

# REACTION PRODUCTS OF CARBONATITE WITH ULTRAMAFIC ROCKS IN THE CATALÃO I COMPLEX, BRAZIL: POSSIBLE IMPLICATIONS FOR MANTLE METASOMATISM

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The Catalão I complex is a semi circular intrusive body with very rare outcrops. Drill-hole cores from different parts of the intrusion have been studied (Carvalho, 1974; Baecker, 1983; Danni et al. 1991). The most abundant rock types in the intrusion are phlogopitites, pyroxenites, carbonatites, and phoscorites. All petrographic varieties occur as veins and dikes in a general cross cutting relation. The evolution of the complex comprises initial intrusion of dunites (and clinopyroxenites?) followed by extensive injection of carbonatite dikes and veins. The ultramafic rocks were transformed into phlogopitites, clinopyroxenites and orthoclase-bearing clinopyroxenites that present a large variety of grain sizes (from millimeter to pegmatitic) and variable modal composition.

Previous mineralogical studies by Araújo and Gaspar (1992, 1993) showed that phlogopite, clinopyroxene, calcite, magnetite, ilmenite, orthoclase, apatite, arfvedsonite, and pyrite are the most abundant phases. Minor phases are chalcopyrite, priderite, pyrochlore, monazite, rutile, ancyllite, baddeleyite, zirkelite(?), and dalyite. Other Zr- and Nb-bearing minerals and a Ni, Fe sulphide are under investigation. Petrographic evidence indicates that phlogopite formation extends for the whole span of carbonatite reactions. It may be found included in orthoclase crystals in the clinopyroxenites as well as replacing diopside. Diopside and orthoclase seem to be the earliest abundant phases to be formed. Ti and Zr minerals are among the latest phases formed.

Araújo and Gaspar (1993) showed that the Al content in phlogopite is extremely variable, ranging from 2.0 down to 0.01 a.p.f.u.. Assuming that vacant tetrahedral site is fulfilled by  $\text{Fe}^{3+}$  the complete solid solution from phlogopite to tetraferriphlogopite end members are present in Catalão I. Phlogopite presents direct pleochroism in the range of 2.0 to 1.75 Al a.p.f.u. and inverse from 1.9 to 0.01 Al a.p.f.u. There exist all degrees of clinopyroxene substitution by phlogopite. Clinopyroxene belongs to the diopside - salite series with the following highest contents:  $\text{TiO}_2 = 1.05\text{wt}\%$ ,  $\text{Al}_2\text{O}_3 = 1.24\text{wt}\%$  and  $\text{Cr}_2\text{O}_3 = 0.24\text{wt}\%$ . In some rocks clinopyroxene crystals present greener rims enriched in the aegirine component. Magnetite presents trellis-type ilmenite lamellae. Magnetite contains up to 1.83 wt%  $\text{TiO}_2$ , 0.08wt%  $\text{Al}_2\text{O}_3$ , 0.94wt%  $\text{Cr}_2\text{O}_3$ , and 1.66wt% MgO. Ilmenite presents very variable composition with MnO ranging from 1.04 to 16.6 wt%, MgO from 1.59 to 4.20wt%, and  $\text{Fe}_2\text{O}_3$  from 0.0 to 6.69wt%. Orthoclase is common in the clinopyroxenites and is an almost pure end member,  $\text{Or}_{99-98.5}$ . Gaspar et al. (1994) showed that magnetite is commonly replaced by pyrite and calcite leaving the ilmenite lamellae as relicts in these later minerals. Parts of these ilmenites are than transformed into priderite and rutile. Priderite may be associated to ilmenite and to magnetite and ilmenite. The former is similar in composition to priderite from lamproites and the last overlap a small portion of the compositional range of hollandite-group minerals found in kimberlites.

The two most striking features of the complex are: 1) multistage formation with many different events of carbonatite intrusion producing clinopyroxenites and phlogopitites with a large variation in grain size, modal and chemical compositions, and 2) the amount of  $\text{K}_2\text{O}$  and  $\text{H}_2\text{O}$  brought by

the carbonatite intrusion. Both are, however, typical of many carbonatite complexes (e.g. Jacupiranga, Sokli, Araxá, etc.). Phlogopite and orthoclase are among the most common products of carbonatite reactions. Phlogopite may, as well, be an abundant primary magmatic phase (e.g. Jacupiranga), clearly indicating that K is undoubtedly a very common and even abundant element in carbonatite magmas. K-richrichterite is also a common phase in carbonatite complexes (e.g. Jacupiranga, Phalaborwa). The K/Na ratio in carbonatite magmas is high. Sodic phases are usually restricted to much less abundant arfvedsonite and aegirine, mainly in country fenites. Sulfides, Ti and Zr minerals seem to be concentrated in the most evolved stages of the reaction as exemplified by priderite and pyrite (Gaspar et al., 1994). In these stages the fluid phase is most probably vapor dominated.

What is the role of K and Na in the composition of primary carbonatite melts?

Based on the existence of natrocarbonatite lavas in the Oldoinyo Lengai volcano and the chemistry of fenitization Le Bas (1987) concluded that primary carbonatite melts are alkali rich and that they lose K and Na in fenitization reactions. In the experiment by Wallace and Green (1988) natrocarbonatite magnesian melt coexisted with an amphibole lherzolite in a field ranging from 21 to 30 kbar and 930 to 1080 °C. The authors stated that the  $K_2O$  and  $P_2O_5$  are strongly partitioned into the melt fraction. The partition coefficients of Na and K to the carbonatite melt was about the same, but slightly higher for K. The starting composition of the experiment contained 10 times more  $Na_2O$  than  $K_2O$ . Thibault et al. (1992) obtained an alkaline dolomitic melt coexisting with a garnet-rich phlogopite lherzolite at 3.0 GPa and 1100°C. The melt contained 4.93wt%  $Na_2O$  and 7.01wt%  $K_2O$ . Schauder and Navon (1994) found hydrous fluids and carbonatitic melts as inclusions in fibrous diamonds from Jwaneng, Botswana. The carbonatitic phase is an alkaline dolomitic melt with 20.7wt%  $K_2O$  but only 2.2wt%  $Na_2O$ . The experiments and melt inclusion in diamonds agree with field evidence that primary carbonatite magmas are alkaline rich with  $K > Na$ .

Carbonatite metasomatism in the mantle

Many authors have suggested that carbonatite fluids may play an important role in mantle metasomatism (for a review see Menzies and Chazot, 1994). Experiments have demonstrated that interaction of carbonatite melts with mantle peridotites result in the formation of diopside and olivine (Green and Wallace, 1988) or diopside + olivine + phlogopite (Thibault et al., 1992), at the expenses of enstatite by decarbonation reactions. The last authors interacted their alkaline dolomitic melt with a spinel wherlite and obtained olivine + phlogopite + calcite. Most authors relate carbonatite metasomatism in the mantle to enrichment in Ca and incompatible elements except Ti and Zr (Menzies and Chazot, 1994). However, Ti and Zr are present in the late stages of reaction in the Catalão I complex. The direct implication of this is that vapor-rich phases evolved from carbonatite melts may cause Ti and Zr enrichment in the mantle besides the well accepted enrichment in LREE, U, Th, P, Sr, etc. Evidence from the Catalão I and other carbonatite complexes, experimental works, and diamond fluid inclusions shows that K is very important in carbonatite fluids (melt and vapor) and should be considered as one strong indicator of carbonatite influence in mantle metasomatism. Phlogopite and K-richrichterite are candidates to be formed by carbonatite reaction in the mantle. Phlogopite and phlogopite-bearing mantle xenoliths should be carefully examined as derived from carbonatite reaction. A revaluation of the role of carbonatite fluids in the mantle potassic metasomatism, usually considered as due to silicate potassic melts, might show that carbonatite has a much larger influence than now accepted.



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