Diffusion of major and minor elements within zoned garnet from the Kaapvaal craton, as determined using NanoSIMS and EPMA

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Linear compositional profiles in zoned garnet from peridotite xenoliths (Wesselton Pipe, South Africa) have been investigated using both electronprobe microanalysis (EPMA) and NanoSIMS. Elemental mapping showed that the crystals are enriched in Na, Ca, Ti, Cr and Fe and depleted in Al and Mg in the rim relative to the core. The garnet equilbrated at 1120 °C and 4.6 GPa, with $\Delta \log fO_2^{[FMQ]}$ varying from -2.4 in the core to -1.0 in the rim (Berry et al. 2013, Geology v.41, p.683). NanoSIMS allowed for higher spatial resolution measurement of the profile (800 nm spot size relative to 3-4 μm excitation volume for EPMA) and showed that EPMA consistently overestimated the length of the profile.

The profiles were modelled as a diffusion process by fitting to a solution of Fick's second law, with published diffusivity values used to determine the time taken for Ca, Fe and Mn to reach the observed state of frozen disequilibrium. Estimates of the time were 2 – 10 years based on Ca, whilst Mn and Fe were less than 100 days.

The timeframe obtained from Ca was then used to determine the relative diffusion coefficients of Na, Ti, Fe, Cr, Mn and Y. Diffusivities relative to Ca (log D = -20.45 m^2s^{-1}) vary from 0.5 m^2s^{-1} (Fe, Mn) to 0.1 m^2s^{-1} (Na, Cr) to -0.2 m^2s^{-1} (Ti, Y). Thus the fastest diffusing elements are Fe and Mn, followed by Ca, Na and Cr and the slowest are Y and Ti. This represents the first determination of diffusion coefficients for Na, Cr, Ti and Y (relative to Ca) in garnet from peridotites in the upper mantle.

This timeframe is extremely short in geological terms. The survival of this compositional zoning, indicates that the metasomatic event responsible occurred almost instantaneously before entrainment in the erupting kimberlite magma and quenching at the surface.