-Zn-Ag ore body (Broken Hill). The Pb isotope ratios measured in K-feldspar are among the most radiogenic ever measured for this mineral ($^{206}Pb/^{204}Pb$ up to 170) implying a source unusually enriched in U. We compare our Pb isotope results to those previously obtained from granites in the Gawler Craton, southcentral Australia, the host of the supergiant U-Cu-Au-Ag Olympic Dam ore deposit. Our results suggest; (i) a widespread lithospheric-scale process which formed a distinct Pb isotope reservoir that repeatedly produced magmatism in both the Curnamona Province and Gawler Craton; (ii) a major crustal fractionation process, resulting in extreme U-enrichment and the formation of a chemical hotspot through high radiogenic heat production; and (iii) a genetic link between the Olympic Dam and Broken Hill ore deposits. High radiogenic heat production facilitated slow cooling and reheating events recorded by apatite U-Pb. This study investigates the spatial scale (Craton? Continent? Global?) and potential mechanisms of this major fractionation event, highlighting the role of lithospheric thinning (Plume? Delamination? Back-arc?) in causing extreme heterogeneous isotopic enrichment.