Inclusions in diamonds constrain thermo-chemical conditions of the Kaapvaal cratonic mantle

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Mineral and fluid/melt inclusions in diamonds, which are encapsulated and isolated during a metasomatic event, offer the opportunity to constrain changes in the sub-continental lithospheric mantle that occurred during individual thermo-chemical events. Fibrous diamonds from the Group I De Beers Pool kimberlites, South Africa (SA), trapped incompatible-element enriched saline high-density fluids (HDFs) and peridotitic mineral microinclusions. Their substitutional nitrogen resides almost exclusively in A-centers. With regard to the elevated thermal conditions that prevailed in the SA lithosphere during and following Karoo volcanism at ~180 Ma, this low-aggregation state of nitrogen suggests a short mantle residence time, constraining the time of saline metasomatism to be close to the eruption of the kimberlites at ~85 Ma.

Thermometry of mineral microinclusions yield temperatures between 875-1080 ºC (at 5 GPa). These temperatures overlap with conditions recorded by touching inclusion pairs, which represent the mantle ambient conditions just before eruption, and are altogether lower by 150-250°C compared to P–T gradients recorded by peridotite xenoliths from the same locality. In addition, the oxygen fugacity calculated for the saline HDF compositions ($\Delta\log fO_{2(FMQ)}$ = -2.5 to -1.3) are higher by about a log unit compared with that recorded by xenoliths at 4-7 GPa.

We conclude that enriched saline HDFs mediated the metasomatism that preceded Group I kimberlite eruptions in the southwestern Kaapvaal craton, and that their 'cold and oxidized' nature reflects their derivation from a deep subducting slab. To reconcile the temperature and oxygen fugacity discrepancy between inclusions in diamonds and xenoliths, we argue that xenoliths did not equilibrate during the last saline metasomatic event or kimberlite eruption. Thus the P-T-fO_2 gradients they record express pre-existing lithospheric conditions that were likely established during the last major thermal event in the Kaapvaal craton (i.e. the Karoo magmatism at ca. 180 Ma).