THE PETROGENESIS OF GROUP-2 KIMBERLITE AND LAMPROITE MAGMAS.

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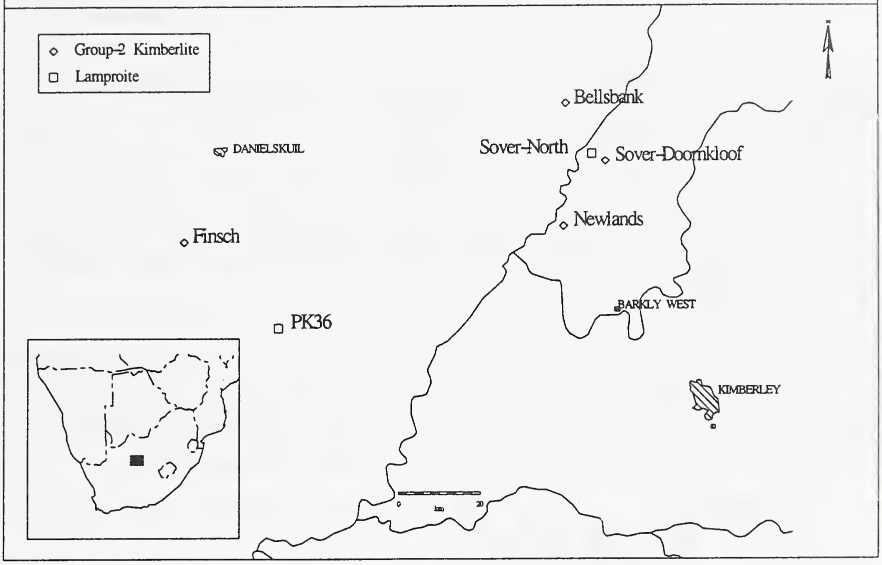
The Barkly West intrusive province consists of a suite of dykes and blows of Cretaceous age, described variously as micaceous kimberlites (Wagner, 1914), Group-2 kimberlites (Smith, 1983) and, more recently, orangeites (Mitchell, 1991). Included in this province are the Sover-North and PK36 intrusions which have been classified petrographically as olivine lamproites (Tainton and Browning, 1991).

Figure 1: Barkly-West Kimberlites and Lamproites



The Group-2 kimberlites and lamproites are characterised by extreme enrichment in the highly incompatible trace-elements. Petrographic studies show that entrainment of a large volume of lithospheric peridotite in the kimberlite or lamproite magma occurred en route to surface, as reflected by the abundance of macrocrystic olivine. The absolute abundances of the incompatible-elements will be modified by such mixing with depleted peridotite, resulting in significant compositional variability within single intrusions. However, mass-balance considerations indicate that the inter-element ratios of the strongly incompatible-elements will be insensitive to such mixing processes (Figure 2). Incompatible-element geochemistry may therefore be used to constrain the processes by which these extreme magma compositions were generated. Data from selected Group-2 kimberlite and related lamproite intrusions from the Barkly-West district, South Africa, are used to draw conclusions regarding the petrogenesis of these magmas.

Systematic geochemical differences are observed between sample suites from different kimberlite and lamproite intrusions (Figure 3). These differences, which are most pronounced in terms of incompatible-trace-element geochemistry, are not attributable to peridotite entrainment, crustal contamination or fractional crystallisation processes. Rather,

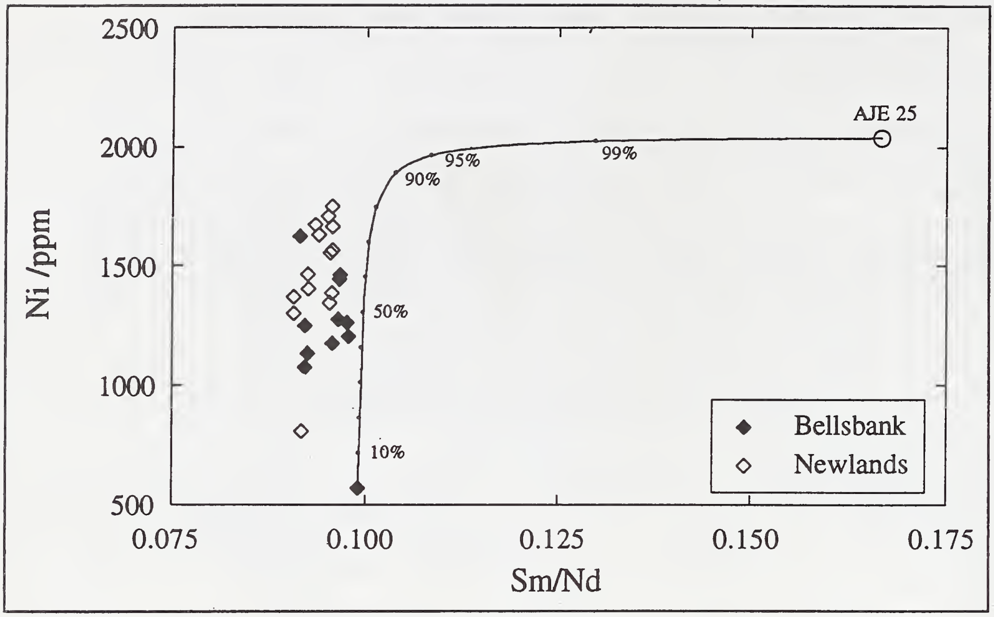


Figure 2: Covariation of Ni with Sm/Nd for the Bellsbank and Newlands kimberlites, demonstrating the insensitivity of incompatible element ratios in kimberlite to mixing of peridotite (garnet peridotite AJE25 from Erlank et al, 1987).

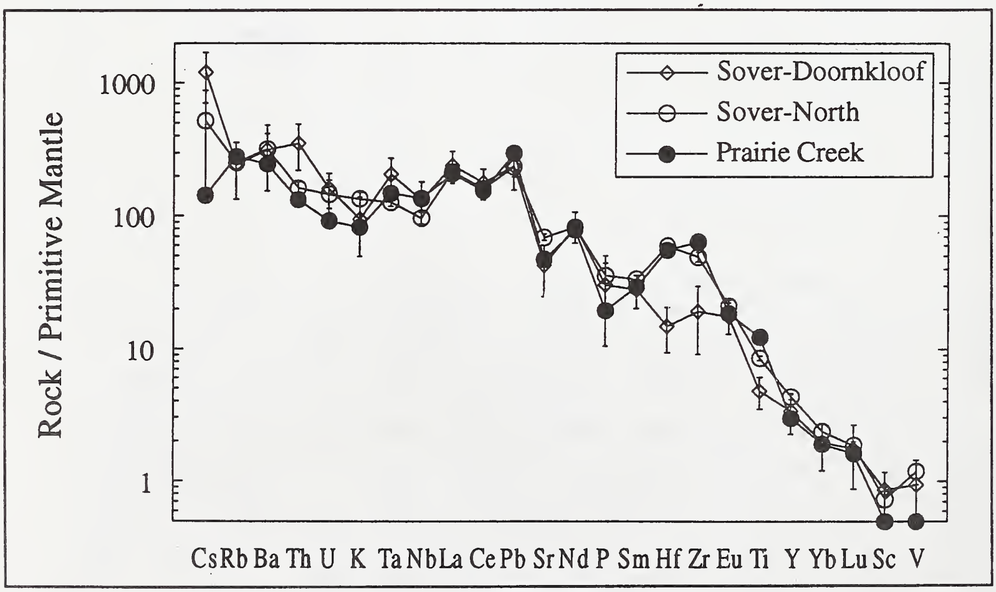


Figure 3: Mean incompatible element abundances, and 1σ variance, for the Sover-Doornkloof kimberlite and Sover-North lamproite, compared to data for the Prairie Creek lamproite (Fraser, 1987). Data are normalised to primitive mantle. Note the similarity in high-field-strength element concentrations for data for the Sover-North and Prairie Creek lamproites.

they are related to variable source compositions or conditions of melt generation. In all the intrusions under consideration, the degree of fractionation of the incompatible-elements, and the rare-earth-elements in particular, is such that the magmas could not have been generated by melting of primitive (or depleted) peridotite, irrespective of the degree of melting. A multi-stage evolution process, involving enrichment of the mantle source region by asthenosphere-derived melt, must be invoked to account for the observed magma compositions.

Modelling of the rare-earth-element compositions of Group-2 kimberlites and lamproites from the Kaapvaal Craton indicates that the lithospheric substrate for metasomatic enrichment was not fertile peridotite. Rather, the lithospheric source must have undergone extensive depletion by removal of mafic/ultramafic melt, prior to enrichment by small-volume silicate melts (Tainton and M^cKenzie, 1994). The rare-earth-element geochemistry of the magmas may be used to constrain the lithospheric depletion and enrichment processes, as well as the magmagenesis.

The evolved radiogenic isotope signature of the Group-2 kimberlite and lamproite magmas (i.e. radiogenic Sr and unradiogenic Nd) requires that this enrichment occurred a minimum of 0.9 Ga prior to magmagenesis, and the source subsequently remained isolated from the convecting upper mantle (Tainton, 1992). This model age constraint is calculated from the measured Sm/Nd ratio of the kimberlites. As these elements were further fractionated on melting of the isotopically evolved source, this represents a minimum age of enrichment.

Rare-earth-element modelling reveals no systematic petrogenetic differences between Group-2 kimberlites and olivine-lamproites in the Barkly West district. Geochemical distinctions between these rock-types (Figure 3) may be readily explained as a response to an increased abundance of carbonate in the source region of the kimberlite magma relative to that of the lamproites. The similarity in the inferred evolutionary histories of the respective source regions of these magmas is consistent with the correspondence of their isotopic compositions.

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