

A DETAILED GEOCHEMICAL STUDY OF A SUITE OF DIAMONDIFEROUS ECLOGITE XENOLITHS FROM THE KAALVALLEI KIMBERLITE, SOUTH AFRICA

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The Kaalvallei kimberlite is situated on the farm Kaalvallei-12 about seven kilometres from Welkom in the Orange Free State, South Africa, and occurs on the Kaapvaal craton. Texturally, the kimberlite is classified as transitional between diatreme-facies tuffisitic kimberlite breccia (TKB) and hypabyssal-facies kimberlite. Mineralogically, Kaalvallei is an ilmenite-rich, monticellite Group 1 kimberlite. Rb-Sr dating of micas extracted from Kaalvallei hypabyssal-facies kimberlite produced an age of 84.6 Ma \pm 0.9 Ma (Viljoen, 1994). Ultramafic xenoliths described from Kaalvallei include corundum eclogites, bimineralic eclogites, diamondiferous eclogites, clinopyroxenites, ilmenite-bearing eclogites, spinel-bearing eclogites, websterites, and alkremites (Schulze, 1989; Viljoen, 1994).

A suite of seventeen eclogite xenoliths were examined in this study. All are essentially bimineralic, with thirteen xenoliths containing accessory diamond and graphite. One eclogite contains accessory ilmenite and diamond. All the eclogites classify as Group 1 eclogites according to the textural classification of MacGregor and Carter (1970), and the chemical classification of McCandless and Gurney (1989).

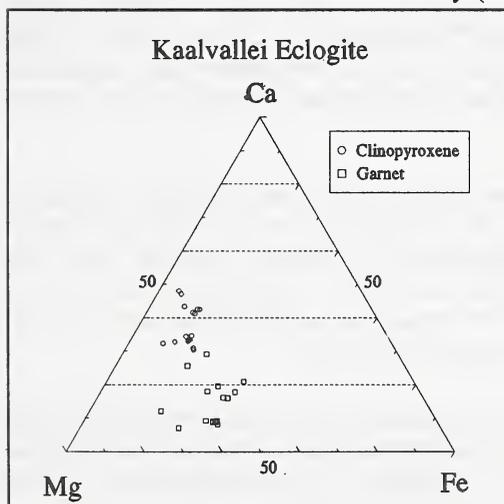


Figure 1. Ca-Mg-Fe ternary diagram of garnet and clinopyroxene compositions from the Kaalvallei eclogite xenoliths.

In Figure 1, the garnet and clinopyroxene compositions display a trend from Mg towards Ca and Fe enrichment. The eclogites form two populations based on major element compositions, temperature, and oxygen isotope compositions - suggesting two different equilibration conditions of formation (Figure 2 and 3). Garnet from the diamondiferous eclogites display a range of $\delta^{18}\text{O}$ values from 4.65 to 7.20‰ (corrected to Standard Mean Ocean Water (SMOW)), and their associated clinopyroxene have $\delta^{18}\text{O}$ values from 4.97 - 7.32‰ (corrected to SMOW). Two non-diamondiferous samples have $\delta^{18}\text{O}$ values which fall in the range measured for the diamondiferous eclogites. Fractionation of $\delta^{18}\text{O}$ values between garnet and clinopyroxene range from 0.03 to 0.36‰.

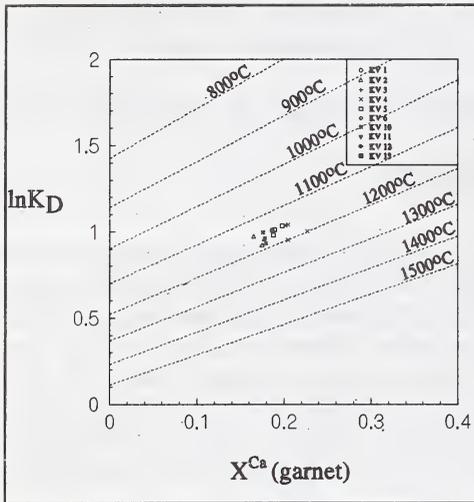


Figure 2. The variation in $\ln K_D$ with X^{Ca} in garnet for the Kaalvallei eclogites. Calculations based on K_D formulation of Ellis and Green (1979).

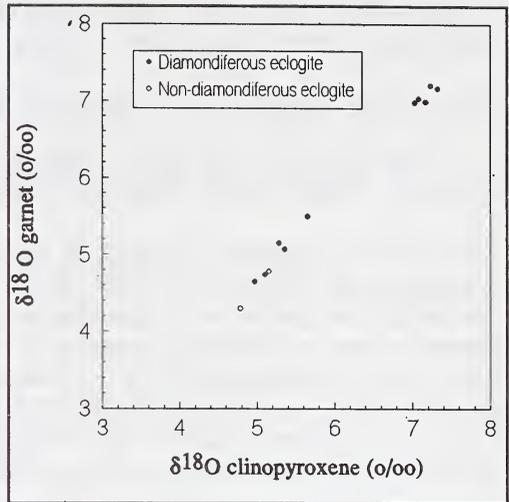


Figure 3. Variations in $\delta^{18}O$ values for garnets and clinopyroxenes from Kaalvallei eclogite xenoliths.

Strontium (Sr) and neodymium (Nd) isotopic compositions were determined for six eclogites. $^{87}Sr/^{86}Sr$ ratios for the clinopyroxene ranges from 0.70313 to 0.70545, while garnet separates yield $^{87}Sr/^{86}Sr$ ratios from 0.70383 to 0.70659. Clinopyroxene has $^{143}Nd/^{144}Nd$ values ranging from 0.51270 to 0.51285, while garnet has $^{143}Nd/^{144}Nd$ ratios of 0.51293 to 0.51307. Model ages calculated for the eclogite xenoliths are similar to the pipe emplacement age - suggesting that the eclogites have equilibrated to the ambient geochemical conditions at the time of kimberlite eruption ($\pm 85Ma$).

Diamonds extracted from the eclogites were inclusions-free and exhibited octahedral morphology showing no resorption features with etching seen only on exposed diamond surfaces. Carbon isotopic compositions determined for diamonds extracted from four Kaalvallei eclogite xenoliths vary between -4.06‰ and -5.83‰ . This range is similar to one of the ranges in the bimodal distribution of $\delta^{13}C$ values for eclogitic diamonds, and also within the range of $\delta^{13}C$ values observed for peridotitic diamonds.

Nitrogen aggregation state and cathodoluminescence characteristics were determined for fifty-five diamonds extracted from eleven of the eclogites. Infrared spectra obtained from diamond cores and edges reveal that eight xenoliths have dominantly Type IaAB diamonds; with the edges being chiefly Type IaA. Two eclogite xenoliths have diamonds mainly of Type IaA. Diamonds from one xenolith are entirely Type IIa. Platelet evolution of diamonds from one xenolith is different from those of the other eclogites examined suggesting perhaps a rapid heating event which affected the xenolith, or origin of that eclogite at greater depth than the rest. Most of the samples exhibit a uniform blue cathodoluminescence pattern, showing no zoned growth of diamond. Exceptions are the Type IIa diamonds which have greenish-blue cathodoluminescence, and Type IaAB diamonds from one eclogite which show patches of blue

and dull blue.

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