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Dutoitspan kimberlite, South Africa: Petrogenesis of the Northwest Corner intrusive phases

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The Dutoitspan kimberlite, a Group 1 diamondiferous kimberlite within the Kimberley cluster, South Africa, comprises 18 distinct intrusive phases, showing clear cross-cutting relationships. The petrography and bulk rock geochemistry of 7 individual phases have been studied in detail to better understand their mutual genetic relationships, and the nature of their mantle source region(s). In general the kimberlite phases can be classified as microporphyritic (Figure 1) to macrocrystic (Figure 2) opaque- and monticellite-rich hypabyssal kimberlite. Olivine is the dominant macrocryst phase (3-40 vol. %), with lesser opaque oxides and phlogopite. Olivine dominates the phenocryst assemblage (10 to 30 vol. %), whereas the groundmass is often dominated by monticellite (up to 30% in highly macrocrystic phases), with opaque oxides, serpentine and carbonate; perovskite is relatively common and accessory groundmass minerals include apatite, clinopyroxene and chlorite.

Major and incompatible trace element compositions of the different intrusive phases show some clear differences, although all are characterized by high Mg # (0.86 to 0.91), low TiO_2 (~0.81 to ~2.00 wt%), and elevated Ba (~500 to 2000ppm), Rb (~40 to 230ppm) and Zr (~145 to 580ppm) abundances. Chondrite-normalised rare earth element patterns are strongly light REE enriched (La/Yb_n = ~55 to 235; La/Sm_n = ~4.6 to 6.7), and patterns for the different intrusive phases are largely sub-parallel, as are primitive mantle-normalised patterns which show superimposed negative K, Sr and Ti anomalies (Figure 3).

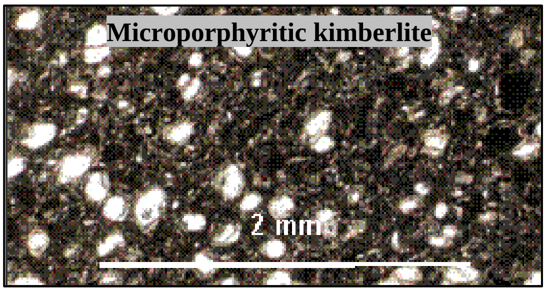

Figure 1: Photomicrograph of microporphyritic kimberlite. Note the abundance of opaque oxides and the lack of olivine macrocrysts.

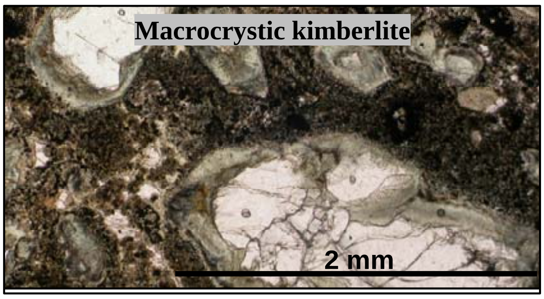

Figure 2: Photomicrograph of macrocrystic kimberlite. Pools of carbonate (colourless) are ubiquitous in this spinel-rich matrix (black).

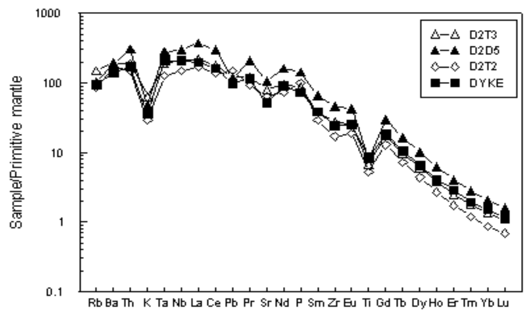

Figure 3: Primitive mantle-normalised trace element patterns of four of the Northwest Corner intrusive phases. Normalizing values from Sun & McDonough (1989).

Correction for macrocryst content, and making allowances for crustal contamination, enables estimation of close-to-primary kimberlite magma compositions that have given rise to the different intrusive phases of the Dutoitspan kimberlite. These estimated primary magma compositions are not strongly different from one another in major element content, and have ~29 wt% SiO_2, 30 wt% MgO, 13 wt% CaO, 1.3 wt% K_2O, 1.9 wt% Al_2O_3 and Mg# ~0.88. The Ni contents are high, ~1100ppm as are incompatible trace elements (e.g. La ~240 ppm; Zr ~500 ppm; Nb ~240 ppm; Ba ~1160 ppm).

The similar compositions of individual pulses of magma giving rise to the different intrusive phases suggest derivation from a common, broadly homogeneous source. Forward modelling of source region characteristics, assuming a low (1%) degree of partial melting of a garnet-bearing lherzolite (Figure 4), coupled with the high Mg-numbers and high Ni contents of the primary magmas, indicate that the mantle source giving rise to the Dutoitspan kimberlite has a multi-stage history consistent with location within the subcontinental lithospheric mantle.

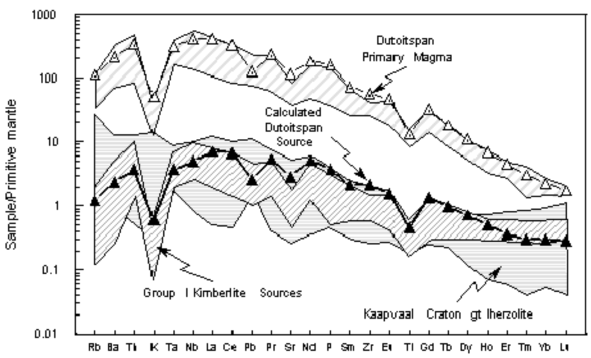

Figure 4: Predicted primitive mantle normalised pattern of the source composition of the Dutoitspan kimberlite, calculated by forward modelling from close-to-primary kimberlite magmas with F=1% and residual source region mineralogy ol:opx:cpx:gt = 0.63:0.23:0.12:0.2. Group I kimberlite primary magma range and calculated source composition range from Becker and le Roex (2006) are shown for comparison. Chondrite values are from Sun and McDonough (1989) and the field of Kaapvaal garnet lherzolites is from Grégoire *et al.* (2003).

The primary magma compositions can be accounted for by derivation from a source region that experienced an early depletion event leading to a refractory composition (high Mg#; Ni), with subsequent metasomatic enrichment of incompatible trace elements and volatiles prior to kimberlite magma generation. The incompatible trace element composition of the inferred metasomatic fluids/melts that infiltrated the SCLM is similar to that characteristic of ocean island basalts (Figure 5).

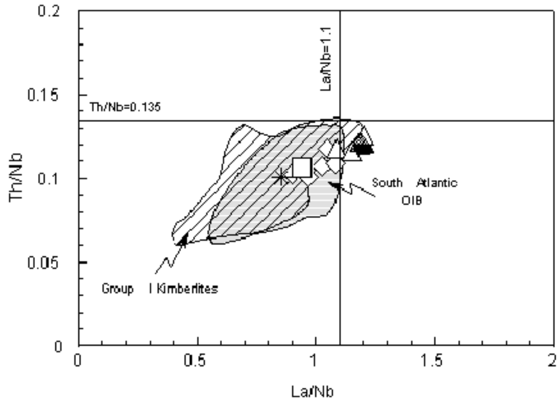

Figure 5: Variation of selected incompatible trace element ratios of the Dutoitspan kimberlitic intrusive phases after Becker & le Roex (2006). Field of South Atlantic ocean island basalts is from compilations of PetDB (www.petdb.ldeo.columbia.edu) after Becker & le Roex (2006). The diagonally shaded fields represent Group I kimberlite data from Becker & le Roex (2006).

References

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