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Continental lithospheric mantle

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Our Treatise on Geochemistry chapter aims to disentangle the processes that formed and modified the subcontinental lithospheric mantle (SCLM). We distinguish cratonic and non-cratonic SCLM by sample emplacement mechanisms, rather than by the age of the overlying crust. Xenoliths hosted by kimberlites and related deep magmas are viewed as sampling cratonic lithosphere, while xenoliths hosted by alkali basalts, and nearly all tectonically emplaced ultramafic massifs, are taken as samples of non-cratonic lithosphere. This simple distinction reveals that cratonic and non-cratonic lithosphere have very different compositions (Fig. 1), reflecting very different histories.

The refractory, Fe-poor composition of the cratonic SCLM indicates onset of partial melting at pressures ≥5 GPa, implying melting in hot mantle plumes. The stratified nature of the cratonic lithosphere, with highly depleted spinel harzburgites overlying more fertile garnet peridotites is consistent with polybaric melt extraction in such upwelling plumes. This gradient was reinforced by extensive refertilization of the deep cratonic SCLM revealed by compositional contrasts between peridotite xenoliths and inclusions in diamonds. The similar conditions of formation of komatiites and cratonic lithospheric mantle, which both involve excess mantle potential temperatures and high melt fractions, suggest a genetic link.

The non-cratonic SCLM composition ranges from highly depleted to fertile, but on average is more refractory than the convecting mantle. Incompatible element enrichment is nearly ubiquitous in non-cratonic SCLM peridotites. In xenoliths, much of this enrichment results from interaction with host magmas or precursory metasomatism. However, such enrichment is profound in massif peridotites as well, with degree of enrichment increasing systematically with major element depletion. Nd and Sr isotopic evidence suggests that this enrichment was often ancient, and temporally associated with the melt extraction event that led to lithospheric stabilization. This interpretation is supported by Os isotopes, which show that refertilization was nearly concomitant with melt extraction. Os isotopes also indicate that the magmatic events responsible for non-cratonic lithosphere formation all occurred between 1.2 and 2.8 Ga (Fig. 2), and were particularly important in the Paleoproterozoic.

Identifying the changes in geodynamic processes that led to the marked compositional contrast between the cratonic and the non-cratonic SCLM remains a major challenge.