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Constraints on the origin of the non-cratonic lithosphere

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The cratonic sub-continental lithospheric mantle (SCLM), which underlies about half of the continental surface and is sampled by kimberlites, has a refractory composition and is depleted in FeO, facilitating its long term stability. In contrast, the non-cratonic SCLM, defined here as the mantle domain sampled by alkali basalts and in orogenic ultramafic massifs, has compositions ranging from refractory to similar to primitive mantle. The origins of this domain, the reasons for its stability, and its relationship with the convecting mantle remain enigmatic. Consideration of a large database (Georoc [1] and additional sources) highlights several features. First, despite its relative fertility compared to cratonic lithosphere, the average composition of non-cratonic SCLM remains substantially more depleted (Al_2O_3=2.5±1.2 wt%) than the mean composition expected for the convecting mantle (viewed as residual to extraction of continental crust and potential early enriched reservoirs [2] from the primitive mantle). Second, incompatible element enrichment of refractory samples, evident as U-shaped or LREE-enriched REE patterns, is ubiquitous, with the degree of relative enrichment correlated with the degree of refractoriness. Harzburgitic samples also tend to have the most "enriched" Sr and Nd isotope compositions, arguing that the incompatible element enrichment was an ancient feature. Third, well-defined correlations between $^{187}Os/^{188}Os$ and Al_2O_3 are quite frequent. Such correlations cannot be explained by recent refertilization of Archean or Paleoproterozoic harzburgitic protoliths [3,4], and instead argue for radiogenic ingrowth since ancient melt depletion events, likely followed soon after by refertilization. These observations are consistent with extensive melt extraction followed by auto-metasomatism [3] in upwelling mantle plumes. The $^{187}Os/^{188}Os$ vs. Al_2O_3 correlations imply that these melt extraction episodes, which were sufficiently vigorous to lead to at least approximate large scale isotopic homogenization, occurred during the period from ~2.8 to 1.2 Ga, with a broad peak around 2 Ga. This is consistent with the hotter mantle temperatures thought to have prevailed in the Paleo to mid Proterozoic Era [5].

[1] DIGIS Team (2022) GRO.data,V5; [2] Hofmann et al. (2022) *G-cubed* 23, e2022GC010339; [3] Rudnick and Walker (2009) *Lithos* 112, 1083-1095; [4] Reisberg (2021) *Chemical Geology* 574, 120245; [5] Herzberg et al. (2010) EPSL 292, 79-88