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ENRICHMENT PROCESSES IN GARNET-BEARING MANTLE XENOLITHS FROM KIMBERLEY PIPES (SOUTH AFRICA)

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ABSTRACT

Eight garnet-peridotites (5 harzburgites and 3 lherzolites) and two garnet-bearing ol-orthopyroxenites from Bultfontein kimberlite dumps (Kimberley pipes, South Africa) were studied. They present protogranular textures with well-equilibrated primary mineralogical assemblage, consisting of large olivine (3-5 mm), orthopyroxene (3-5 mm), garnet (2-6 mm), phlogopite (up to 1 mm), and smaller clinopyroxene (2-3 mm), and spinel (up to 0.5 mm) crystals. Three types of secondary textures, superimposed on the primary paragenesis, were distinguished on the basis of geometric relationships and relative proportions of primary and secondary phases.

Type A is characterised by the development of reaction coronas around garnets, which beside a dark keliphitic rim, consist of small subeuhedral crystals of phlogopite (up to 0.05 mm), spinel (100-400 μm) and clinopyroxene (0.05-0.1 mm).

Type B is characterised by reaction areas around orthopyroxene. The secondary assemblage is constituted by small grains of olivine (200-300 μm), clinopyroxene (200-400 μm) and phlogopite (up to 0.05 mm) which usually include subeuhedral spinels.

Type C is characterised by veins and patches filled with secondary olivine (200-300 μm), clinopyroxene (200-300 μm), phlogopite (400-600 μm) and spinel (50-100 μm). Small amounts of carbonates (80-100 μm) and apatite (90-100 μm) set in serpentinitic matrix may also be found.

Primary olivine, orthopyroxene and garnet show consistently lower Mg# values (Mg/(Mg+Fe)*100) in lherzolites (ol, 90.7-91.3; opx, 91.5-92.3; gt, 79.9-81.1) with respect to harzburgites (ol, 91.5-92.8; opx, 92.3-93.7; gt, 80.6-83.9). On the other hand, in contrast with what usually observed in spinel-bearing metasomatized peridotites, secondary phases record systematically lower mg values than the primary phases.

Chondrite-normalized REE patterns for garnets are typically "humped" with higher values in MREE (Gd and Eu) and $(La/Yb)_N$ ratios varying between 0.010-0.017. They are remarkably homogeneous in composition from core to rim and display a strong negative Ti anomaly.

Clinopyroxenes show the widest range of major element compositions, clearly related to the various textural positions. Primary clinopyroxenes are very homogeneous in composition with moderate Al_2O_3 (2.38-2.87 wt%), and high Na_2O (up to 3 wt%) contents. With respect to the primary clinopyroxene, secondary clinopyroxenes in type B textures (associated with orthopyroxene) are depleted in Al_2O_3 and Na_2O and enriched in TiO_2 contents, while secondary clinopyroxenes in type A textures (related to garnet) are enriched in Al_2O_3 (6.07-9.07 wt%) and FeO and depleted in SiO_2 and Na_2O. As a result, clinopyroxenes related to orthopyroxene are easily distinguished from clinopyroxenes related to garnet on the basis of their quite different SiO_2 and Al_2O_3 contents.

As far as trace element are concerned, in chondrite-normalized diagram, primary clinopyroxenes show a remarkable Ti and Zr negative anomalies (Ti/((Eu+Gd)/2)), Ti*=0.01-0.06; Zr/((Nd+Sm)/2), Zr*=0.04-0.05) and enriched $(La/Yb)_N$ ratios (42.67-45.62), which would speak in favour of equilibrium condition with garnet. On the other hand, both secondary clinopyroxenes display similar patterns, which are characterised by i) a decrease in the La/Yb ratios ($(La/Yb)_N$=5.08-27.4), caused by a HREE enrichment, ii) a less pronounced Ti negative anomaly, iii) the appearance of a slight Sr negative anomaly, and iv) the disappearance of Zr negative anomaly. Particularly Ti content results higher than every primary Ti-bearing phases (including phlogopite).

In accordance with what already observed for the other primary phases, phlogopite in lherzolites tends to have lower Mg# values with respect to that in harzburgites, although with a wide overlap probably due to the difficulties in calculating the Fe^{3+}/Fe^{2+} ratios in hydrous minerals. Secondary phlogopite is enriched in TiO_2 and FeO and depleted in MgO. In chondrite-normalized patterns primary phlogopite are characterised by higher amount of Ba, Sr and Nb and lower Ti contents with respect to the secondary crystals. So far, no clear geochemical markers have been found for discriminating between phlogopite in type A, B or C textures.

Spinels display a wide range of both Cr# (Cr/(Cr+Al)*100) and Mg# values irrespective from textural positions (Cr#=32.5-87.4; Mg#=41.3-64.3). Only in pyroxenites they are characterised by a substantially lower Mg# values (9.16-16.37).

Carbonates are mainly constituted by calcite, but rare crystals of dolomite were also found within a serpentinitic veins. Apatite present a fairly homogeneous composition, with a highly fractionated chondrite-normalized REE patterns ($(La/Yb)_N \simeq 120$) and a Sr content up to 17,500 ppm. Amphibole is very rare. It has been observed only in type B reaction zones (in orthopyroxenite). It has pargasitic composition.

Several chemical balances, using both major and trace elements, were put forward in order to constrain the process which caused the secondary paragenesis observed in type A, B and C textures. Trace element contents in secondary clinopyroxenes point toward a link with garnet destabilization, as testified by the HREE enrichment. The contribution of orthopyroxene in producing secondary clinopyroxene is also highly supported by the high SiO_2 content (type B tex-

tures). Primary phlogopite does not participate to any reaction as evidenced by the petrographic characteristics, thus the remarkable Ti enrichment observed both in secondary clinopyroxene and phlogopite remain unbalanced. Also apatite crystallization seems affect secondary clinopyroxene formation as suggested by its lower LREE and Sr contents.

In conclusion these preliminary data may indicate an enrichment event which affected the garnet peridotite. Corona around garnet will not (at least only) result by a simple decrease in pressure conditions, which may have caused the crossing of the garnet/spinel stability field. Garnet (and orthopyroxene) may have reacted with a metasomatic fluid/s (enriched in Ti) giving rise to secondary clinopyroxene, phlogopite, apatite and, possibly, carbonate minerals.