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PYROPE GARNET FROM THE EL KSEIBAT AREA, ALGERIA AND LITHOSPHERE BENEATH THE NORTH-EASTERN PART OF THE WEST AFRICAN CRATON

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INTRODUCTION

In the 1980s to 1990s, the sub-economic Djebel Aberraz alluvial diamond placer deposit was discovered in the Bled-el-Mas Valley approximately 30 km south of Reggane near the border of the Sahara Plate and the WAC (Kaminsky et al., 1992). About 1500 diamond grains were recovered from exploration pits in the alluvial sediments. Numerous kimberlite indicator mineral grains, such as pyrope garnet, chrome spinel and picroilmenite, also were identified in the deposit.

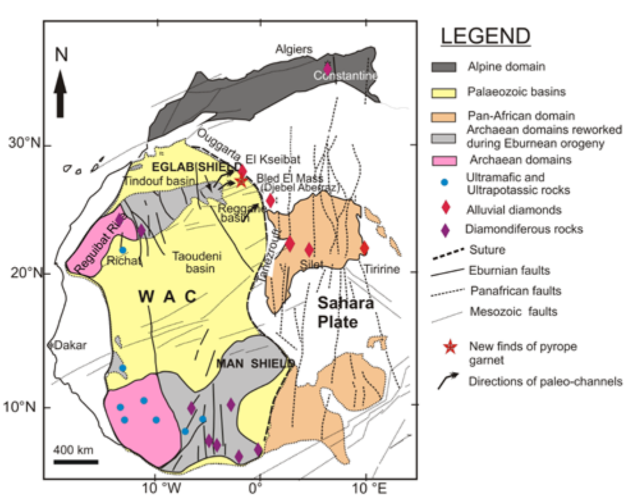

Fig. 1. Tectonic map of Northwestern Africa, showing the position of the El Kseibat area.

Besides the Djebel Aberraz deposit, diamonds were found north and south of Reggane within a large area extending over 1000 km from Tanezrouft, Silet, and Tiririne in the southeast to El Kseibat in the northwest (Fig. 1). In 2005, as a result of the work organised by the ORGM, several dozen pyrope garnet grains were found in the El Kseibat area. The primary source(s) of both diamonds and pyrope garnets have not yet been found.

PYROPE FROM THE EL KSEIBAT AREA

Pyrope grains have rounded or elliptic shapes and range in size from 0.35 mm to 1.2 mm (average 0.7 mm). Almost all other grains suggest a distant origin and transport for several tens of kilometres, most likely from the south-west, *i.e.*, from the Eglab Shield. The continental mass displacement from the Reguibat Rise in NE-NNE directions, according to paleogeographical reconstructions, started in the Cambrian and has continued since then through all epochs. Quaternary paleo-channels inherited these directions and are oriented NE-ENE; predominant winds have the same directions; therefore, the pyrope grains were derived from the easternmost part of the Eglab Shield of the West African Craton.

All grains belong to the pyrope-almandine series (with 65-73% of pyrope and 13-16% of almandine). According to their Cr_2O_3 – CaO compositions most are of the lherzolitic paragenesis; only two grains of the thirty-nine studied are Ca-harzburgitic, very close to the borderline with lherzolitic garnet (Fig.2). Within the lherzolitic field, according to the Dawson-Stephens classification, not only grains of Group 9 exist, but also Group 11 (uvarovite-pyrope) and Group 1 (titanian pyrope) are present. The parameter *mg* (at.

Mg/(Mg+Fe)) varies from 0.780 to 0.842, with the average at 0.820. Ca-harzburgitic grains have higher *mg* (0.837 and 0.823) and Cr_2O_3 (7.46 and 7.25 wt.%) but in general belong to the same population as the lherzolitic ones.

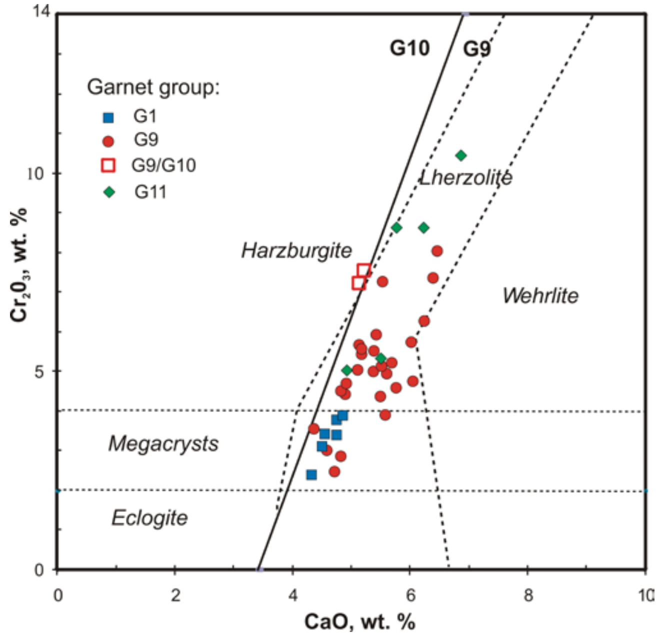

Fig. 2. Cr_2O_3 *vs* CaO (wt.%) plot for pyrope garnets from the El Kseibat area.

Using the Ti-Y-Zr-Sr ratios, three differently metasomatised groups can be distinguished among the studied pyrope grains (Fig. 3): (1) depleted, with low Sr, Y, Ti and Zr; (2) grains with low Sr and Y, but moderate Ti and high Zr (3) grains with high Y, Ti and Zr. In addition to their characteristic elements (Sr, Y, Ti and Zr), depleted grains have low Nb and high V compared to other groups, and the second group of grains is particularly rich in P

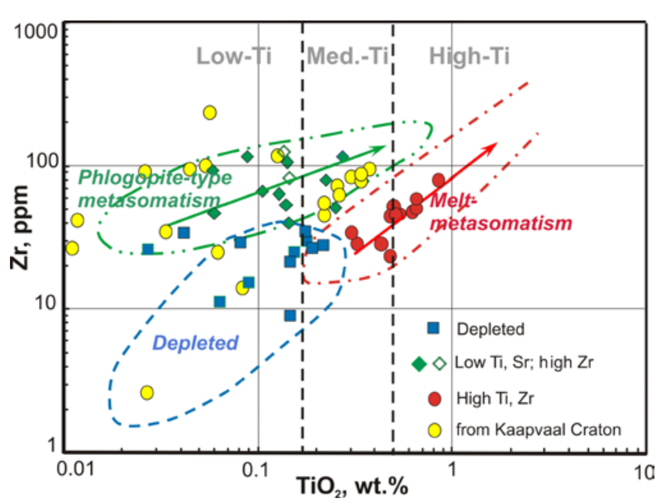

Fig. 3. Zr *vs* Ti in garnet from the El Kseibat area compared with garnet from the Kaapvaal Craton (after Griffin *et al.*, 1999b). Empty diamonds are harzburgitic grains.

The Y *vs* Zr plot (Fig. 4) also demonstrates great variations in the concentrations of these elements. A few grains can be considered as depleted; the others demonstrate a wide range in the intensity and style of metasomatism, although the differences in the two trends are expressed less clearly than in Fig. 3.

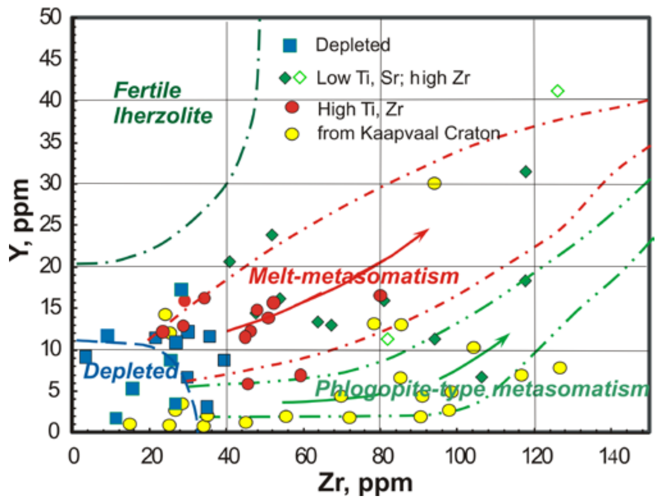

Fig. 4. Y *vs* Zr plot for garnets from the El Kseibat area compared with garnets from the Kaapvaal Craton (after Griffin *et al.*, 1999b).

Four types of REE_n distribution can be distinguished in the garnet grains (Fig. 5).

1. The *sloped* REE_n pattern, with a steep positive slope through the $LREE_n$ followed by a shallower positive slope for the $MREE_n$ and then by a very shallow $HREE_n$ with approximately 10-18× chondritic Lu, predominates among the studied garnet grains.
2. The *normal* pattern is similar to the sloped one but has a virtually flat $MREE_n$- $HREE_n$ slope, starting from Sm, owing to enrichment in $MREE_n$ and a small deficit (relative to the sloped pattern) in $HREE_n$, with approximately 6-16× chondritic Lu.
3. The *humped* pattern has further enrichment in $MREE_n$, mainly in Sm, Eu, and Gd (11-20× chondritic values), with similar (or lower) values of Lu (5-10×).
4. The *sinusoidal* pattern, usually characteristic of harzburgitic, subcalcic garnet grains including those associated with diamond (*e.g.*, Stachel *et al.*, 2004), is most variable in the REE distribution.

There is no correlation between the major-element composition of the garnets and their REE_n pattern; in each REE_n group, all metasomatic varieties exist, depleted with low Sr content, high Zr, and high Ti and Zr.

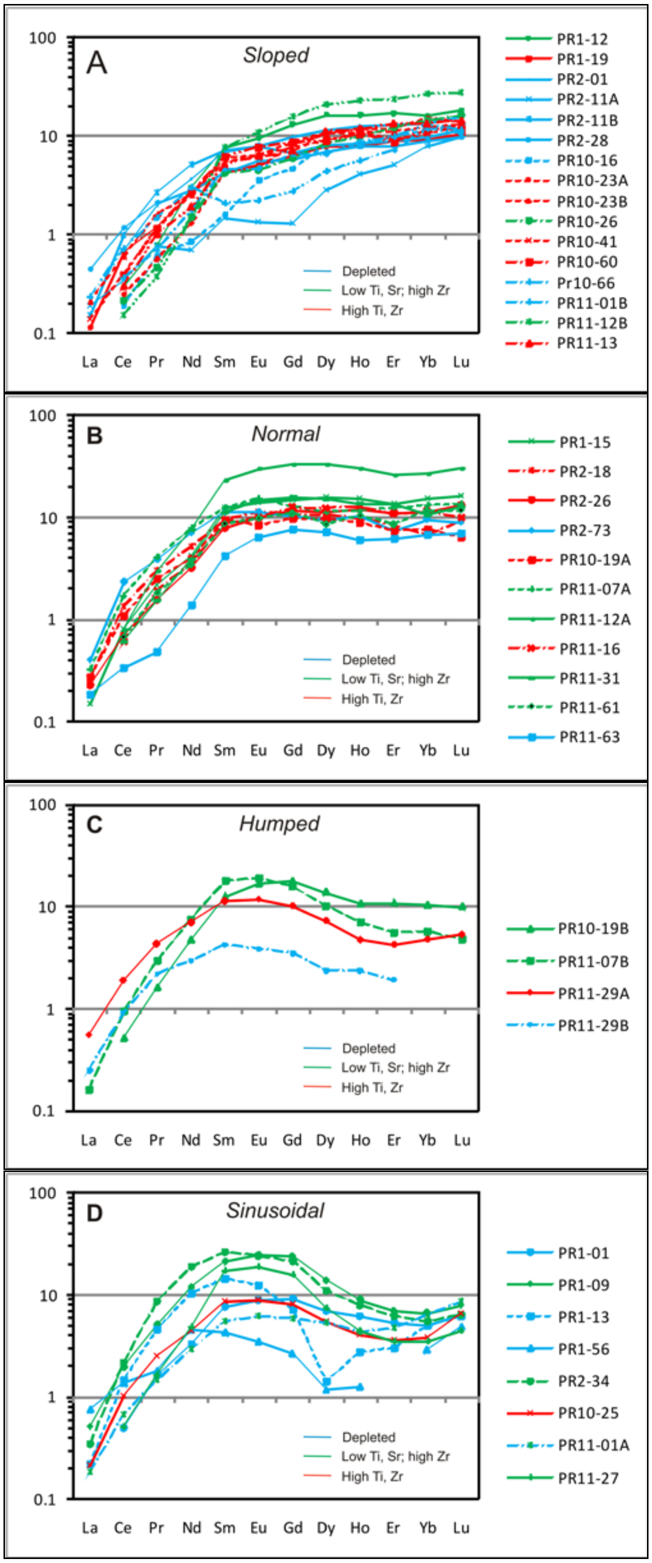

Fig. 5. Chondrite-normalised REE patterns of El Kseibat garnet. A – grains with sloped REE_n patterns; B – grains with normal REE_n patterns; C - grains with humped REE_n patterns; D – grains with sinusoidal REE_n patterns.

CONCLUSIONS

The lithosphere beneath the Eglab Shield

The garnet grains are derived from lithosphere in the north-eastern part of the West African Craton. The lithospheric mantle in this area has a predominantly depleted-lherzolitic composition with a minor admixture of Ca-harzburgitic material. The maximum P estimates at each temperature define a 40 mW/m^2 conductive geotherm to *ca* 40 kbar (*ca* 125 km). This is higher than the value (33 ± 8 mW/m^2) derived for the interior of the craton, but is a typical value for the environment from which many kimberlites worldwide are derived (Griffin *et al*. 1999a-c). In Fig. 6, grains with T > 1000 °C scatter away from a conductive model geotherm, suggesting that they did not coexist with chromite, and thus record minimum estimates of P, while being affected by heating. Most of these grains show the high Ti and Zr contents typical of metasomatism by silicate melts, and this suggests that the lithospheric mantle below *ca* 125 km depth was being heated and metasomatised at the time of eruption, producing an inflected geotherm as seen in many kimberlites worldwide (*e.g*. Griffin *et al*., 1999b).

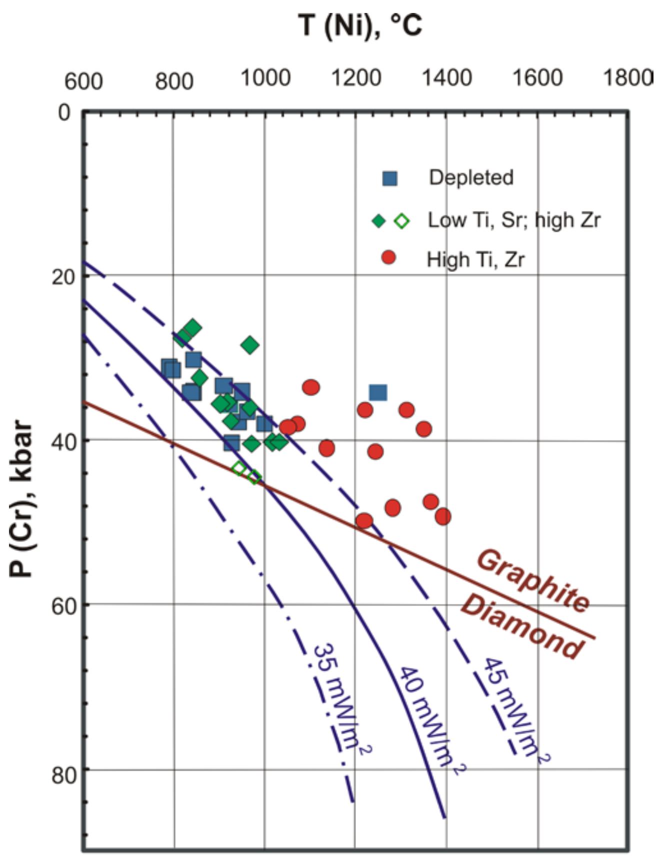

Fig. 6. Pressure-temperature conditions for El Kseibat garnet. Empty diamonds are harzburgitic grains.

Metasomatism in the lithosphere

The garnet-bearing rocks underwent a series of metasomatic events that produced variations in trace element compositions in garnet grains. The Ti *vs* Zr plot (Fig. 3) and the Y *vs* Zr plot (Fig. 4) demonstrate two types of metasomatism (after Griffin *et al*., 1999b): (1) the 'phlogopite-type', low-temperature metasomatism with increasing Zr and Y contents but low Sr and Ti contents; and (2) 'melt-type', high-temperature metasomatism, with high enrichment in Zr and Y as well as in Ti and Sr. The two types of metasomatised Algerian garnet grains, as in the Kaapvaal Craton lithosphere (*e.g.*, Griffin *et al*., 2009b), are interpreted to reflect metasomatism at different depths. The low-temperature metasomatism, involving an increase in Zr (and Ca) with minor increases in Y and no increase in Ti, is limited to depths <125 km (Fig. 6). The high-temperature metasomatism, with a sharp increase in Ca, Zr, Y, and especially Ti, appears to belong, in general, to the deeper levels of the lithospheric mantle (Fig. 6). The garnets registering the highest pressures belong to this group, while the other high-T garnets give lower calculated P values, which may reflect a lack of equilibrium with chromite. The wide diversity of REE_n patterns in garnet from the El Kseibat area may be explained by metasomatism of garnetiferous host rocks by CHO fluids with highly fractionated trace element compositions (Stachel *et al*., 2004).

Available data on lithospheric garnets from the Wesselton (Griffin *et al*., 1999b) and Kimberley (Simon *et al*., 2007) kimberlites from the Kaapvaal Craton demonstrate that they are, on the whole, significantly less metasomatised.

Age of the Eglab Shield

For a long time, the age of the Eglab Shield was disputable. Initially, it was considered to be Palaeoproterozoic, Eburnean. Recently, a small outcrop of Archaean amphibolites intercalated with plagiogranitic orthogneisses and garnet–hornblende banded grey gneisses, dated at 2.73 Ga (U-Pb zircon method), was recognised in the south-western part of the shield. The amphibolite is now considered a relic of the Archaean oceanic crust of the Eglab Shield. This age gives a link to the SW extension of the Eglab Shield, the Reguibat Rise (Shield) where the 2.73 Ga granitic magmatism followed transpressive movements between two major Mesoarchaean blocks. The geochemical data on the studied garnet grains offer some support for the Archaean age of the Eglab Shield. In the plot Y/Ga *vs* Zr/Y, most grains fall into the field where data for garnets from Archons (> 2.5 Ga) and Protons (2.5-1.0 Ga) overlap. However, a significant minority of grains (*ca* 25 %) falls into and around the Archon field. The overall pattern suggests an Archean lithospheric mantle that has been significantly overprinted by later metasomatism (Griffin *et al*., 2009).

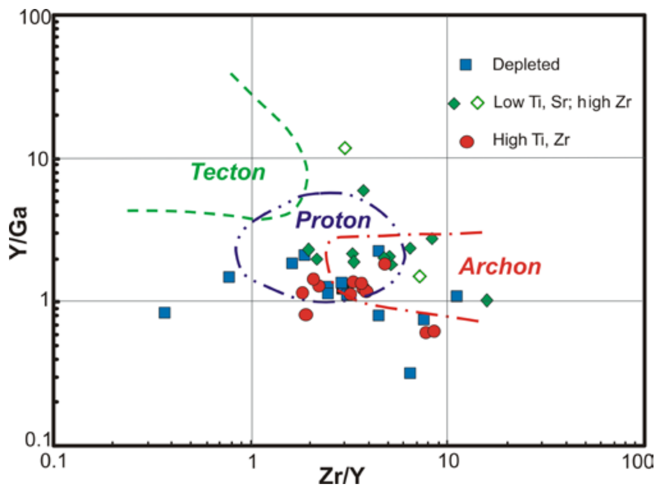

Fig. 7. Y/Ga *vs* Zr/Y for the El Kseibat garnet grains. Archon, Proton, and Tecton fields after Griffin et al., 1998.

Previously, Kahoui *et al.* (2008), based on structural, geophysical, geological and geochemical data, and particularly on the identification of Archaean blocks within the Eglab Shield, suggested a possibility of locating the primary sources of diamond and garnet within the Eglab Shield. The data presented here support that suggestion. The plot Y/Ga *vs.* Zr/Y for the El Kseibat garnet grains (Fig. 7) is characteristic for the Archaean lithosphere, and the north-eastern part of the Eglab Shield can thus be suggested to be Archaean. In this case, the entire shield may be considered to be Archaean (most likely Neoarchaean). This conclusion, based on geochemical data, is at least consistent with geophysical data on the upper-mantle shear-wave velocity structure of the north-eastern part of the WAC, which shows a thick (250-275 km), cool lithosphere characteristic of Archaean cratons.

Diamond potential of the area

The P-T estimates for the analysed garnet (Fig. 6) all lie within the graphite stability field, but since the P estimates of the higher-T garnets represent minimum values, it is still possible that diamondiferous mantle may have been sampled by the magmas that carried the garnets to the surface. Using the Nd/Y ratio in garnet as a criterion (Griffin et al., 1995), several grains fall into the field of diamond-inclusion garnets (Fig. 8), but these are also low-T garnets that would not lie within the P-T stability field of diamond. The deeper garnets in the present sample suite all show the effects of melt-related metasomatism, which appears to be destructive of diamond. The available data are thus not strongly encouraging in terms of diamond potential, but the presence of diamonds in the sampled placers of the El Kseibat area suggests that the garnets are not giving the full story; diamonds may have been present in the deeper lithospheric levels, and survived metasomatic attack until entrained in the kimberlite.

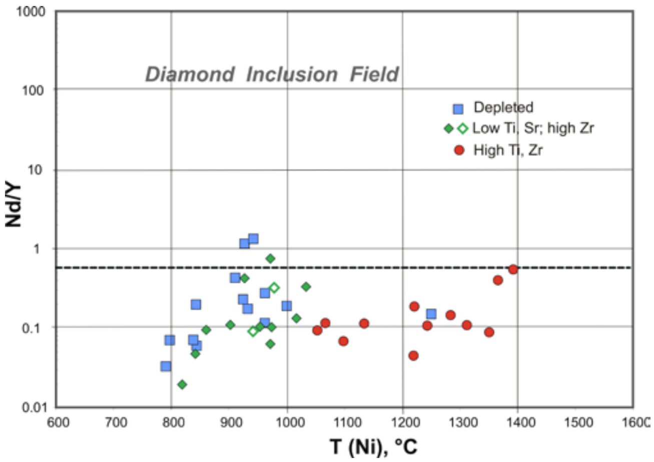

Fig. 8. Nd/Y *vs* T(Ni) for the El Kseibat garnet grains. Empty diamonds are harzburgitic grains.

REFERENCES

Faure, S., Godey, S., Fallara, F. and Trepanier, S. (2011) Seismic architecture of the Archean North American mantle and its relationship to diamondiferous kimberlite fields. Econ. Geol., 106, pp. 223-240.

Griffin, W.L. and Ryan, C.G. 1995. Trace elements in indicator minerals: Area selection and target evaluation in diamond exploration. J. Geochem. Explor., 53, pp. 311-337.

Griffin, W.L., O'Reilly, S.Y. and Ryan, C.G. (1999a) The composition and origin of subcontinental lithospheric mantle, in: Fei, Y., Bertka, C.M., Mysen, B.O. (Eds.), Mantle Petrology: Field Observations and High Pressure Experimentation: A Tribute to Francis R. (Joe) Boyd. Geochem. Soc. Spec. Publ. No. 6, pp. 13–45.

Griffin, W. L., Shee, S. R., Ryan, C. G., Win, T. T. and Wyatt, B. A. (1999b) Harzburgite to lherzolite and back again: metasomatic processes in ultramafic xenoliths from the Wesselton kimberlite, Kimberley, South Africa. Contr. Mineral. Petrol., 134, pp. 232-250.

Griffin, W. L., Fisher, N. I., Friedman, J., Ryan, C. G. and O'Reilly, S. Y. (1999c) Cr-pyrope garnets in the lithospheric mantle. I. Compositional systematics and relations to tectonic setting. J. Petrol., 40, pp. 679-704.

Griffin, W.L., O'Reilly, S.Y., Afonso, J.C. and Begg, G. (2009) The composition and evolution of lithospheric mantle: A re-evaluation and its tectonic implications. J. Petrol., 50, pp. 1185-1204.

Kahoui, M., Mahdjoub, Y. and Kaminsky, F.V. (2008) Possible primary sources of diamond in the North African diamondiferous province, in: Ennih, N., Liégeois, J.-P. (Eds.), The boundaries of the West African Craton. Geol. Soc. London Spec. Publ., 297, pp. 77–109.

Kaminsky, F.V., Verzhak, V.V., Dauev, Yu.M., Buima, T., Boukhalfa, L., Kahoui, M., Salhi, A. and Slougi, M. (1992) The North-African diamondiferous province. Russ. Geol. Geophys., 33(7), pp. 91-95.

Simon, N.S.C., Carlson, R.W., Pearson, D.G. and Davies, G.R. (2007) The origin and evolution of the Kaapvaal cratonic lithospheric mantle. J. Petrol., 48, pp. 589–625.

Stachel, T., Aulbach, S., Brey, G., Harris, J.W., Leost, I., Tappert, R. and Viljoen, K.S. (2004) The trace element composition of silicate inclusions in diamond: a review. Lithos, 77, pp. 1-2