Origin of silicate-bearing diamondites

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Diamondites ('polycrystalline diamonds', 'framesites') are fine- to coarse-grained (50 µm to >1 mm) rocks consisting almost entirely of diamonds with variable amounts of pores and cavities. The masses of our samples range from 5 to 60 ct and their sizes from 1 to 3.5 cm. Diamondites occasionally contain silicates, oxides, and sulfides in interstitial space as well as intergrown with diamonds. Microscopic investigation suggests that diamondites are the product of rapid crystallisation from a fluid and the intergrowths of diamond and silicate clearly indicate that both precipitated in the same event (Gurney and Boyd, 1982; Kurat and Dobosi, 2000).

Until now we have studied in detail more than 40 diamondite xenoliths from an unknown source (presumably from southern Africa). In this contribution we focus on the trace element abundances in the silicates of diamondites. We summarize the earlier published major, minor and trace element data on 10 diamondites and added 27 new diamondite samples. This greatly extended database allowed us to gain additional insight into diamond genesis and present a refined model here.

The most common silicate is garnet which occurs in a variety of colors and chemical compositions (Kurat and Dobosi, 2000; Dobosi and Kurat, 2002), i.e., orange and purple garnets (Fig. 1) that are similar to inclusion garnets from diamond monocrystals and garnets known from upper mantle eclogites and garnet peridotites, respectively (for a recent summary see Taylor and Anand, 2004). In this study we distinguish 5 chemical garnet groups: peridotitic (P), transitional (T) and 3 eclogitic garnets, namely E1, E2 and E3. Approximately one third of the garnets belongs to the peridotitic suite and the chemical compositions of all but one P garnets plot in or very close to the lherzolitic garnet field in the CaO vs. Cr_2O_3 diagram (Fig. 2) as defined by Sobolev (1977). The single exception has a harzburgitic garnet composition with low CaO (2.61 wt%) and high Cr_2O_3 contents (12.3 wt%). Transitional and E1 garnets have the same Mg-numbers as P garnets (0.82-0.86, similar to mantle peridotites), while E2 garnets have slightly lower (0.76-0.82) and E3 garnets much lower (0.52-0.61) Mg-numbers. Clinopyroxenes are associated with three P and one T garnets only.
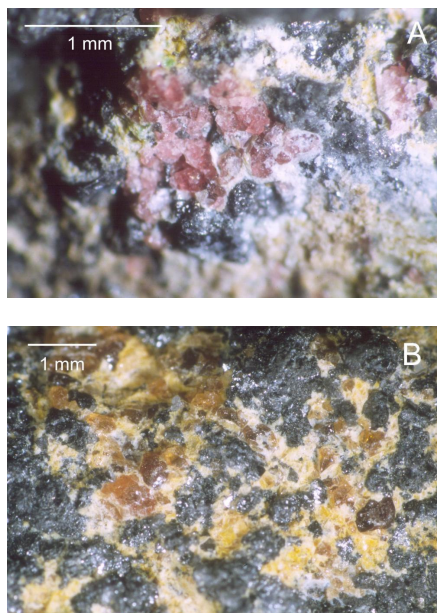

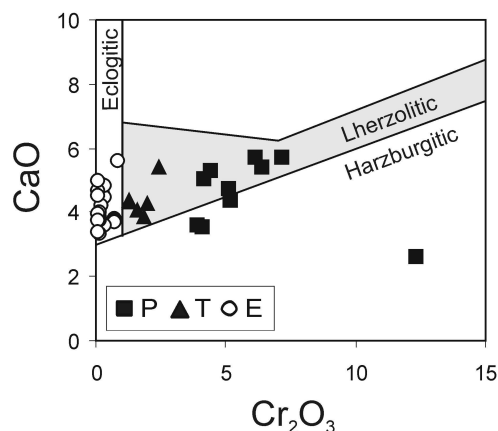Fig. 1. Diamondite with purple peridotitic (A) and orange eclogitic (B) garnet.

Fig 2. CaO vs. Cr_2O_3 plot of garnets from peridotitic (P), transitional (T) and eclogitic (E) diamondites.

Trace element contents of garnets and clinopyroxenes were determined by LA-ICP-MS in 37 diamondites. Chondrite-normalized abundance patterns are complex and roughly correlate with the major and minor element composition. In the chondrite-normalized REE abundance plots (Fig. 3A) most of the peridotitic

garnets show a slightly sinusoidal pattern with a small hump at Eu and Sm. They show some resemblance to the harzburgitic garnet inclusions in diamond monocrystals, but they never have a deficit in the HREE. Of the non-REE trace elements, Sr and Ti are depleted relative to elements with similar geochemical behavior, while chondrite-normalized abundances of Nb, Ta, U and Th are always higher than those of the LREE (Fig. 3B).
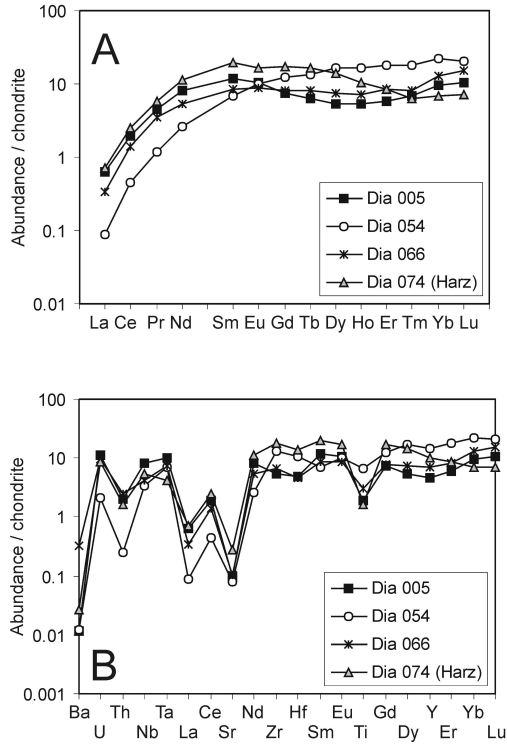

Fig. 3. Chondrite-normalised REE (A) and other trace element patterns (B) of a selected set of peridotitic garnets in diamondites. Dia 074 garnet is harzburgitic.

The chondrite-normalized REE abundance patterns of E garnets show a continuous increase from the LREE towards the HREE (Fig. 4A). In E1 and E2 garnets, high field strength elements (HFSE, Nb, Ta, Zr, Hf and Ti) have positive anomalies relative to the REE of similar incompatibility (Fig. 4B), but such anomalies are not present in E3 garnets. Of all garnet groups, E3 garnets are the poorest in highly incompatible elements. In general, there is an almost continuous decrease in the abundances of strongly incompatible trace elements from peridotitic through transitional to eclogitic (E3) garnets. This trend is well documented by the decrease in the content of Nb with decreasing Cr_2O_3 content in garnets (Fig 5).
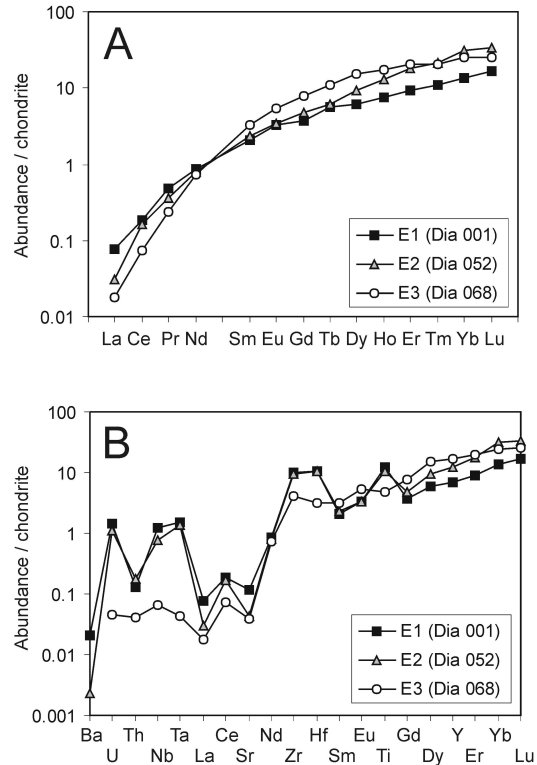

Fig 4. Chondrite-normalised REE (A) and other trace element patterns (B) of representative eclogitic (E1, E2 and E3) garnets.
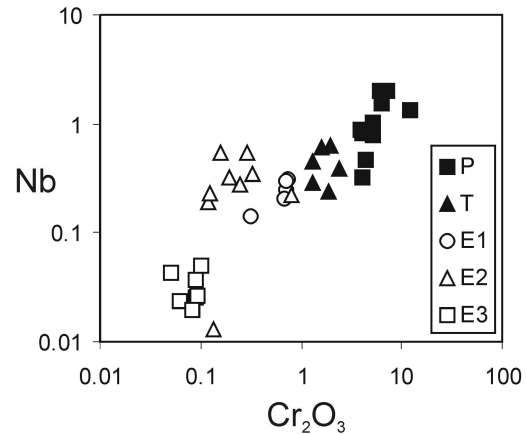

Fig. 5. variation of Nb vs. Cr_2O_3 in garnets.

The chondrite-normalised REE patterns of the hypothetical fluids/melts in equilibrium with garnets show different degrees of enrichment of LREE relative to the HREE abundances (Fig. 6) which is very similar to the normalised REE patterns of alkaline melts from the Earth's upper mantle. Fluids in equilibrium with P garnets show LREE enrichments, which are similar to those of kimberlitic and carbonatitic liquids - in agreement with the earlier results and conclusions of Dobosi and Kurat (2002), who suggested that

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diamondites with peridotitic garnets crystallised from carbonate-bearing fluids/melts. The less fractionated normalised REE patterns of the hypothetical liquids in equilibrium with eclogitic garnets have alkali basaltic rather than kimberlitic or lamproitic composition. Our results and conclusions are strongly supported by the results obtained by Rege (2005), who determined the trace element composition of the fluid/melt inclusions in diamonds (trapped melts) from a subset of our diamondite sample suite. The agreement of the trace element contents between the calculated liquids in equilibrium with the silicates and the directly analysed trapped melts in diamonds suggests that the trace element composition of the garnets is a good record of the fluids/melts, which precipitated both phases.

Fluids that precipitated peridotitic and most of the eclogitic garnets had similar Mg/Fe ratios indicating a peridotitic source for both types. The differences in the Cr and highly incompatible element contents between them could be the result of differences in the properties of these fluids/melts rather than of different source rocks. This view is supported by the carbon isotope abundances in diamonds with $\delta^{13}C$ mostly between –16 and –24 ‰ in diamondites with P or E garnets, indistinguishable from each other.
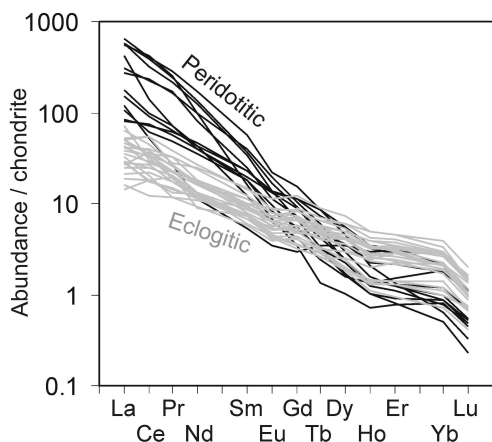

Fig 6. REE composition of hypothetical fluids in equilibrium with peridotitic (black) and eclogitic (gray) garnets

The formation of Cr-rich and Cr-poor garnets from an apparently peridotitic environment could be the result of different degrees of partial melting of the peridotitic source. There is a clear positive correlation between the abundances of Cr and some highly incompatible HFSE in garnets (Fig. 5), which supports the view that low degree of partial melting creates the Cr-rich fluids to form Cr-rich garnets. Chromium behaves only slightly incompatibly in peridotite-silicate liquid systems (e.g., Kurat et al., 1980), but apparently becomes strongly incompatible in peridotite-carbonate liquid systems. The anti-correlation of the Mg-number, a fractionation index, with the abundances of highly incompatible HFSE also indicates fluid/melt fractionation processes,

which must be different from the standard igneous fractionation processes based on fractional crystallization. This problem is still unsolved and deserves our attention in the future.

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