

Oxygen Isotopic Evidence for Distinct Sources of the Archean and Proterozoic Lithium-rich Pegmatites in Australia

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The classical model of lithium-rich pegmatites proposes partial melting of sedimentary sequences as the principal source of peraluminous granitic magmas that subsequently evolve into pegmatitic melts. Although this concept holds for numerous deposits, new evidence suggests lithium-rich pegmatites can also originate from other sources. This study presents SHRIMP-SI in-situ oxygen isotope analyses of quartz and apatite from several Australian lithium-rich pegmatites including the Archean Greenbushes and Forrestania pegmatites of the Yilgarn Craton, the Archean Pilgangoora pegmatite of the Pilbara Craton, and the Proterozoic Bynoe pegmatite of the Pine Creek Orogen. The Archean pegmatites are characterized by moderate $\delta^{18}\text{O}$, for instance at Greenbushes, quartz yields $\delta^{18}\text{O}$ of 8.2–10.7‰ and apatite ranges from 6.1–7.7‰. Other Archean pegmatites such as Forrestania and Pilgangoora display similar $\delta^{18}\text{O}$ ranges to those of Greenbushes. In contrast, the Proterozoic Bynoe pegmatite exhibits significantly higher $\delta^{18}\text{O}$, with quartz ranging from 13.8–15.5‰ and apatite from 8.5–10.3‰. These data indicate distinct sources for Archean and Proterozoic pegmatites, where the Archean pegmatites may have originated from a continental metaigneous source due to their moderate $\delta^{18}\text{O}$, and the Proterozoic Bynoe pegmatite derived from clastic (clay-rich) metasedimentary rocks as reflected by its elevated $\delta^{18}\text{O}$. Although localized post-crystallization modification (e.g., hydrothermal alteration) is observed in some samples, most of the oxygen isotope data are considered to be a reliable magma source indicator. Furthermore, by using established empirical fractionation, the quartz-apatite equilibrium temperatures were estimated to constrain crystallisation temperatures. Quartz-apatite equilibrium temperatures for the Archean pegmatites are 480–610°C for Greenbushes, ~390°C for Forrestania, and ~570°C for Pilgangoora. The Proterozoic Bynoe pegmatite yields anomalously low temperatures below 300°C, likely reflecting disequilibrium between magmatic quartz and fully hydrothermal apatite. Despite different melt sources, the low equilibrium temperatures for both Archean and Proterozoic pegmatites suggest they represent volatile-rich late-stage melts which then interacted with hydrothermal fluids.