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Manganoan magnesian ilmenite and titanian clinohumite from the Jacupiranga carbonatite, São Paulo, Brazil

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Abstract

Apatite–phlogopite–magnetite carbonatite contains manganoan (2–8 per cent MnO) magnesian (15–24 percent MgO) ilmenite as oxidation exsolution lamellae in a host magnesioferrite–magnetite solid solution. These ilmenites are distinct in paragenesis and composition to magnesian ilmenites found in kimberlites. Titanian clinohumite (3 percent TiO_2) is found as reaction rims upon forsterite inclusions in the carbonatite. Titanian clinohumite is unlikely ever to be a liquidus phase in carbonatitic or kimberlitic magmas.

Introduction

Magnesian ilmenite (5–22 percent MgO) is a rare mineral which is characteristically found only in kimberlites as discrete monomineralic nodules or as lamellar intergrowths with pyroxenes. Ilmenites from common basic and acidic rocks typically contain less than 5 percent MgO, the majority containing less than 1 percent MgO (Mitchell, 1973; 1977). This note describes magnesian ilmenite from a new paragenesis in a carbonatite.

The Jacupiranga alkaline complex consists of an ovoid intrusion of jacupirangite, peridotite, ijolite, and nepheline syenite, with a central core of carbonatite being the latest phase of the intrusion (Melcher, 1966). Samples studied in this work were taken from the main carbonatite outcrop at Morro da Mina, and are coarse-grained apatite–magnetite–phlogopite carbonatites which contain large (up to 10 cm) rounded olivine (dunite) "inclusions".

Ilmenite

Ilmenite[1] occurs exclusively as oxidation exsolution lamellae within large (1 cm) euhedral magnetite crystals. Representative analyses are given in Table 1 and the compositional variation is depicted in Figures 1 and 2. The outstanding feature of the ilmenite composition is the high and variable MgO content (15–24 percent). Individual lamellae are homogeneous but lamellae within the same host magnetite crystal can vary in composition by several percent MgO. Figure 1 shows that the Jacupiranga ilmenites overlap the compositional field of kimberlite ilmenites and can have even higher $MgTiO_3$ contents than kimberlitic ilmenites. Figure 1 also illustrates that the Jacupiranga ilmenite differs in MgO content to that of oxidation exsolution ilmenites found in other carbonatites, these latter ilmenites being characteristically poor (<1 percent) in MgO (Prins, 1972; Haggerty, 1976).

Figure 2 shows that the Jacupiranga ilmenites can be easily distinguished from kimberlite ilmenite of similar MgO content on the basis of their $MnTiO_3$ content. Kimberlite ilmenites always contain less than 0.5 percent MnO (Mitchell, 1977) and the high MnO (2–8 percent) content of the Jacupiranga ilmenite is in keeping with Haggerty's (1976) observation that ilmenites from alkaline rocks, carbonatites, and granites are commonly enriched in MnO. McMahon and Haggerty (1976) have, for example, described primary manganese-rich ilmenite ($Py_{50}Ilm_{40}Hm_{10}$) from the Oka carbonatite. The Jacupiranga ilmenites and other carbonatite ilmenites lack detectable Cr_2O_3 (0.1 percent), this being a second feature which distinguished them from kimberlite ilmenites, which typically contain from 0.1–2.5 percent Cr_2O_3 (Mitchell, 1973; 1977).

Magnetite

Representative analyses of host magnetite are given in Table 1. Magnetites in carbonatites show a

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[1] Ilmenite is used here in the sense of the ilmenite series, *i.e.* all compositions with the ilmenite structure within the $FeTiO_3$–$MgTiO_3$–$MnTiO_3$–Fe_2O_3 system; the compositions reported in Table 1 all have more than 50 percent $MgTiO_3$ and thus fall within the compositional range of geikielite.

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Table 1. Composition of ilmenite, magnetite and spinel

	ILMENITE					MAGNETITE			SPINEL
	1	2	3	4	5	6	7	8	9
TiO_2	55.83	57.59	57.05	58.84	59.24	0.63	0.80	2.11	0.18
Al_2O_3	0.00	0.00	0.00	0.00	0.00	0.16	0.56	0.59	67.23
Fe_2O_3*	6.46	5.61	6.80	6.20	4.56	65.44	65.08	65.07	0
FeO*	18.95	13.10	12.91	10.90	9.15	29.44	29.28	29.27	6.79
MgO	15.69	17.24	19.61	21.86	23.46	2.75	4.01	3.34	25.04
MnO	3.25	7.87	3.40	3.02	2.29	0.61	0.53	0.60	0.77
	100.19	101.40	99.77	100.82	98.70	99.04	100.26	100.98	99.49
$MnTiO_3$	6.2	14.6	6.3	5.5	4.2				
$MgTiO_3$	52.6	56.6	64.3	69.9	75.6				
$FeTiO_3$	35.7	24.1	23.8	19.6	16.5				
Fe_2O_3	5.5	4.6	5.6	5.0	3.7				

*Fe_2O_3 and FeO calculated by Carmichael's (1967) method.

wide range in MgO content. The majority contain less than 0.5 percent MgO (*e.g.* Fen, Chipman Lake) whilst others (*e.g.* Oka) contain from 1–4 percent MgO (Prins, 1972; Haggerty, 1976; McMahon and Haggerty, 1976). The Jacupiranga magnetite is similar to the high-MgO magnetites. These magnetites contain little TiO_2 and are members of the magnesioferrite–magnetite solid-solution series. The Jacupiranga spinels are unlike the spinels found in kimberlite, in which high MgO coupled with high TiO_2 represents solid solution towards magnesian ulvöspinel (Mitchell and Clarke, 1976). The magnetites are not particularly enriched in MnO compared with carbonatite magnetites in general; these can contain from 1–12 percent MnO (Haggerty, 1976; McMahon and Haggerty, 1976). MnO at Jacupiranga was evidently preferentially partitioned into the rhombohedral phase during exsolution.

Rounded inclusions of spinel (Table 1) of unknown origin can also be found in the magnetite.

Olivine–titanian clinohumite–carbonate

The large rounded olivine crystals are extremely magnesian (Table 2), and may be either an early cumulus phase in the carbonatite or xenoliths derived by the fragmentation of the earlier peridotites (Melcher, 1966). Whatever their origin, they were not at the time of emplacement in equilibrium with the liquid which formed the carbonatite, as evidenced by their corrosion and alteration to serpentine (Table 2) and titanian clinohumite. Orange titanian clinohumite is found as irregular (0–1 cm) discontinuous rims around olivine when this mineral is in contact with carbonate (Table 2). Fractures within the olivines have been penetrated by carbonate, these two phases commonly being separated from each other by a zone of titanian clinohumite. The titanian clinohumite on textural evidence appears to have formed by metasomatism and reaction with the CO_2, H_2O, CaO, and MgO-rich fluid which eventually crystallized apatite, carbonate, and phlogopite (Table 2). A similar reaction origin for titanian clinohumite has been postulated by Smith (1977) for the origin of this mineral in kimberlite. In this case xenoliths of mantle lherzolite have reacted with the liquid which eventually formed the kimberlite groundmass. The rare reaction formation of titanian clinohumite occurring upon the immersion of forsterite in carbonated ultrabasic liquids appears to place in doubt the suggestion that titanian clinohumite is ever a liquidus phase in

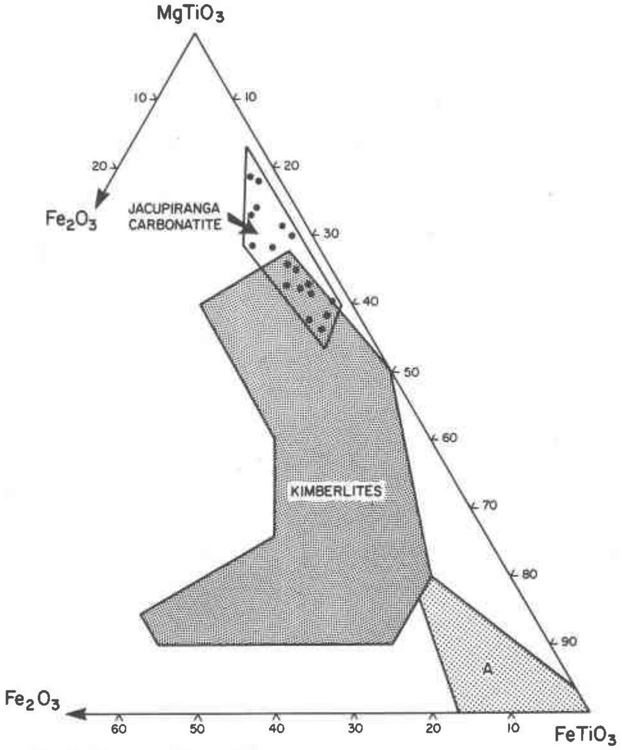

Fig. 1. Composition of ilmenites expressed as ternary molecular percentages of Fe_2O_3–$FeTiO_3$–$MgTiO_3$. Field of kimberlite ilmenites from Mitchell (1973, 1977) and Haggerty (1975). Field A is for ilmenites from lamprophyres, granites, basalts and carbonatites (Prins, 1972; Haggerty, 1976; Bergstøl, 1972; Czamanske and Mihalik, 1972; and unpublished data.)

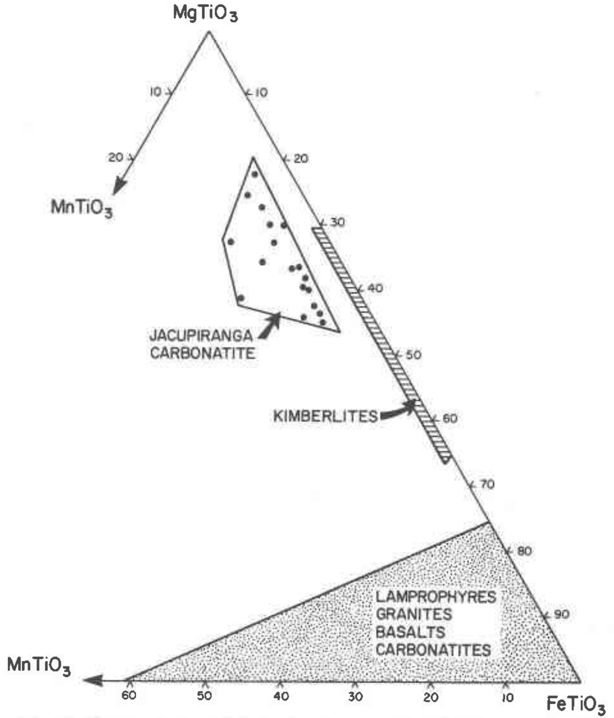

Fig. 2. Composition of ilmenites expressed as ternary molecular percentages of $MnTiO_3$–$FeTiO_3$–$MgTiO_3$. Data sources as in Fig. 1.

Table 2. Average composition of minerals in the Jacupiranga carbonatite

	1.	2.	3.	4.	5.
SiO_2	38.12	41.81	40.98	41.09	-
TiO_2	3.10	0.00	0.15	1.18	-
Al_2O_3	0.00	0.00	0.86	12.32	-
FeO*	3.99	6.13	1.81	4.86	0.04
MnO	0.51	0.50	0.05	0.11	1.77
MgO	53.32	52.38	40.16	24.69	20.72
CaO	0.00	0.00	0.00	0.00	33.66
Na_2O	0.08	0.00	0.00	0.23	-
H_2O	0.00	0.00	0.00	10.07	-
	99.12	100.87	84.23	94.57	56.49
Structural formula					
O	18	4	9	24	
Si	4.178	0.999	2.541	6.431	
Ti	0.256	-	0.007	0.139	
Al	-	-	0.063	2.273	
Fe	0.366	0.123	0.939	0.636	
Mn	0.047	0.010	0.003	0.015	
Mg	8.711	1.867	3.712	5.760	
Ca	-	-	-	-	
Na	0.017	-	-	0.070	
K	-	-	-	2.011	
			Fo_{93}	$Phl_{90}Ann_{10}$	

1. titanian clinohumite 2. olivine 3. serpentine 4. phlogopite 5. carbonate

* Total iron calculated as FeO.

kimberlites or is important in the mantle (Aoki *et al.*, 1976). The Jacupiranga titanian clinohumites differ from those in kimberlite (Aoki *et al.*, 1976) in being poorer in TiO_2 and richer in MgO, a reflection of the TiO_2-rich nature of late fractions of kimberlite magmas (Mitchell and Clarke, 1976).

Comments

The development of magnesian ilmenite and titanian clinohumite at Jacupiranga is a result of the unusually magnesian nature of this complex relative to other carbonatite complexes. Manganoan magnesian ilmenite can be expected to form whenever titaniferous magnesioferrite–magnetite undergoes exsolution. This occurrence of magnesian ilmenite should not be used as evidence in favor of any petrogenetic relationship between kimberlite and carbonatite, as advocated by some petrologists (Malkov, 1975; Wyllie and Huang, 1976), since the composition (MnO) and paragenesis are distinct from that of kimberlite ilmenites.

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