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Transitional pyroxenitic-lherzolitic xenoliths from Roberts Victor, Kaapvaal craton

Karen V. Smit, Kaydi O. Govender, Kananelo Letete, Fezeka Dliwako
School of Geosciences, University of the Witwatersrand, South Africa, karen.smit@wits.ac.za

Introduction

The Kimberley block of the Kaapvaal craton has a distinctive origin and evolutionary history to the eastern Witwatersrand-Swaziland blocks. Available data show that the Kimberley crust and mantle are not older than 3.3–3.2 Ga, whereas the eastern Wits-Swazi blocks have 3.66–3.2 Ga crust. These two cratonic terranes collided at 2.9 Ga, with westward subduction beneath the Kimberley block along the Colesberg Lineament (Schmitz et al., 2004). The Roberts Victor carbonate-rich olivine lamproite (CROL, previously Type II kimberlite) erupted at 128 Ma near the Colesberg Lineament, though it could sample either the Kimberley or Witwatersrand cratonic lithosphere at depth. Lutetium-Hf isotopes in Roberts Victor peridotitic garnet xenocrysts from the literature give isochron ages of 3266 ± 150 Ma and 2949 ± 49 Ma yielding both the time of lithospheric mantle formation and lithospheric modification at the time of continental collision (Shu et al., 2013). To further investigate the composition and age of the central Kaapvaal lithosphere near the suture of the Kimberley-Witwatersrand cratonic blocks, we are studying a suite of nine rare lherzolitic-pyroxenitic xenoliths from Roberts Victor (Figure 1).

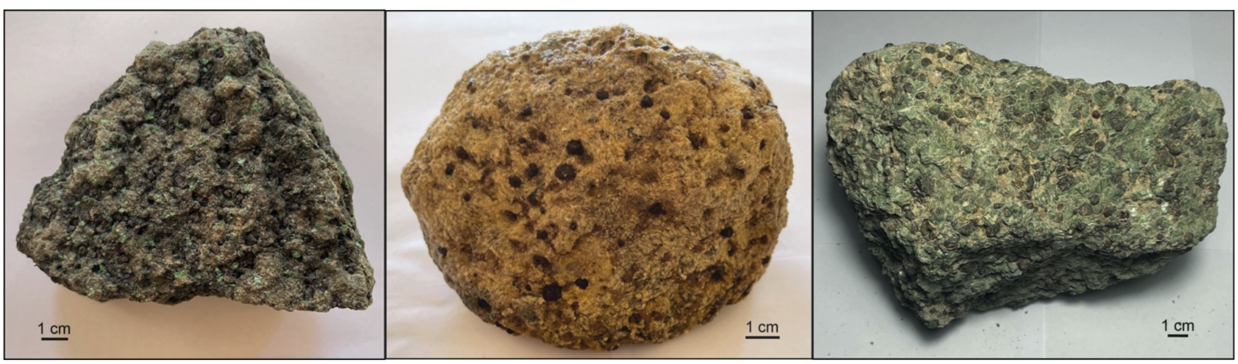

Figure 1. Roberts Victor peridotites are altered with abundant serpentine, calcite, and quartz (see also Viljoen et al., 1991). Six xenoliths contain lherzolitic G9 garnets, and three xenoliths contain either G11, G10 or G4 garnets.
Left) SRV01 – with lherzolitic G9 garnet and Cr-diopside clinopyroxene. Middle) SRV04 – with harzburgitic G10 garnet and transitional omphacitic-diopsidic clinopyroxene. Right) SRV10 – with pyroxenitic G4 garnet and transitional omphacitic-diopsidic clinopyroxene.

Major and trace element compositions

Eight out of the nine xenoliths contain *peridotitic garnets* with 19.5–21.5 wt.% MgO, 3.2–7.1 wt. % Cr_2O_3 and 4.2–6.2 wt. % CaO. Garnets from six of these eight xenoliths classify as lherzolitic (G9), with garnet from one xenolith classifying as harzburgitic (G10), and garnet from one xenolith classifying as high-TiO_2 peridotitic (G11). Garnet from two xenoliths (G10 and G9) have sinusoidal REE_N patterns with maxima at Sm_N (where REE_N refers to chondrite normalisation). The remainder of the garnets have broadly 'normal' REE_N patterns that are depleted in $LREE_N$, with flat to slightly fractionated $MREE_N$ to $HREE_N$.

Clinopyroxene in these eight xenoliths have Na/(Na+Ca) that range between 0.09 and 0.31 and molar Cr/(Cr+Al) between 23.9 and 49.6 (Figure 2). These compositions are *transitional* between Cr-diopside and omphacite, similar to the compositions of clinopyroxene inclusions in Voorspoed diamonds that were found to be 'transitional websteritic-lherzolitic' (Viljoen et al., 2018). Interestingly, in one xenolith, harzburgitic G10 garnet with a sinusoidal REE_N pattern, co-exists with clinopyroxene that simultaneously has high Na content resembling omphacite (Na/(Na+Ca) = 0.25) and high molar Cr/(Cr+Al) of 49.6 resembling Cr-diopside (Figure 2). Clinopyroxenes in the eight xenoliths with peridotitic garnets, are generally $LREE_N$-enriched, with $LREE_N$ between 10–100× chondrite (Sun and McDonough, 1989) and La_N/Lu_N = 0.3–670.

One xenolith contains *pyroxenitic (G4) garnets* with 21 wt.% MgO, 0.4 wt. % Cr_2O_3 and 3.89 wt. % CaO. These garnets have broadly 'normal' REE_N patterns that are depleted in $LREE_N$ (with La_N/Eu_N = 0.11) and slightly fractionated $MREE_N$ to $HREE_N$ (with Tb_N/Lu_N = 0.4). Clinopyroxene in this xenolith has Na/(Na+Ca) of 0.21, with Mg# (Mg/(Mg+Fe) × 100) of 91.8 and molar Cr/(Cr+Al) of 3.75 suggesting a *transitional* omphacitic-diopsidic composition (Figure 2). Clinopyroxene has a relatively flat REE_N pattern, with La_N/Lu_N = 0.7.

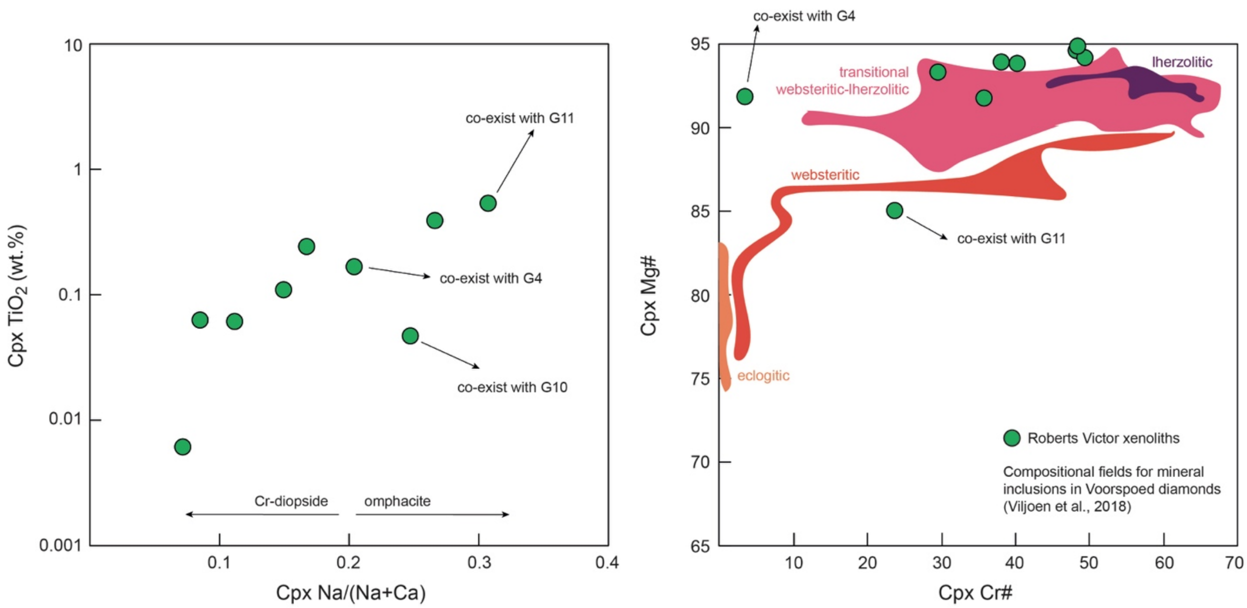

Figure xx. Major element compositions of clinopyroxene in Roberts Victor xenoliths that are transitional between omphacite and Cr-diopside .

Geothermobarometry

After compositional filtering, clinopyroxene from seven xenoliths was used to determine pressures and temperatures (Nimis and Taylor, 2000, with the empirical pressure correction of Nimis et al., 2020) and a FITPLOT geotherm (Figure 3). Calculated pressures and temperatures range between 2.8 GPa and 5.2 GPa and 681 and 1021 °C, yielding a lithospheric thickness below the Colesberg Lineament of 220–230 km. Along the calculated geotherm, diamonds are stable above 900 °C (130 km), where clinopyroxene from four of the seven xenoliths gave depth estimates within the diamond stability field. The lithospheric thickness estimate from Roberts Victor is only slightly thicker than the depth estimates for nearby localities such as Kimberley (210 km) and Voorspoed (215 km) (Nimis et al., 2020).

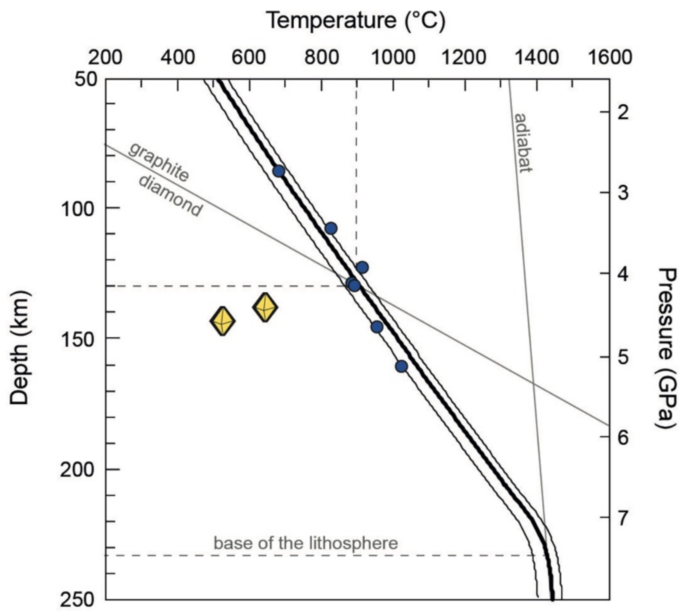

Figure 3. Goetherm calculated from Roberts Victor peridotites, using the single clinopyroxene geothermobarometer from Nimis and Taylor (2000), with the empirical pressure correction of Nimis et al. (2020).

Ongoing work

For the *transitional* websteritic-lherzolitic assemblage at Voorspoed, Viljoen et al. (2018) suggested their formation as the reaction between the peridotitic lithosphere and fluids from subducting slabs and/or a mantle plume. Ongoing work on Roberts Victor xenoliths will assess whether plume vs subduction geochemical signatures can be identified and whether these signatures can be linked to either the impact of 2.9 Ga intracratonic subduction-accretion, or the 2.7 Ga Ventersdorp LIP. We plan to analyse a range of isotopic systems in these samples to explore lithospheric age constraints: Pb and Sr isotopic ages of clinopyroxene, Lu-Hf isotopic ages of garnet, and potentially Os isotopic ages of any remnant fresh olivine.

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