
THE GEOCHEMISTRY OF A SUITE OF ECLOGITE XENOLITHS FROM THE RIETFONTAIN KIMBERLITE, SOUTH AFRICA

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INTRODUCTION

The Rietfontein kimberlite is a barren, off-craton kimberlite pipe. It is located west of the Kaapvaal Craton and is intruded into the Rehoboth subprovince. This Group I kimberlite has been dated at 71.9Ma (Davis, 1977) and hosts a range of xenocryst lithologies, including peridotite, eclogite and a suite of megacryst minerals. This study focuses on a suite of eclogite xenoliths, which were subject to a detailed petrographical and geochemical study, aimed at their characterisation and comparison to eclogites from on-craton and other off-craton localities. Garnet, clinopyroxene, accessory and secondary minerals were analysed for major element compositions using electron microprobe techniques and garnet and clinopyroxene trace element compositions determined by Laser Ablation Inductively-Coupled-Plasma Mass Spectrometry (LA-ICP-MS) techniques. Oxygen isotopic compositions of five garnet samples were obtained using laser fluorination techniques, followed by analysis by gas source mass spectrometry.

PETROGRAPHY

Three petrographically distinct eclogite groups can be identified *viz.* biminerally, opx-bearing and kyanite eclogites. The kyanite eclogites are markedly fresher than the biminerally and opx-bearing eclogites and contain fewer accessory and secondary minerals. Many of the biminerally and opx-bearing eclogites are highly altered, with orthopyroxene generally showing more alteration than garnet or clinopyroxene. Triple junctions in many samples indicate good equilibration. Accessory minerals in the eclogites include sulphides, ilmenite and rutile, whereas micas and amphiboles are common secondary minerals. The accessory minerals occur mostly interstitially, whereas the secondary minerals most commonly form alteration rims around the primary minerals. One sample shows an excellent example of garnet exsolution from clinopyroxene (Figure 1).

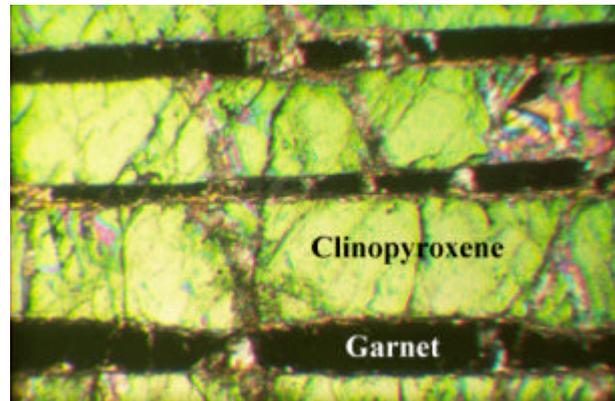


Figure 1 Garnet exsolution lamellae in a large, optically continuous clinopyroxene grain in eclogite sample CMA 1. Lamellae can be up to 0.5mm in diameter. Cross-polarised light, 2.5x magnification, field of view = 3mm.

Texturally, both Group I and Group II eclogites can be identified (MacGregor & Carter, 1970), but Group II eclogites dominate the suite. The modal proportions of garnet:clinopyroxene in the samples vary from 70:30 to 30:70, with an average ratio of 49:51, although small sample sizes and large degrees of alteration often made estimates of modal proportions difficult. Kyanite and orthopyroxene both reach a maximum of 20 volume %.

MINERAL CHEMISTRY

The kyanite eclogites are geochemically distinct from the remaining eclogites with regards to both major and trace element compositions. Garnets from the kyanite eclogites are richer in Ca (Figure 2) and are Cr-depleted relative to garnets from the biminerally and opx-bearing eclogites, which tend to be more magnesian. A visual comparison of the end-member components of the Rietfontein eclogitic garnets with garnets from on- and off-craton localities is inconclusive (Figure 2). There is much overlap between the off-craton eclogites, represented by the Cape Province off-craton suite (Robey, 1981) and on-craton eclogites, represented by Roberts Victor eclogites. Clinopyroxenes from the kyanite eclogites are more sodic, with higher Al₂O₃ and lower MgO contents than the biminerally and opx-bearing eclogites. The higher Na₂O and lower MgO

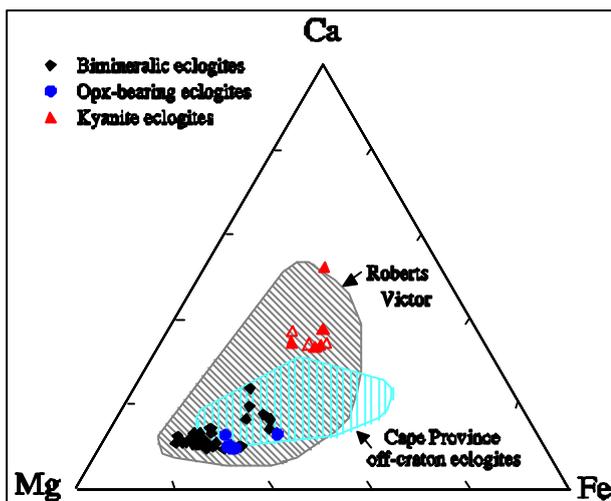


Figure 2 Ca-Mg-Fe ternary diagram for garnets from the Rietfontein eclogites. Data from the off-craton field from Robey (1981); Roberts Victor data from Hatton (1978), MacGregor & Manton (1986), Ongley *et al.* (1987), McCandless & Gurney (1989) and Bell & Rossman (1992).

contents in clinopyroxenes from the kyanite eclogites result in these eclogites being classified as Group B eclogites (Figure 3), whereas the bimineralic and opx-bearing eclogites classify as Group A and Group B eclogites, after the classifications of Taylor & Neal (1989). Low $\text{Na}_2\text{O}_{\text{gt}}$ and $\text{K}_2\text{O}_{\text{cpx}}$ concentrations mean that the majority of the Rietfontein eclogites are also Group II eclogites (McCandless & Gurney, 1989). All primary minerals are homogeneous, indicating compositional equilibrium within the samples.

Garnets from both the bimineralic and opx-bearing eclogites show smoothly varying REE patterns and are relatively depleted in LREE, whereas clinopyroxenes show enrichment in LREE. Garnets and clinopyroxenes from the kyanite eclogites have distinctly different patterns. Garnets exhibit a positive Eu anomaly and clinopyroxenes have an overall convex upwards REE pattern and both are extremely depleted in LREE. Garnets from the kyanite eclogites have Sr, Sm and Nd contents greater than the bimineralic and opx-bearing eclogites, whereas clinopyroxenes from the kyanite eclogites have lower REE, Sc and Y abundances than the remaining eclogites. Partitioning of trace elements between clinopyroxene and garnet in the Rietfontein eclogites is shown to be primarily dependent on the Ca content of garnet, with the more Ca-rich garnets having greatest REE concentrations.

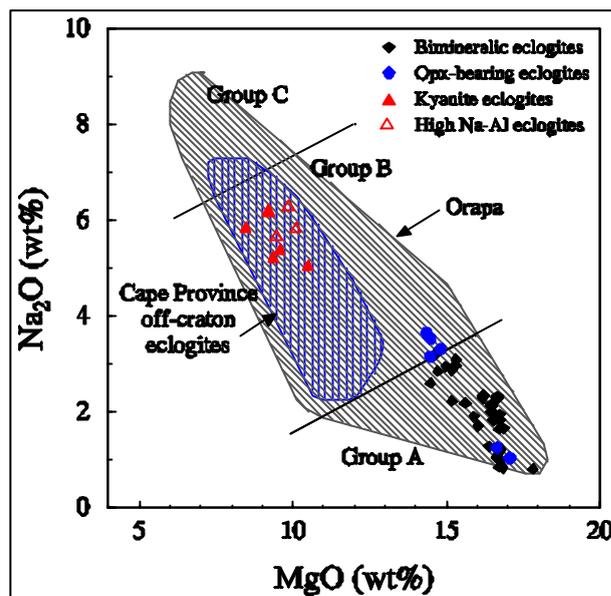


Figure 3: Na_2O (wt%) vs MgO (wt%) for Rietfontein clinopyroxenes. Orapa data from Shee (1978) and Deines *et al.* (1991); off-craton data from Robey (1981). Group A, B and C fields are based on the composition of Bellsbank eclogites, defined by Taylor & Neal (1989).

WHOLE ROCK CHEMISTRY

Whole-rock compositions of the eclogites have been reconstructed using equal proportions of garnet and clinopyroxene. In the case of the opx-bearing and kyanite eclogites, the relevant proportions of orthopyroxene and kyanite were also included in the reconstruction. The Rietfontein eclogites are found to be largely basaltic, as is expected of eclogites. The kyanite eclogites are richer in Na and Al than the bimineralic and opx-bearing eclogites, which are more magnesian. The kyanite eclogites exhibit compositional similarities to oceanic gabbros and mid-ocean ridge basalts. Most of the Rietfontein eclogites show strong similarities to boninites with regards to their MgO , CaO and Na_2O contents. The kyanite eclogites have distinctly different whole-rock REE patterns when compared to the opx-bearing and kyanite eclogites, with strong LREE depletion and positive Eu anomalies being exhibited. The bimineralic and opx-bearing eclogites exhibit a range of patterns, mostly flat or showing a regular transition from relative LREE enrichment to relative HREE depletion. (Figure 4).

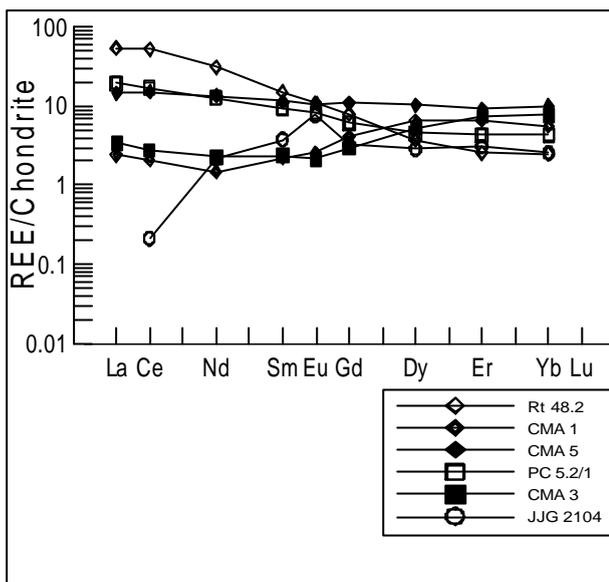


Figure 4 Reconstructed whole-rock REE abundances of selected bimineralic (diamonds), opx-bearing (squares) and kyanite (circles) eclogites. Concentrations are chondrite normalised after Sun & McDonough (1989).

OXYGEN ISOTOPES

Oxygen isotope compositions of garnets from five Rietfontein eclogites range from 5.16-6.84‰. The most Ca-rich sample, a kyanite eclogite, exhibits the highest $d^{18}\text{O}$ values, whereas the most Mg-rich garnets exhibit the lowest $d^{18}\text{O}$ values. If one disregards the outlier value of 6.84‰, all data for the Rietfontein garnets fall within the “normal” mantle range of 5-6.5‰, defined by Deines *et al.* (1991), as well as the range of $5.5 \pm 0.7\text{‰}$ for ultramafic upper mantle xenoliths (Mattey *et al.*, 1994). The oxygen isotope data thus provides no clear evidence of a crustal precursor.

GEOTHERMOBAROMETRY

The major element compositions of garnet, clinopyroxene and, in the case of the opx-bearing eclogites, orthopyroxene, were used to calculate equilibration pressures and temperatures of the Rietfontein eclogites. The results indicate derivation from mantle depths, with temperatures of 733-1000°C (Krogh, 1988) and pressures of 24-39kb (Brey & Köhler, 1990) having been estimated. This large range in equilibration pressures and temperatures represents a significant range in mantle stratigraphy and the higher

average equilibration temperatures of the kyanite eclogites provide evidence for derivation of these eclogites from greater depths than that of the bimineralic and opx-bearing eclogites. Geotherms constructed from the temperature and pressure estimates of the opx-bearing eclogites yield heat flow approximations of 41-44mW.m⁻², most similar to geotherms for established on-craton areas.

CONCLUSIONS

The unambiguous differences in composition and equilibration conditions between the kyanite eclogites and the bimineralic/opx-bearing eclogites indicate that the Rietfontein eclogites represent samples from two distinct eclogite sources situated at depth. A model is proposed whereby all three groups of eclogites originate as unrelated remnants of oceanic crustal material, with one body represented by the kyanite eclogites, the other by the bimineralic and opx-bearing eclogites. Subduction of plagioclase-rich, basaltic oceanic crust to eclogite facies depths would yield eclogites with compositional characteristics similar to those of the Rietfontein kyanite eclogites, *viz.* positive Eu anomalies and Na- and Al-rich whole rock compositions. In contrast, subduction, hydrothermal alteration and metamorphism to eclogite of an oceanic crustal section consisting of basalt, gabbro and boninite is suggested to be the source of the Rietfontein bimineralic and orthopyroxene-bearing eclogites. Underplating of the continental lithosphere by these unrelated eclogite bodies would then allow the Rietfontein kimberlite to separately sample each eclogite body as it ascended towards the surface.

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