9th International Kimberlite Conference Extended Abstract No. 9IKC-A-00104, 2008

Trace Element Chemistry of Mineral Inclusions in Eclogitic Diamonds from the Premier and Finsch Kimberlites, South Africa: Implications for the Evolution of their Mantle Source

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Diamonds of eclogitic paragenesis are commonly encountered in the productions of many Southern Africa kimberlites. They vary widely in abundance from <5% at Finsch mine in South Africa (Phillips et al., 2004) to >60% in the case of the Orapa kimberlite in Botswana (Gurney et al., 1984). The nature and evolution of the protolith to eclogitic diamonds is still poorly understood. There is some evidence that these protoliths (and possibly also the diamonds) may be related to subduction of oceanic crust, although this is not a universally accepted view.

In order to further investigate the eclogitic protolith/diamond relationship, garnets and a few clinopyroxene inclusions in 18 eclogitic diamonds from the Finsch diamond mine, as well as 23 eclogitic diamonds from the Premier mine, were analysed for their trace element composition (Fig. 1). The inclusions in diamonds from Finsch derive from the study of Appleyard et al (2004), while the eclogitic diamonds from the Premier kimberlite are a new collection assembled for the present study. Inclusions in these diamonds were broken out through crushing, mounted in epoxy resin contained in brass stubs, polished, and analysed on a Cameca SX-50 electron microprobe at the De Beers GeoScience Centre in Johannesburg. Methods and detection limits are as described in Appleyard et al (2004). Ion microprobe analyses were conducted on the IMS-4f ion probe facility at the University of Edinburgh. Analytical procedures and precision are the same as described in Stachel and Harris (1997) and Harte and Kirkley (1997).

From both mines a strong correlation between the garnet Ca-content (Fig. 1) and the chondrite-normalised rare earth element pattern is evident (Fig. 2). Garnets with comparatively low Ca-content are characterised by rare earth element patterns (REE) which show a steady increase in abundance from light rare earth elements (LREE) to heavy rare earth elements (HREE). With increasing Ca content in garnet, the abundance of LREE (La, Ce, Pr, Nd) as well as the middle REE (Sm, Eu, Gd, Tb) both progressively increase, ultimately giving the trace element pattern a distinct 'humped' appearance (Fig. 2).

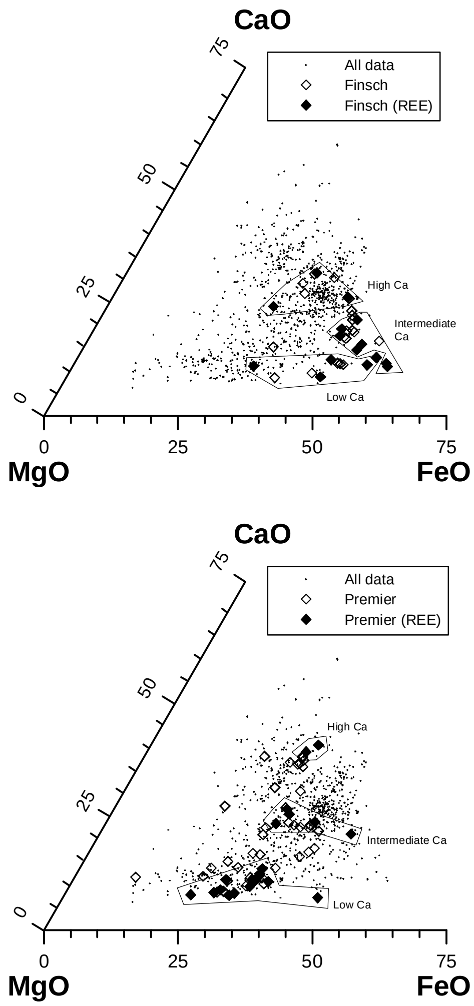

Fig. 1 Ternary plot of the CaO, MgO and FeO contents of eclogitic garnets in diamonds worldwide as well as the Finsch (Appleyard et al., 2004) and Premier kimberlites (Gurney et al., 1985). Solid symbols refer to garnets analysed for their rare earth element content by ion microprobe.

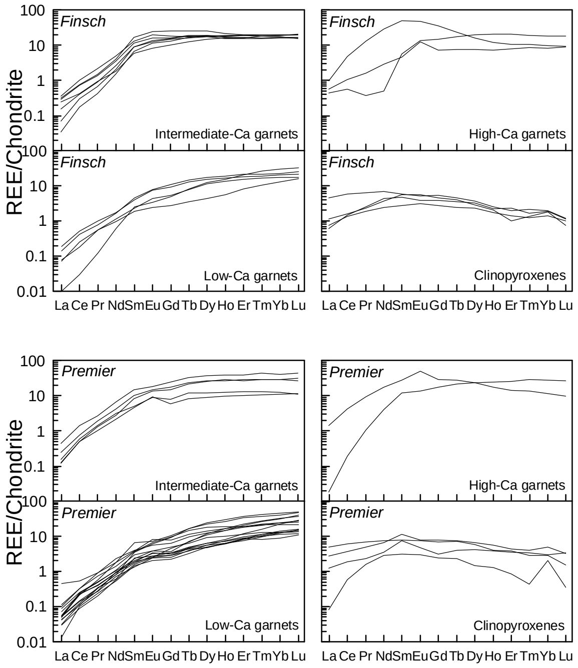

Fig. 2 Rare earth element abundance patterns for garnet and clinopyroxene in eclogitic diamonds from Finsch and Premier, determined by ion microprobe. All data normalized to the C1 carbonaceous chondrite of McDonough and Sun (1995).

Partitioning of trace elements between garnet and clinopyroxene is controlled by pressure, temperature, and composition (Harte and Kirkley, 1997). In the present cases, the protoliths to these eclogitic diamonds probably experienced similar high P-T conditions within the diamond stability field. In this scenario it is likely that REE partitioning between garnet and clinopyroxene of the host eclogite is primarily controlled by the Ca content in garnet. Hence bulk-rock REE patterns can be reconstructed from the measured REE contents in garnet as well as calculated REE concentrations in clinopyroxene, based on known clinopyroxene-garnet partition coefficients (Harte and Kirkley, 1997).

At both Finsch and Premier, the low-Ca group samples have relatively flat bulk-rock REE patterns at approximately 10 times chondrite concentrations (Fig. 3). The intermediate-Ca group samples are slightly LREE-depleted and have HREE contents that overlap with the low-Ca group. The high-Ca group samples are typically LREE-depleted and have HREE contents that are slightly less than the low-Ca group samples.

These calculated bulk-rock REE patterns for the host protoliths to the eclogitic diamonds at Finsch and Premier, are very similar to those obtained from garnets and clinopyroxenes in diamond-bearing eclogites from the Mir kimberlite in Russia (Beard et al., 1996). In that case, the results were consistent with a protolith evolution involving seawater alteration of basaltic crust. The low-Ca group eclogites represent low-temperature alteration in the upper section of an ophiolite complex, whilst the high-Ca group represents alteration in the mid to lower sections of the ophiolite.

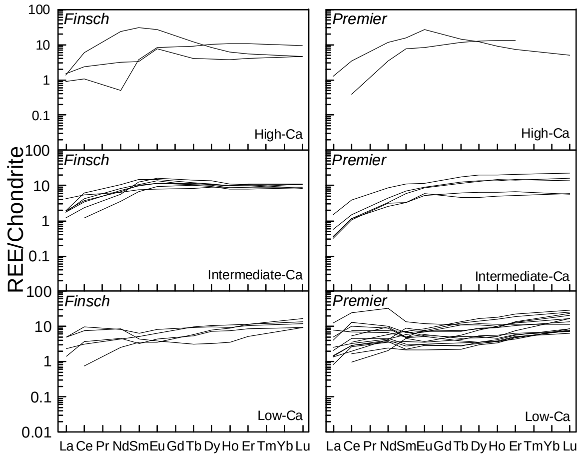

Fig. 3 Reconstructed bulk eclogite rare earth element abundance patterns for eclogitic diamonds from Finsch and Premier, calculated for a 50:50 garnet-cpx ratio. Where not available, clinopyroxene rare earth element contents were calculated using the cpx/garnet partition coefficients reported in Harte and Kirkley (1997). Compositional data normalized to the C1 carbonaceous chondrite of McDonough and Sun (1995).

The variation in REE patterns found in the present work demonstrates that garnet inclusion chemistry is also a reflection of the evolution of the eclogite protolith in which these diamonds crystallised.

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