On the nature and origin of garnet in highly-refractory Archean lithospheric mantle

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The widespread occurrence of pyrope garnet in Archean lithospheric mantle remains one of the 'holy grails' of mantle petrology. Most garnets found in peridotitic mantle equilibrated with incompatible-trace-element-enriched melts or fluids and are the products of metasomatism. Less common are macroscopic intergrowths of pyrope garnet formed by exsolution from orthopyroxene. Spectacular examples of these are preserved in both mantle xenoliths and large, isolated crystals (megacrysts) from the Kaapvaal craton of southern Africa, and provide direct evidence that some garnet in the sub-continental lithospheric mantle initially formed by isochemical rather than metasomatic processes. The orthopyroxene hosts are fully equilibrated with their exsolved phases (low-Cr pyrope garnet + Cr-diopside). Significantly, *P-T* estimates of the post-exsolution orthopyroxenes plot along an unperturbed conductive Kaapvaal craton geotherm and reveal that they were entrained from a large continuous depth interval (85 to 175 km). They therefore represent snapshots of processes operating throughout almost the entire thickness of the sub-cratonic lithospheric mantle.

The exsolved garnets occupy the full spectrum of REE patterns recorded by garnets in mantle peridotites and also diamond inclusions. A key finding is that a few low-temperature exsolved garnets, derived from depths of ~90 km, are more depleted in light REEs than previously observed in any other mantle sample. Importantly, the REE patterns of these exsolved, strongly LREE-depleted garnets resemble the hypothetical composition proposed for pre-metasomatic garnets that are thought to pre-date major enrichment events in the sub-continental lithospheric mantle, including those associated with diamond formation [1]. The recalculated compositions of pre-exsolution orthopyroxenes have higher Al_2O_3 and CaO contents than their post-exsolution counterparts and most likely formed as shallow residues of large amounts of adiabatic decompression melting in the spinel-stability field. It is inferred that exsolution of garnet from Kaapvaal orthopyroxenes may have been widespread, and perhaps accompanied cratonization at ~ 2.9 to 2.75 Ga. Such a process would considerably increase the density and stability of the continental lithosphere.

[1] Gibson, SA (*in press*), Mineralogical Magazine.