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The Origin of Eclogitic Corundum and Garnet Xenocrysts from the Kareevlei Kaapvaal Lamproite (Group II Kimberlite)

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1. Introduction

The Kareevlei diamond mine is the first of its kind where diamonds are hosted in highly evolved K-richterite and leucite-bearing Kaapvaal lamproites. While diamond grades are low (~5 carats per hundred tons), the diamond quality is high (US$300 per carat) ranking it in the top-10 diamonds mines worldwide (Grills and Lorentz, 2019). The garnet indicator mineral suite is characterised by ~60% eclogitic garnets with lower proportions of G9 and G10 garnets. In addition, garnet thermobarometry showed that the G9+G10 garnets were predominantly sourced from shallow depths outside of diamond stability (Qashani et al., 2023). Thus, it is likely that the high-value diamonds at Kareevlei are predominantly eclogitic in origin. To constrain the possibly diamond substrate at Kareevlei, here we present the petrology of garnet and corundum xenocrysts along with rare eclogite xenoliths from the Kareevlei diamond mine. In particular, the high abundance of corundum xenocrysts, often up to cm-scale, in the heavy mineral concentrate was particularly unusual and is the primary focus of this project.

Eclogitic xenocrysts and xenoliths were sourced from the heavy mineral concentrate at the Kareevlei diamond processing facility in Kimberley, South Africa. Attempts were made to find eclogite xenoliths at the Kareevlei open pit mine; however, none were found. In general, xenoliths are exceptionally rare with only ~6 found over the last 3 years.

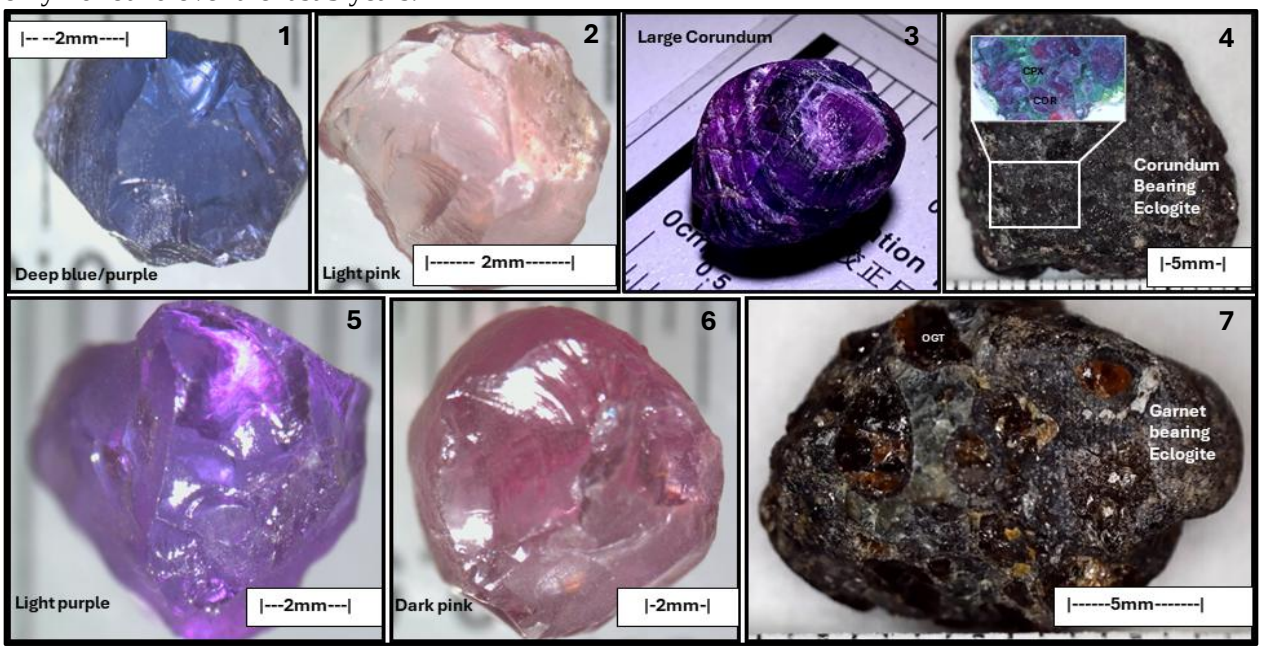

Fig.1. Digital light microscope images of corundum xenocrysts (**1**,**2**,**3**,**5**, & **6**), corundum-bearing eclogite (**4**), and garnet-bearing eclogite (**7**).

However, eclogitic garnets and corundum xenocrysts are abundant in the heavy mineral concentrate and thus form the bulk of the samples analysed. Here we present EPMA major element and LA-ICP-MS trace element data for 112 corundum and 120 garnet xenocrysts along with oxygen isotope data for representative samples across the geochemical ranges observed for 24 corundum and 5 garnet xenocrysts. We also present oxygen isotope data for one corundum-bearing xenolith.

2. Results

The corundum xenocrysts have a range in colour from deep purple to pink-purple and distinctly pink. They have a wide compositional range of chromophore-influencing transition metal concentrations with Ti (62 - 1100 ppm), Mg (79 980 ppm), Fe (85 - 6735 ppm), Cr (1075 – 6285 ppm) and V (2 - 273 ppm). Elevated Ni concentrations at (up to169 ppm for these samples) are consistent with corundum that occur in diamond inclusions from eclogites in other locations worldwide. There is a significant overlap in Ti and V within a similar Cr range of the corundum, but the purple varieties show more elevated Ti and V (**Fig.2.**).

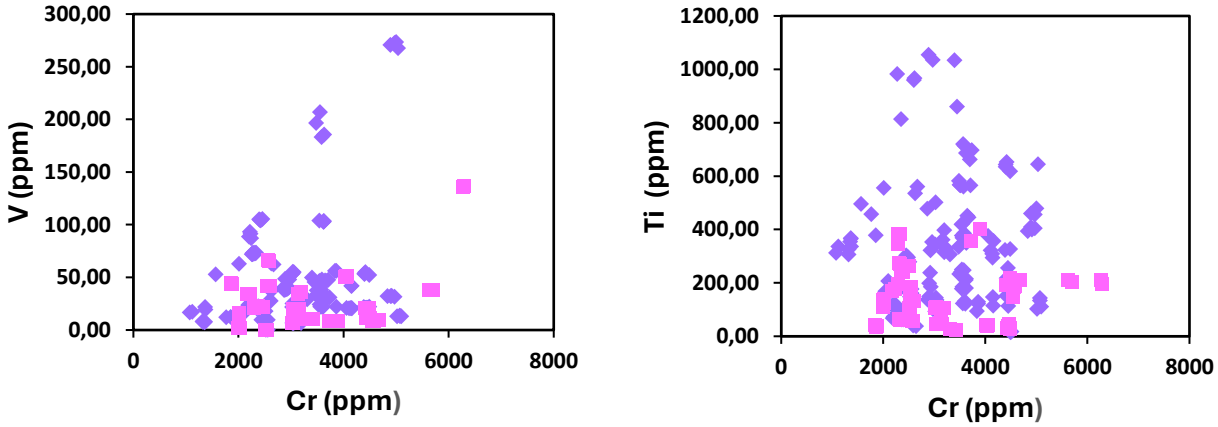

Fig.2. Ti and V concentrations vs Cr outlining compositional distinction between the pink and purple corundum.

Eclogitic garnets are characterised by a typical orange colour but do not show significant compositional variations. The orange garnets are typically low Ca with positive inclined middle to heavy REEs and depletion of light REEs. A positive Eu anomaly in some eclogitic garnet REEs serves as evidence of a plagioclase rich crustal protolith.

Corundum $\delta^{18}O$ values range from a 2.94‰ to 4.81‰ (n = 24, **Fig. 3.**). Corundum and omphacite grains selected from the single crushed xenolith have values 4.97‰ and 5.13‰, respectively. From the small sample set of garnet xenocrysts (n = 5) analysed so far, a wider range in $\delta^{18}O$ values were obtained, 5.04‰ to 7.26‰, extending to higher values than observed for corundum.

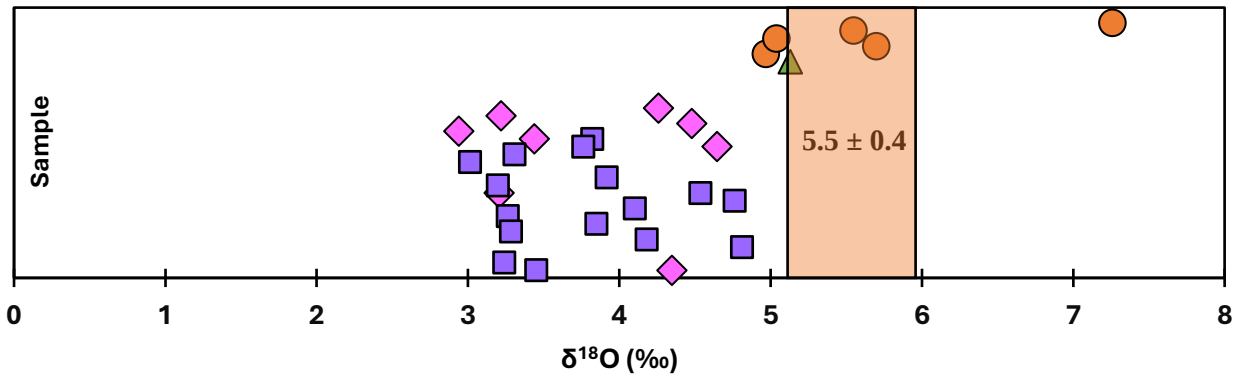

Fig.3. $\delta^{18}O$ composition of corundum (purple squares and pink diamond shapes), garnet (orange circles) and omphacite (green triangle)

3. Discussion

The Kareevlei corundum are lower in $\delta^{18}O$ than the 'normal' range expected for mantle-derived phases. This range in $\delta^{18}O$ is interpreted to reflect that of the protolith(s) and was probably caused by the water-rock exchange at relatively high temperatures in the Archean oceanic crust before incorporation into the mantle. The presence of highly aluminous phases like corundum with low $\delta^{18}O$ values is consistent with the recycling of hydrothermally altered plagioclase-rich gabbro, as opposed to clay-rich sediments, which typically have $\delta^{18}O$ values above the mantle range High-temperature alteration typically occurs within cumulate gabbroic rocks, as seen from ophiolite sequences obducted onto cratonic crust. The entire array of eclogite-facies rocks found in cratonic settings, together with the suggested oceanic crustal origin of these aluminous eclogites, complete the tectonic picture and eliminates any uncertainty regarding their low-pressure ancestry in the mantle lithosphere.

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