Restoration of premetasomatic protolith compositions in mantle xenoliths

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Metasomatic overprints in peridotites of the Kaapvaal Craton document mantle refertilization. Compositions of most mantle peridotites document depletion in Al, Fe, Ca due to earlier partial melting events, whereas their incompatible trace element contents indicate reenrichment. Additionally, metasomatism may introduce clinopyoxene (cpx) and garnet (grt) as well as phlogopite (phl), transforming harzburgites into lherzolites. The original mantle composition can be restored from metasomatised peridotites by subtracting the effects of metasomatising agents.

We report results on wehrlite and websterite xenoliths from the Kimberley kimberlites, South Africa. These contain olivine (ol), cpx, opx, grt and phl in different abundances and exhibit mineral chemistry similar to peridotite xenoliths. While wehrlites comprise Mg-rich minerals (pyroxene Mg# 0.90-0.93), websterites can be subdivided into high-Mg (Mg# 0.90-0.92) and low-Mg (Mg# 0.87-0.90) groups. Pyroxene and grt in both wehrlite and websterite xenoliths have worm-like embayed forms which may indicate healed veinlets. Cpx exhibits convex upward rare earth element (REE) patterns, similar to cpx in lherzolite xenoliths, and garnets are light REE depleted and heavy REE enriched, similar to grt rims in lherzolite and harzburgite xenoliths. This indicates that these chemical signatures are characteristic for metasomatically introduced cpx and grt even where textural evidence for their metasomatic origin has been lost. Additionally, oxygen isotope composition of ol, opx, cpx and grt in the wehrlite and websterite xenoliths lie within the mantle range, but show disequilibrium partitioning between the minerals. Incomplete equilibration is also documented by thermometry: temperatures within grt-cpx-opx clusters are similar (Tgrt-cpx = 1043°C; Tcpx-opx = 1075°C), whereas the Tgrt-ol thermometer gives 100° higher (1150°C) for mineral pairs at the edges of clusters.

The texture of cpx in wehrlite xenoliths can be used to classify them as pervasively enriched mantle peridotites, whereas websterites are recognisable as vein assemblages crystallized from percolating metasomatic melts. The simpler mineralogy of wehrlites compared to lherzolites makes it easier to recalculate their premetasomatic protolith composition. Subtracting the metasomatic minerals cpx and grt and adding opx to the wehrlites results in harzburgitic to dunitic compositions with major element compositions that lie upon the mantle depletion trend.