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Multiple episodes of fluid and melt migration in the Kaapvaal Craton lithospheric mantle associated with group-I kimberlite activity: evidence from a harzburgite containing a unique assemblage of metasomatic Zr-phases

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Nowadays it is widely accepted that volatile-rich magmas forming kimberlites, orangeites and lamproites require a peridotitic mantle source that was enriched in H_2O-(CO_2)-REE-HFS-LIL elements with respect to primitive mantle. When injected into cool subcontinental lithospheric mantle, these magmas again release large amounts of hydrous incompatible element-enriched fluids during cooling and differentiation which may lead to extensive but localized metasomatism. Whether metasomatism took place as a single event or as a more complex succession of repeated fluid/melt-rock interaction episodes can usually not be decided based on available textural and compositional information. Here we present results of a mineral chemical-structural and textural investigation of a metasomatized harzburgite xenolith sampled by one of the group-I kimberlites of the Kimberley cluster from the Kaapvaal Craton, South Africa, for which such a distinction is possible. Based on textures and phase compositions we propose three episodes of rock-melt/fluid interaction involving both silicate and carbonatite melts/fluids. These events gave rise to a uniquely complex assemblage of LILE-HFSE-rich phases rich in Zr including zircon together with both monoclinic (baddeleyite) and cubic (tazheranite) zirconium oxide, srilankite and a new Mn-Fe-rich member of the pyrochlore-group of phases. The primary pre-metasomatic assemblage is olivine + orthopyroxene + chromite + traces of clinopyroxene. Subsequent modal metasomatism formed phlogopite + K-richterite + crichtonite-group (lindsleyite-mathiasite) phases + Nb-Cr-rich rutile + srilankite + zircon + Fe-Ni-sulfide. K-richterites are strongly zoned in Ca, Na, Fe and Cr with up to 2.0 wt% $Cr2O_3$ which is the highest Cr-concentration reported so far for K-richterite. SIMS U-Pb dating of the zircons yields ages in the range 81 ± 2 to 91 ± 2 (2σ) Ma which are indistinguishable from emplacement ages of the host group-I kimberlites. This coincidence in ages further supports a temporal and genetic link between group-I kimberlite activity and hydrous potassic metasomatism in the central Kaapvaal Craton. Thermobarometry of the harzburgite yields 750-760°C at 3 GPa with a redox state of +0.9 to +1.2 log units relative to FMQ. Infiltration of a hot and alkali-rich (kimberlitic ?) melt into the cool metasomatized peridotite led to partial breakdown of K-richterite, crichtonite-group phases, sulfides and zircon and formed Al-Ti-Ni-rich spinel + K-Cr priderite + Nb-rich titantite + baddeleyite + tazheranite + Mn-Fe-betafite. The latter two phases were unambiguously identified with electron microprobe analysis combined with selected area diffraction using FIB-TEM. The tazheranite from this study represents the first occurrence reported so far from a mantle rock. In addition, a second generation of Ni-poor and Mn-rich olivine formed along with Ti-rich K-richterite, phlogopite and clinopyroxene. Evidence for a short-lived episode of carbonatite melt/fluid infiltration is provided by an inclusion in rutile containing LREE-Sr-Ba-Na-rich phosphates one of which with 17.5 wt% Na2O, 0.5 % K2O, 3.3 wt% SrO, 2.0 wt% BaO and 4.8 wt% $Ce2O_3$.