Diamond formation from the lithosphere to the lower mantle revealed by Koffiefontein diamonds

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Because of their robust nature, diamonds survive mantle processes and protect occluded minerals since the time of diamond formation. For the Kaapvaal Craton – the archetype for craton formation and evolution – the geochemical signatures of inclusions in Koffiefontein diamonds tell a story from craton formation to evolution and from lithospheric (below about 160 km) to lower mantle (>660 km) environs. We analysed a suite of 94 lithospheric to lower mantle diamonds and their silicate and oxide inclusions. Geochemical results confirm that the diamond substrates are very depleted, with $Mg\#_{OL}$ of 91.5-95.0 and a dominance of low-Ca (<1.8 wt% CaO), presumably dunite-derived garnet. The Si-rich nature and preserved high Mg# of the peridotitic diamond substrates beneath Koffiefontein and the formation of $KNbO_3$ (goldschmidtite) from an extremely fractionated melt/fluid indicate that potentially both mantle- and subduction-related fluids are the cause of metasomatism in the Kaapvaal cratonic root. Mantle-like, restricted carbon isotopic compositions of both P- and E-type diamonds (avg. $\delta^{13}C$ -5.7 ‰ and -6.6 ‰, respectively) indicate that an abundant, mantle-derived CHO fluid is responsible for diamond formation. Diamonds have a large range in nitrogen concentrations and isotopic compositions, suggesting decoupling from carbon and heterogeneous sources. $\delta^{18}O$ of former bridgmanite and $\delta^{13}C$ of its host diamond document a purely mantle-derived lower mantle component. Combined, these results reveal a complex and multistage evolution of the Kaapvaal Craton whereby multiple episodes of fluid and melt metasomatism re-enriched the craton already, prior to diamond formation, followed by diamond entrainment in a kimberlite possibly derived from the lower mantle.