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Constraining the depth and timing of silica enrichment of the cratonic lithosphere

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An unexpected feature of the Archean lithosphere is that it has variable silica contents, extending to much higher concentrations than can be produced by melting of fertile peridotite. Silica enrichment has been attributed to melt-rock reaction, either at low pressure prior to lithospheric thickening, or at higher pressure via interaction between existing lithosphere and rising melts. Silica enrichment is an important feature of the Kaapvaal and Siberian cratons and occurs to a lesser extent in the Slave and Rae lithosphere. Constraining the depth and timing of silica enrichment is key to unravelling the processes that occurred during the evolution of the Archaean lithosphere.

We present geochemical and thermodynamic modelling results for a suite of clinopyroxene-free granular peridotites from Kimberley (Kaapvaal), containing orthopyroxene with exsolved garnet lamellae. Garnet and orthopyroxene from the exsolved and granular portions of the xenoliths have sinusoidal REE patterns and identical trace element and Lu-Hf isotope compositions. Exsolution from orthopyroxene offers a unique opportunity to determine the original formation conditions by comparison of the reconstructed precursor orthopyroxene with intersections of thermodynamically modelled orthopyroxene isopleths. Using this approach, we show that (1) the studied peridotites contained up to 2% garnet before exsolution; and (2) the sample formed at 5-7GPa and 1750-1800^{o}C, suggesting that orthopyroxene addition occurred at high pressure. The pressure is ~1GPa higher than the conditions at which the samples equilibrated on the geotherm. The garnets define a Lu-Hf isochron age of ~2.7Ga with a non-chondritic initial $^{176}Hf/^{177}Hf$ composition of 0.282411±5. Therefore, the cratonic lithosphere must have obtained its thickness of 200km by 2.7Ga.

The age of the garnets, and therefore of their precursor orthopyroxenes, is close to that of the Ventersdorp large igneous province. Ventersdorp magmatism is associated with plume-related rifting of western and central Kaapvaal, providing a mechanism for lithospheric thinning. he high Mg# and low Ca content of the host peridotites requires that the reacting magma was ultramafic, consistent with the high formation temperature. We attribute silica enrichment of the Kimberley lithosphere to high pressure interaction with a komatiitic parental magma to the Ventersdorp supergroup, represented by the Al-depleted komatiites of the Westonia formation.