Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.7127

Timing and causes of metasomatism revealed by combined zircon U-Pb isotope and trace element analysis

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Models of metasomatism in the lithospheric mantle are critical to understanding the formation of diamond and the generation of diamond-hosting intra-cratonic magmas. Establishing when metasomatism happened may be achieved through geochronology on metasomatic phases. Further information is provided by trace element analysis of metasomatic phases, which may offer information on the composition of the metasomatic agents.

Previous works have demonstrated that zircon growth (and thus metasomatism) in the western Kaapvaal region was a protracted event coinciding mostly with Cretaceous intraplate magmatism. However, small sample sizes meant that it was not possible to determine whether metasomatism was episodic or more continuous, and trace elements that could tie zircon growth to specific metasomatic agents were not analysed.

Here, we utilize larger zircon populations, n=>40 per xenolith sample, to accurately and precisely date metasomatism in the Kaapvaal craton of South Africa using the laser ablation U-Pb method. We integrate those data with simultaneously acquired trace element data enabling us to trace variations in the composition of the metasomatic agents through time.

Our data show that metasomatic zircon growth is broadly coincident with nearby expressions of late Cretaceous kimberlite magmatism and mid-Cretaceous orangeite magmatism. Using combined U-Pb isotope and trace element analysis we demonstrate that earlier zircon shows geochemical affinity to lamproitic (and crustal) zircon and are coincident and succeeding orangeite (a CO_2-rich lamproite variety) magmatism. By contrast most late-Cretaceous zircon growth in the mantle underlying Kimberley, coincident with peak kimberlite magmatism, precipitated zircon with trace-element compositions similar to that seen in megacrystic zircon - a suite thought to be cognate to early high-pressure proto kimberlitic liquids/fluids. The presence of zircon spanning the entire range of Cretaceous intra-cratonic magmatism in Kimberley from single xenolith samples shows trace element and isotopic disequilibria on cm-scales and demonstrates that a hybrid origin is required for the formation K-rich metasomes in the underlying mantle.