Carbonate metasomatism at the continental scale: insights from kimberlite-hosted zircon megacrysts

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Metasomatism, or chemical alteration of the Earth's mantle by a variety of melts and fluids, has been a key tenet in studies of mantle evolution for the past four decades. The consequences of such processes are often inferred to be far-reaching and yet, the evidence for their existence and operation is often highly localised, being confined, for example, to individual xenoliths or suites from a particular volcano or region. Metasomatised samples often display highly variable textures, ages and compositions making the characterisation of any individual process or event a difficult undertaking. We demonstrate that megacrystic zircons derived from kimberlites erupted at 19 locations across southern Africa, preserve a record at least two temporally and compositionally discrete metasomatic events. The influence of these events extends over length-scales of thousands of kilometres, apparently unaffected by lithospheric structure.

A detailed investigation of the most recent event reveals that the metasomatic agent is best characterised as a carbonatite melt with a high Lu/Hf composition. This carbonatite was itself derived from a source carrying an unradiogenic Hf isotope signature, and was stored in the sub-continental lithospheric mantle, tapped by successive kimberite magmatic events. As a consequence, zircon megacrysts formed shortly prior to kimberlite eruption, preserve a circa 60 Ma record of this metasomatised subcontinental lithospheric mantle source, including the evolution of its Hf-isotope composition through time.

This model has important implications for kimberlite petrogenesis as there is a close similarity between the Hf isotope compositions of the zircon megacrysts and their host kimberlite magmas. The latter, like the zircon megacrysts, also preserve a correlation between Hf isotope composition and age.