Mantle metasomatism, oxidation and kimberlite magma genesis

GREGORY M. YAXLEY[1] & STEPHEN F. FOLEY[2]

[1]Research School of Earth Sciences, The Australian National University (greg.yaxley@anu.edu.au)
[2]Deapartment of Earth and Planetary Sciences, Macquarie University (stephen.foley@mq.edu.au)

High pressure experimental studies investigating the petrogenesis of kimberlites have focussed on the effects of CO_2 and/or H_2O on deep, partial melting of peridotite, or on locating the point of multiple saturation of peridotite phases on the liquidus of putative "primary" kimberlite melts in pressure-temperature space. These studies have failed to reach consensus regarding the source mineralogy or the pressure-temperature conditions of partial melting.

An alternative hypothesis is that precursor melts to Group I kimberlites formed under conditions too reducing for carbonate stability, around the iron-wüstite (IW) buffer in the asthenospheric mantle below the cratonic lithosphere. The few experimental constraints on the nature of partial melts produced under these conditions suggest they are hydrous, highly olivine-normative and may contain a small dissolved carbonate component; they are not yet kimberlites at this early stage.

Kimberlites have sampled large vertical sections of the cratonic lithospheric mantle in many locations, as garnet peridotite xenoliths. Studies of these xenoliths show that the cratonic mantle decreases in oxygen fugacity (fO_2) with depth, reaching values ≈ IW near the base of the lithosphere at 6-7 GPa. However, many deep samples were metasomatically enriched and oxidised to fO_2 values at which carbonate phases are stable [1,2]. Metasomatism in the deep cratonic mantle may also lead to enrichment in K_2O, CaO, CO_2 and H_2O as modal metasomatic phases such as carbonates, phlogopite and clinopyroxene [3].

The asthenosphere-derived, reduced precursor melts to kimberlites may segregate from their source region and interact with this metasomatised lithosphere, dissolving these metasomatic components and evolving to high K/Na, CaO, CO_2 and H_2O-rich melts, which on modification during transport to the surface, may erupt as kimberlites.

[1] Yaxley, Berry, Kamenetsky, Woodland & Golovin (2012) Lithos 140-141, 142-151.
[2] Yaxley, Berry, Rosenthal, Woodland & Paterson (2017) Scientific Reports 7, 30.
[3] Foley (2008), Nature Geoscience 1, 503-510.