The geochemistry of the platinum-group elements (PGE) in kimberlites and the nature of the PGE in the subcratonic lithospheric mantle

I. McDonald
M.J. de Wit
L.A. Bizzi

Department of Geological Sciences, University of Cape Town, Rondebosch 7700, South Africa.

Introduction.

Concentrations of the platinum-group elements (PGE) in kimberlites and related alkaline rocks are poorly constrained and the behaviour of these elements during the generation and emplacement of deeply-derived alkaline magmas is largely unknown (Mitchell 1986). McDonald *et al.* (1994) determined PGE concentrations in 34 kimberlites, melilitites, alkali volcanics and carbonatites from Brazil and southern Africa using a combined fire assay and neutron activation method. The principal aim of this investigation was the characterisation of PGE signatures in kimberlites which had been previously subdivided on isotopic grounds into Group I, Group II, and Transitional rocks; and also to identify the PGE signatures of cratonic and off-craton intrusions. This latter aspect was an attempt to assess earlier suggestions (e.g. Tredoux *et al.* 1989) that the subcratonic lithospheric mantle (SLM) holds elevated concentrations of PGE and might therefore be a store for these elements, in addition to diamonds.

Principal observations.

The study indicates that the PGE are poorer discriminators for cratonic Group I, Group II and Transitional kimberlites than the lithophile elements. There is complete overlap for Os, Ir, Ru and Rh but cratonic Group II and Transitional kimberlites contain slightly higher concentrations of Pt and Pd than Group I kimberlites. In contrast, there appear to be important first order differences in the PGE signatures of cratonic and off-craton intrusions with similar lithophile element chemistries, as indicated in Figure 1. Cratonic kimberlites show only moderate fractionation (as shown by Pd/Ir and Pd/Os ratios) relative to chondrite. Concentrations of Os and Ir are higher than those typically found in basalts or even komatiites and they compare with (and sometimes exceed) concentrations typically found in mantle peridotites (Mitchell and Keays 1981). Off-craton intrusions have lower concentrations of Os and Ir and show greater fractionation relative to

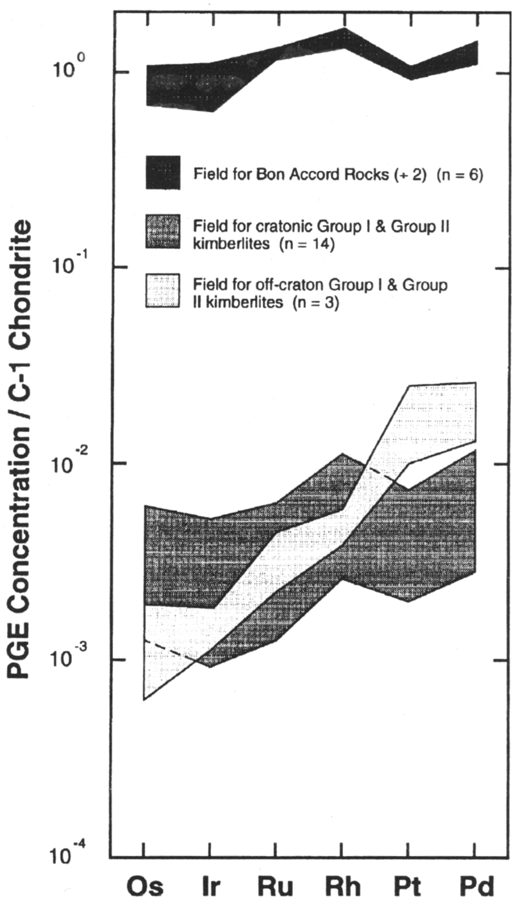

FIG. 1. Summary of fields for cratonic and off-craton kimberlites. The field for Bon Accord rocks is taken from Tredoux *et al.* (1989). Chondrite PGE concentrations are from Anders and Grevesse (1989).

chondrite. In addition, alkali basalts from pericratonic and cratonic settings are also characterised by strongly fractionated PGE patterns, with low concentrations of Os, Ir and Ru.

Discussion.

Great care was taken to minimise any contribution from xenolithic peridotite material in the samples and it seems unlikely that this could account for the high Os, Ir and Ru concentrations in the cratonic samples. Any contamination would appear to come from material which was more PGE-rich than normal mantle peridotite. We suggest that the elevated Os, Ir and Ru concentrations and the curious negative Ir anomaly seen in cratonic kimberlites, along with the corresponding absence of these features in off-craton kimberlites and shallow alkali basalts, reflects the sampling of some PGE-rich material concentrated deep within the Archean keel of the SLM which is absent from younger and shallower lithospheric mantle domains. The consistency of PGE patterns and ratios among cratonic Group I kimberlites and Group I-like Transitional kimberlites (in both Brazil and South Africa), and particularly within three separate intrusive phases of one kimberlite (Premier) place important constraints on the suggested PGE-rich material in the SLM.

We note the possible similarity between cratonic Group I PGE signatures and the Ni-rich Bon Accord (BA) body exposed in the 3.5 Ga Jamestown Ophiolite Complex of the Kaapvaal craton. A comparison of chondrite normalised PGE patterns for the cratonic kimberlites and is shown in Figure 1. The two have similar PGE signatures although the absolute concentrations are 300-1000 times lower in the kimberlites. Tredoux *et al.* (1989) suggested that BA was a siderophile element-rich relic of core formation which had been emplaced, via a deep mantle plume, into 3.5 Ga oceanic lithosphere. This lithosphere may have subsequently formed the roots of the first protocontinents (de Wit *et al.* 1992). McDonald *et al.* (1994) suggested that PGE signatures in cratonic kimberlites might reflect the physical assimilation and dilution of a volumetrically small amount of PGE-rich material with a signature similar to BA by a kimberlite with very low PGE concentrations ($<$ 1ppb). Using this as a basis for modelling, it was found that the PGE signatures of Brazilian and South African Transitional kimberlites could be closely simulated by the contamination of a kimberlite (which was initially fractionated relative to chondrite) with varying amounts of material with a BA signature. Similar calculations performed using a chondritic contaminant produced a much poorer simulation.

Both BA and chondrite are comparable with the limited range of PGE ratios obtained to date from subcratonic spinel and garnet lherzolites and either could be the source of the intergranular PGE-rich component in the SLM proposed by Mitchell and Keays (1981). Although the present evidence from kimberlites is suggestive that a BA-like signature may be present in the SLM, we stress that the present uncertainty over the true signature will only be settled when systematic studies of all six PGE in spinel and garnet peridotites are undertaken.

Summary.

Kimberlites which exploit grain boundaries between SLM minerals during intrusion might assimilate and become contaminated by PGE-rich intergranular material and this will be reflected in the final PGE signature of the kimberlite. Furthermore, if a chondritic or BA-like PGE component was predominantly acquired by the SLM during the earliest stages of continental lithospheric construction, this might explain the apparent restriction of the contamination to cratonic kimberlites. The presence or absence of this signature in kimberlites might therefore be a useful indicator that the kimberlite passed through deep, cratonic (possibly diamond bearing) lithosphere at some point during ascent. Such an indicator might find application as an additional tool for assessing the diamond potential of some kimberlites emplaced in areas of poorly constrained tectonic setting.

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