Peridotitic garnet geochemistry: key to the understanding of lithospheric structures and kimberlites diamond potential in Southern Congo

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Kimberlites occur in the southern part of the Democratic Republic of the Congo (Fig. 1) in the Kasai Province (eg. Mbuji Mayi, Luebo) and the Kundelungu Plateau (Katanga Province). The Mbuji Mayi kimberlites are Cretaceous (Demaffife et al., 1991). U-Pb dating of perovskites indicates that Kundelungu kimberlites intruded at 32 Ma (Batumike et al., 2008).

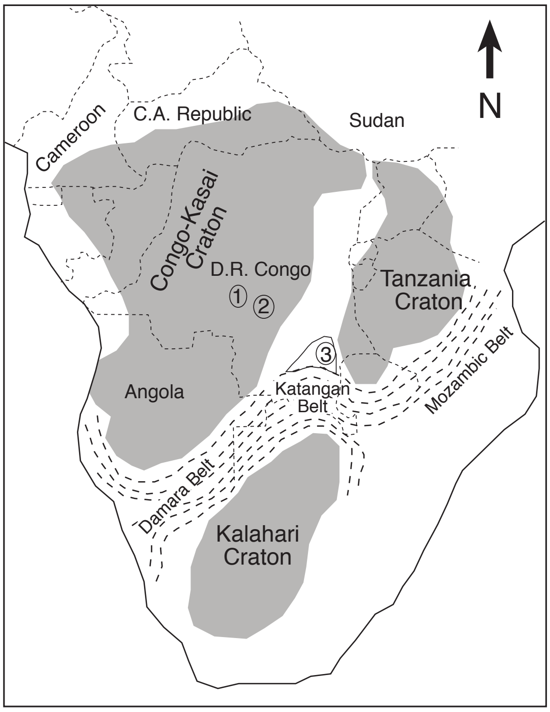

Fig.1. Location of study areas: 1, Luebo; 2, Mbuji Mayi; 3, Kundelungu Plateau

The Mbuji Mayi and Luebo kimberlitic fields are located inside the Congo Craton. The Kundelungu kimberlites intruded the Neoproterozoic Katangan Belt and the off-craton basement beneath the region is predominantly Paleoproterozoic (Batumike et al., 2007). This study uses major- and trace-element compositions of peridotitic garnets in order to map the chemical heterogeneity of the subcontinental lithospheric mantle and to assess the diamond potential of the kimberlites.

Kundelungu Plateau

The peridotitic garnets in the Kundelungu kimberlites are mainly lherzolitic with very few harzburgitic and wehrlitic garnets.

The garnets show two different populations in terms of Y, Ti and Ni contents (Fig. 2). These two populations define different geotherms. The conductive geotherm defined by the population with high Y/Ti is quite low, in general between 35 and 37.5 mW/m^2 at depths <ca 130 km; the other group defines a geotherm closer to a 40 mW/m^2 model, mainly at depths >130 km (Fig. 3). This pattern suggests that the initially low conductive geotherm in the region has been perturbed by high-T melts which induced the metasomatism (high Ti/Y) observed in the garnets.

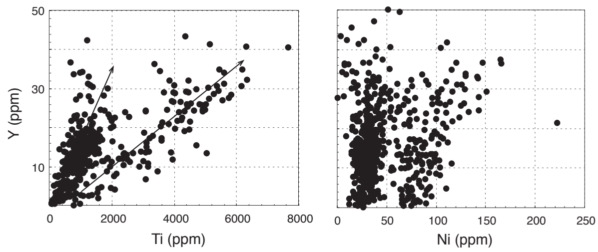

Fig. 2. Y-Ti-Ni relationships in Kundelungu garnet concentrates, showing two different clusters separated by a Ni (T) gap.

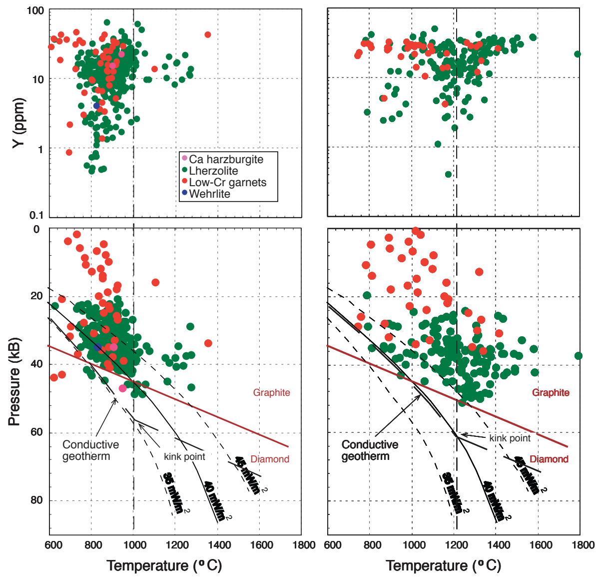

Fig. 3. Geotherms (lower panels) and distribution of Y with Temperature (Ni) in Kundelungu, for (a) low-T and (b) high-Ti/Y garnets. The envelope of maximum P at each T defines the Garnet Geotherm (Ryan et al, 1996).

The garnets characteristic of the higher geotherm are also characterised by a low calculated *X*Mg in coexisting olivine (after Gaul et al., 2000), typical of peridotites metasomatised by asthenosphere-derived melts (Fig. 4).

The lithosphere-asthenosphere boundary represents a zone where there is interaction between a depleted lithosphere and fertile asthenosphere. The depth of this zone is estimated by the lower depth limit of low-Y garnets. In the Kundelungu Plateau the lithosphere-asthenosphere boundary depth is estimated at 175 km (Fig. 4), but detailed data from the region show that the lithosphere is slightly thicker in the eastern than the western part of the plateau. The lithospheric section shows the presence of a thin layer of harzburgites within the diamond stability field (Fig. 4).

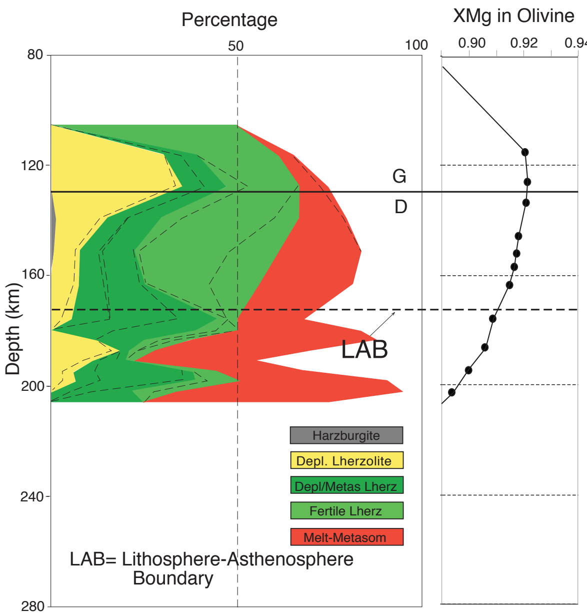

Fig. 4. Chemical tomography section of the lithosphere beneath the Kundelungu Plateau and distribution of *X*Mg in olivine coexisting with garnets.

Mbuji Mayi Region

The mantle beneath the Mbuji Mayi kimberlite field, which includes the Mbuji Mayi and Tshibwe clusters, is characterised by predominantly harzburgitic and lherzolitic garnets but there are also low-Cr garnets, wehrlitic and low-Ca harzburgitic garnets. The conductive geotherm is ~35 mW/m^2, which is quite low and typical of cratonic settings. The estimated lithospheric thickness is 210 km (Fig. 5).

The lithospheric section of this region is characterised by the presence of two harzburgitic layers within the diamond stability field (Fig. 5). Melt-related metasomatism and phlogopite metasomatism were the main processes that have affected the lithosphere; melt-related metasomatism becomes progressively more important below ca 180 km depth.

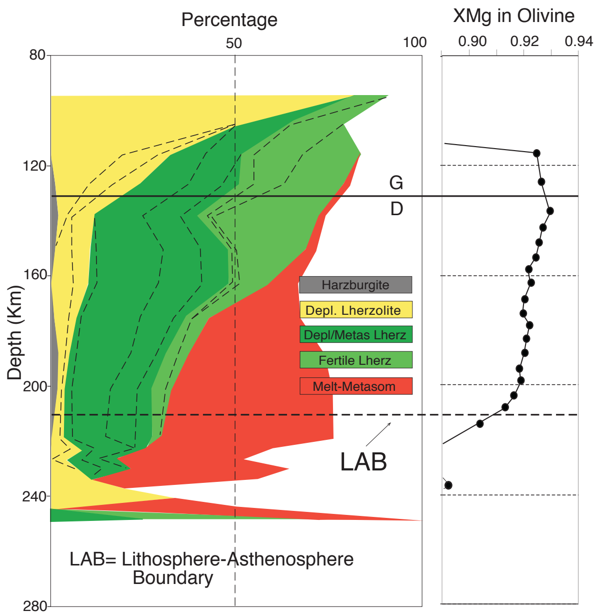

Fig. 5. Chemical tomography section of the lithosphere in Mbuji Mayi region and distribution of *X*Mg (calculated) in olivine coexisting with garnets.

Luebo Region

The Luebo garnet population consists of lherzolitic, Ca- and low-Ca harzburgitic, and low-Cr garnets. The conductive geotherm derived from the garnets is ~35 mWm^{-2}, which is low and typical of cool cratonic lithosphere.

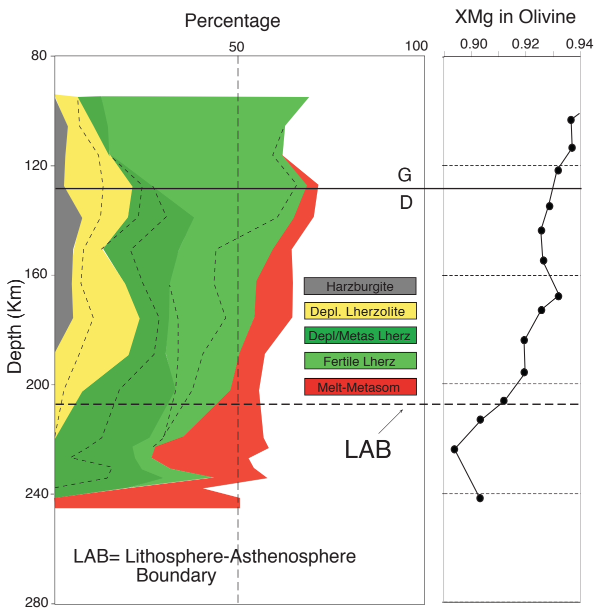

Fig. 6. Chemical tomography section of the lithosphere in Luebo region and distribution of *X*Mg in olivine

The Luebo garnets are characterised by a near-absence of low-Y garnets above 1100 ^{o}C, which corresponds also to a drop of *X*Mg in coexisting olivine to <91%. This temperature corresponds to a depth for the lithosphere-asthenosphere boundary of about 205 km (Fig. 6), which is similar to the LAB estimates for the

Mbuji Mayi region. Garnet compositions indicate melt-related and phogopite-related metasomatism as shown by anomalous enrichment in elements such as Ti, Y and Zr in some garnets. There is a relatively high abundance of harzburgitic garnets within the diamond stability field in the lithosphere beneath the region.

Diamond potential

The low conductive geotherm in Kundelungu is similar to that of cratonic regions where diamonds are found. The garnets from Kundelungu Plateau are mostly lherzolitic in composition. The rare harzburgitic garnets are restricted to the Talala pipe, where Verhoogen (1938) found also the highest grade in diamond (~6.3 carats per 1000t) for the whole Kundelungu area. There are also some lherzolitic garnets with composition similar to diamond inclusions (Fig. 7a). The absence of diamond in Kundelungu may be due to the thermal perturbation and metasomatism by hot asthenospheric melts.

The garnet populations from Luebo and Mbuji Mayi are characterised by abundant garnets with sinusoidal REE patterns, which are similar to patterns observed in diamond inclusions. The sinusoidal REE patterns are shown in Fig. 7 by high Nd/Y. The relationships between Nd, Y and temperature (Ni) indicate the presence of garnets with diamond-inclusion affinities within the diamond stability field (Fig. 7b). The relative proportion of such garnets is similar in the Luebo and Mbuji Mayi districts, and much higher than in the Kundelungu kimberlites as also shown by the greater abundance of harzburgitic rocks within diamond stability field in these two regions compared to that in Kundelungu. This is consistent with what is known about diamond potential in these areas. .

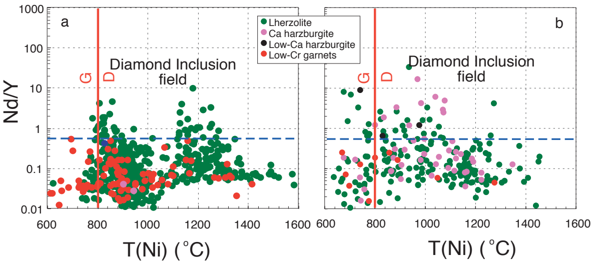

Fig. 7. Nd/Y vs T in garnets from the Kundelungu kimberlites (a) and the Luebo region (b). Vertical lines (G/D) show the T of intersection between the geotherm and the diamond stability field (G: Graphite, D: Diamond); garnets with high Nd/Y and T >G/D may coexist with diamond. Since the high-T Kundelungu garnets are strongly metasomatised, the Luebo field clearly has the higher diamond potential.

Conclusions

The Kundelungu, Mbuji Mayi and Luebo regions are characterised by a low conductive geotherm, but the deeper parts of the Kundelungu section have been thermally disturbed. The lithosphere beneath the Kundelungu Plateau is also relatively thin compared to that beneath Mbuji Mayi and Luebo. This is compatible with the location of these regions, Kundelungu being located off-craton whereas Mbuji Mayi and Luebo are within the craton. The 32 Ma kimberlite magmatism in the Kundelungu Plateau is correlated with the initial stage of the opening of the East African Rift, and the disturbance of the initially low conductive geotherm may reflect the upwelling of melts related to the opening of the rift. Both Mbuji Mayi and Luebo have garnet compositions indicating melt-metasomatism processes but not to the same extent as observed in Kundelungu Plateau. Mbuji Mayi and Luebo have higher diamond potential than Kundelungu. The low diamond potential of Kundelungu could be attributed to the melt metasomatism that affected the lithosphere in this region.

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