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Lherzolitic diamond formation: Early and deep lithospheric conditioning for carbon extraction through cratonic lithosphere

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Lithospheric mantle is a major repository for carbon, emplaced through reaction with infiltrating sublithospheric melts [1]. Cratonic lithosphere was stabilised by Neoarchaean by extraction of exceptionally high melt fractions [2]. Combined with more reducing conditions in their Archaean convecting mantle source [3], the resultant depletion generated a highly refractory and reducing mantle lithosphere out of equilibrium with carbonated melts [4]. Consequently, the earliest lithospheric diamonds formed by precipitation from methane-dominated fluids in a subsolidus harzburgitic substrate [5], and kimberlite formation beneath early-thickened cratonic lithosphere was limited [3]. However, even when conditions in the convecting mantle became oxidised enough to permit the formation of carbonated melts (e.g. kimberlites) either by local volatile enrichment or temperature anomalies, their extraction through initially depleted and reducing lithosphere required prior refertilisation and oxidation of pathways [6,7]. Indeed, the emplacement of exotic metasomatic assemblages (mica-amphibole- rutile-ilmenite-diopside) emplaced at mid-lithospheric levels is temporally and genetically linked to kimberlite magmatism, and has been recognised as a necessary precursor to successful kimberlite eruption [7]. Thus, although small-volume oxidising melts are probably continually produced at depth, they rarely reach the surface and instead are trapped and metasomatise the cratonic lithosphere [8].

Here, we explore the role of lithospheric diamond formation through time in facilitating carbon extraction through cratonic mantle, via redox reactions that account for the presence of C-O-H fluids and fo2 buffered by the coexisting mineral phases. Dated diamond inclusion suites reveal that Archaean diamond formation in refractory harzburgite (Kaapvaal, Slave, Siberia) gave way to Proterozoic diamond formation in refertilised lherzolitic rocks: at 2.0 Ga in Premier (Kaapvaal), 2.0 Ga in Udachnaya (Siberia), 1.4 Ga in Ellendale and Argyle (Western Australia) and 0.7 Ga in Attawapiskat (Superior) [9,10]. This likely occurred during refertilisation of an initially depleted lithosphere in the presence of melt [11]. The record also reveals a time lag between monocrystalline diamond formation and kimberlite magmatism, which is evident from contrasting peridotitic diamond and host kimberlite ages world-wide [9]. We propose that formation of lherzolitic diamonds from oxidising small-volume kimberlite-like melts (consistent with generally mildly sinusoidal REE patterns of lherzolitic garnet inclusions worldwide [11]) by redox freezing is the expression of a carbon cycle that constitutes an integral early part of the preconditioning of deep lithospheric pathways. This is eventually followed by shallower emplacement of metasomes precursory to and required for ultimate successful kimberlite eruption [7], through upward displacement of the redox freezing front. Fibrous diamonds and diamond coats, which have been genetically and temporally related to kimberlite magmatism [11], may testify the latest diamond formation event in cratonic roots enabling eventual carbon transfer through ancient lithosphere.

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