THE TOPAZ-ALBITE GRANITE AND RELATED ROCKS FROM THE SN-IN MINERALIZED ZONE OF MANGABEIRA GRANITIC MASSIF (GO, BRASIL)

MÁRCIA ABRAHÃO MOURA[1] AND NILSON FRANCISQUINI BOTELHO[1]

ABSTRACT The Mangabeira Massif is part of the Goiás Tin Province and is constituted of an A-type Paleoproterozoic biotite granite, evolved granites and greisens. The Main Greisenized Zone of the massif (MGZ) is composed of the less evolved Li-siderophyllite g2d granite, the topaz-albite granite (TAG), Sn-mineralized greisens and a quartz-topaz rock, with anomalous indium contents (up to 0.4 wt%). Micas are important for the characterization of each facies and define a phengite-zinnwaldite series, so far only described in the Paranã Subprovince rocks. Late/post-magmatic processes affected the MGZ rocks, causing the mobility of many elements, except TiO_2, Ta and Th .

The topaz-albite granite (TAG) is similar to the rare topaz granites and has derived from g2d granite by magmatic differentiation. TAG is subsolvus, leucocratic, equigranular, medium-grained and contains essential quartz, albite, topaz, microcline and zinnwaldite. Topaz occurs either as inclusions (20mm) in albite or as large subhedral grains. The accessory minerals are monazite, cassiterite, zircon and magnetite. In the Qz-Ab-Or system, TAG samples plot near the minimum for 0 wt. %F. Chemically TAG is characterized by molar Na/K mainly >1, A/CNK ratio between 1.3 and 1.5, high contents of F, Li, Al_2O_3, Rb, Zn and Sn and low TiO_2, MgO, P_2O_5, CaO, Zr, Ba and Sr. The granites REE pattern is flat with a pronounced Eu anomaly.

The quartz-topaz rock occurs associated with the TAG and resembles topazites, interpreted as magmatic rocks in the literature, but it can also be the product of topaz-albite granite hydrothermal alteration. The rock also contains sphalerite, wolframite, löllingite, chalcopyrite, bismutinite, galena, stannite, tennantite, In minerals (yanomamite, roquesite and dzhalindite) and hydrated arsenates of Sn, U, Ba, K, Pb and Bi.

Keywords: Topaz-albite granite, topazite, indium, geochemistry, Goiás Tin Province

INTRODUCTION

Topaz granites constitute a very rare type of rock and occur in nature as small stocks or dykes. Besides their petrologic significance, topaz granites are of economic importance, as they are commonly related to Sn-W and Ta-Sn mineral deposits (Pollard and Taylor 1991, Taylor 1992). The Mangabeira Massif (GO) contains the only known occurrence of this type of granite in central Brasil.

The Mangabeira granitic Massif is located in the Goiás Tin Province, which comprises an A-type granite province, with two different ages of granite groups: 1.77 and 1.57-1.58 Ga (Botelho 1992, Pimentel *et al*. 1991). The older granites were named g1 and the younger ones, designated g2, are related to the most important tin deposits in the province. The Massif is mainly composed of a pink, porphyritic to equigranular biotite granite (g1). The Main Greisenized Zone (MGZ) encompasses the less evolved g2d granite, the topaz-albite granite, a quartz-topaz rock, metasomatized granites and greisens (Fig. 1), where Sn and In mineralization are concentrated (Botelho and Moura 1998).

The purpose of this paper is to describe and discuss petrographic, mineralogical and chemical data of the topaz-albite granite and related rocks, specially the quartz-topaz rock, of the main mineralized zone of the Mangabeira granitic Massif, leading to constraints about their origin.

PETROGRAPHY AND HYDROTHERMAL ALTERATION

The dominant rock in the MGZ is the pink equigranular g2d granite, composed of quartz (30%), microperthitic microcline (30-35%) and albite An_0 (30-35%). Primary Li-siderophyllite is rarely preserved, but is commonly transformed to phengite. The accessory minerals are zircon, monazite, magnetite and, locally, ilmenite. When greisenized, the granite becomes richer in phengite (10%) and contains metasomatic anhedral topaz, monazite, fluorite and disseminated cassiterite. The g2d greisen, or phengite-quartz greisen, contains late Ba, Bi, Cu and Pb arsenates.

The topaz-albite granite (TAG) is intrusive in the g2d granite, enabling the development of a metasomatic aureole. The granite is white and contains quartz (35%), microperthitic microcline (20%), pure albite (20%), magmatic topaz (5 to 20%) and zinnwaldite (10%). Zircon, monazite and cassiterite are rare. Two albite generations are distinguished: the magmatic albite, automorphic and plenty of euhedral topaz crystals (20mm) (Fig. 2), and a metasomatic albite, developed on the borders of primary microcline and albite grains. Aside from the topaz inclusions, topaz occurs as milimetric to submilimetric subhedral grains, generally fractured and altered to Li-mica. Topaz and albite were probably the first minerals to crystallize, as observed in other regions (Pollard and Taylor 1991, Pichavant and Manning 1984).

Two types of greisen have formed from TAG, one containing quartz, topaz and up to 10% zinnwaldite and zinnwaldite greisens. Both types have zinnwaldite, topaz, cassiterite and monazite in different proportions.

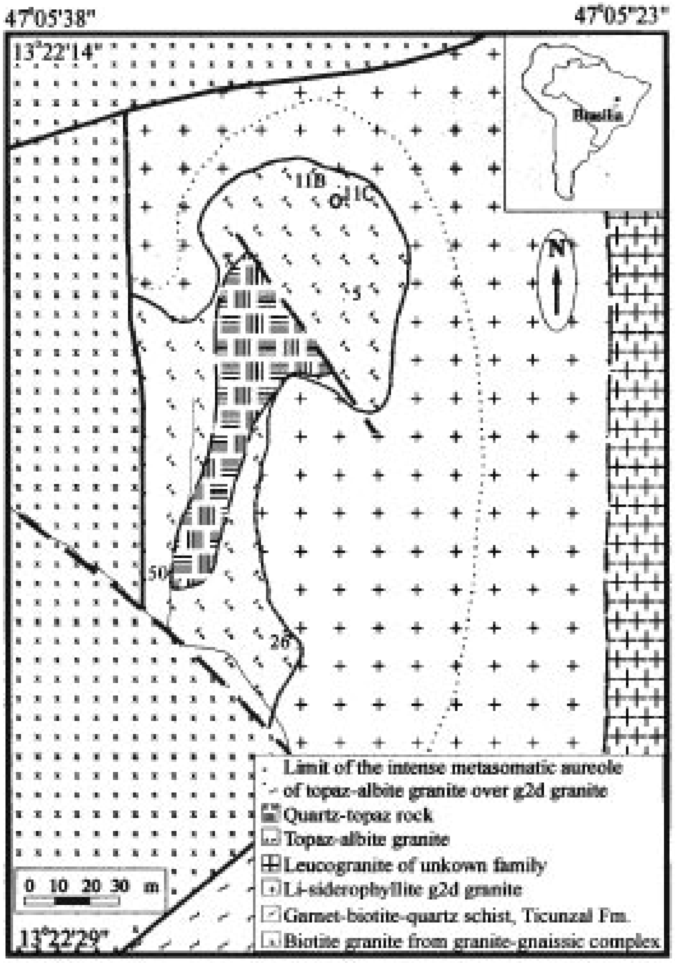

Figure 1–Geological map of the Main Greisenized Zone of the Mangabeira granitic Massif.

The quartz-topaz rock (QTR) outcrops within the topaz-albite granite, as an elongated body (Fig. 1). Its relation with TAG is not well established and it could be either a product of metasomatism or a magmatic evolved phase. The rock is white, massif, composed mainly of quartz, topaz, zinnwaldite, arsenopyrite and cassiterite. Other minerals include monazite, zircon, fluorite, sphalerite, wolframite, löllingite, chalcopyrite, bismuthinite, galena, stannite, and tennantite.

Universidade de Brasília, Instituto de Geociências, Departamento de Mineralogia e Petrologia, 70910-900, Brasília-DF, Brazil, mamoura@unb.br

Late minerals are scorodite, malachite, covellite and In, Bi, Ba, K, Pb, U and Sn arsenates. Indium economic concentrations (up to 0.4%) and minerals (roquesite, dzhalindite and yanomamite) are found only in quartz-topaz rock. Topaz occurs either as subhedral grains (0.5 mm), fractured and altering to zinnwaldite, or as tiny euhedral crystals (30 mm) included in quartz or in the larger topaz crystals. At least this type of topaz is interpreted as magmatic.

TAG and g2d granite were submitted to infiltration greisenization, related to the TAG intrusion, which caused the albitization of g2d granite and greisenization of both, g2d and TAG. The hydrothermal alteration process involved remobilization of several elements and produced economic Sn concentration. According to Gresens (1967) method, the final hydrothermal rocks were enriched in Al_2O_3, SiO_2, K_2O, Fe_2O_3, P_2O_5, Y, Zr, F, Zn, Li, Rb, Be, Sn and W and depleted in Na_2O. The REE, specially the light rare earth elements, were also mobile during the greisenization, which is probably related to their complexation with fluorine, giving rise to the crystallization of hydrothermal monazite. TiO_2, Ta and Th were little mobile during the granites transformation (Moura 1993).

LITHIUM MICAS Lithium micas study was used to complement the characterization of the different MGZ granite types. On the basis of its chemistry and petrography, three mica groups have been distinguished (Moura and Botelho 1994). Foster (1960) nomenclature was used, in order to better characterize the micas poles. The group A mica is zinnwaldite from QTR and TAG and it is rich in FeO_t (>10wt%), F (>6wt%), Rb and Mn and poor in Al. These micas have high F/Li_2O ratios (2-3) and their Li_2O contents are always below the stoichiometric proportions. The group B micas are aluminous phengites from g2d granite, with FeO contents between 5 and 9.5wt% and F contents between 2.0 and 4.5wt%. These micas have low Rb, Li and Mn and high Al. The group C micas occur in some metasomatized TAG samples and are represented by lithium phengites, with F, FeO_t, Mn, Al, Li and Rb contents intermediary between those from the other two mica groups, possibly representing a mixture. They have FeO(t) medium values of 8.0 and F contents up to 6.0wt%.

GEOCHEMISTRY The topaz-albite granite has a tendency to be richer in Na_2O than in K_2O (molar Na/K is predominantly >1), while g2d granite has $K_2O>Na_2O$. The topaz-albite granite less altered samples have A/CNK ratio between 1.3 and 1.5 and are rich in F, Li, Al_2O_3, Rb Zn, Ta, Nb, Y, In and Sn and poor in TiO_2, MgO, P_2O_5, CaO, Zr, Ba and Sr (Table 1).

The MGZ rocks together with other evolved g2 granites of the Goiás Tin Province are Ta-rich, although they still have Nb>Ta (Botelho and Moura 1998).

In the Qz-Ab-Or system, at 1 Kbar, the granite plots near the minimum for the fluorine-free system (Fig. 3), which seems to be due to TAG metasomatism. Pichavant and Manning (1984) explained the plots for topaz granites from southwest England (1-1.5wt.%F) between the minima for the Qz-Ab-Or system without fluorine and with 1wt.%F at 1Kbar on the basis of the peraluminous character of the granite, because the complexes AlF_6^{3-} formed within the melt will

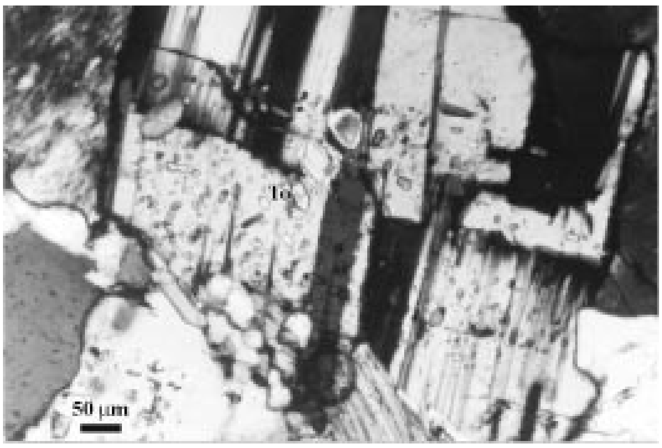

Figure 2–Topaz (To) euhedral inclusions in magmatic albite grains from the Mangabeira topaz-albite granite.

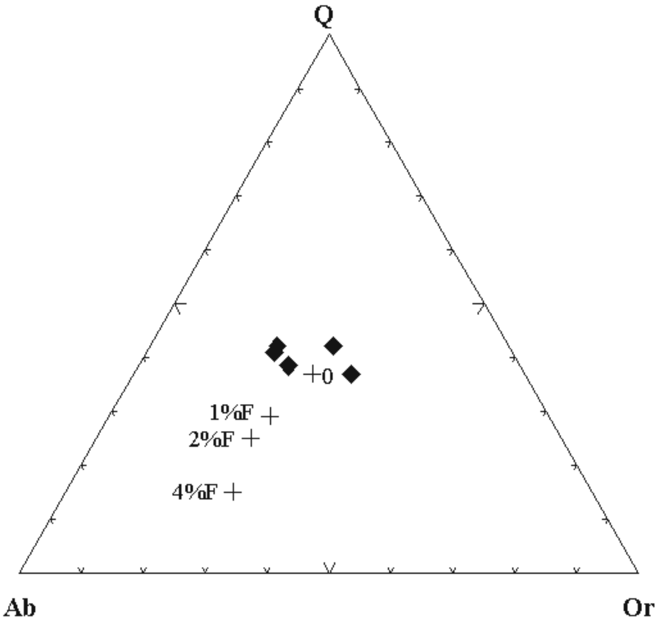

Figure 3–Normative Qz-Ab-Or composition of topaz-albite granite, showing the minima for the system with 0 to 4wt.%F and excess water at 1Kbar.

reduce the effect of a given fluorine content on the diagram for peraluminous melt compared with a metaluminous one. Similarly, loss of F during late to post-magmatic stages can shift the rock pole from its expected position. These situations can also have influenced TAG plots in the Qz-Ab-Or diagram.

In TiO_2-MgO, Al_2O_3-FeO, Li-Ta, Li-FeO, Rb-FeO, Zn-FeO Al_2O_3-F and Sn-FeO diagrams, TAG and g2d granite define a linear trend (Moura 1993), which is interpreted as consequence of magmatic evolution from g2d to TAG and, in the case of Li, F, Rb and Fe, strongly reflects the mica specialization toward TAG.

Al_2O_3-F and F-FeO relations allow a good distinction among the different types of rocks from MGZ. The contents of F, FeO and Al_2O_3 increase in the following order: g2d granite, TAG, phengite greisen and QTR + zinnwaldite greisen. The results obtained can also be used to distinguish the phengite greisen from the zinnwaldite greisen.

The MGZ granites are enriched in REE (111-255ppm for g2d and 107-160 ppm for TAG), as the other granites in the Paranã Subprovince. The patterns of TAG, g2d, their greisens and QTR are similar. The topaz-albite granite and g2d granite have flat REE patterns (La/Yb_N=2.0 to 3.5), with strong negative Eu anomaly (Eu/Eu*<0.1). Eu contents decrease from g2d to TAG (Fig. 4). These results and the data obtained by Botelho (1992) demonstrate the existence of a progressive impoverishment in Eu during the evolution of g2 family. TAG is poorer in HREE, what can suggest that the HREE were compatible during g2d differentiation.

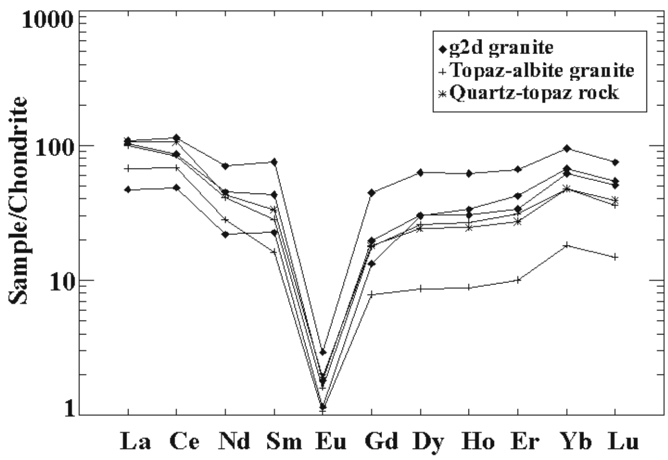

Figure 4–Chondrite-normalized rare-earth element plot of g2d granite, topaz-albite granite and quartz-topaz rock samples. The values of Boynton (1984) were used for the normalization.

Table 1–Representative geochemical data for Li-siderophyllite g2d granite, topaz-albite granite and quartz-topaz rock from the Main Greisenized Zone of Mangabeira granitic Massif.

Rock	g2d granite				Topaz-albite granite						Quartz-topaz Rock	
Sample	MM 22	MG 34	MG 8A1	MG 40	MG 7A4	MG 11B	MG 11G	MG 26A	MG 28	MG 32A	MG 7A1	MG 50A
wt%												
SiO_2	75.20	75.10	76.20	73.30	73.46	74.32	72.80	74.20	75.10	74.60	60.70	79.96
TiO_2	0.14	0.02	0.05	0.03	0.03	0.02	0.01	0.06	0.10	0.03	0.10	0.00
Al_2O_3	12.75	13.76	11.81	14.04	14.56	15.33	14.65	14.07	15.13	14.25	32.62	11.03
Fe_2O_3	0.16	0.84	0.41	0.76	<0.20	<0.20	0.13	0.18	0.20	1.07	0.20	<0.20
FeO	0.49	0.23	0.14	0.34	0.87	0.68	1.04	0.66	0.62	0.81	1.90	2.30
MnO	0.02	0.10	<0.01	0.04	0.07	0.05	0.10	0.10	0.07	0.08	0.10	0.02
MgO	<0.10	0.10	0.02	0.01	0.01	0.02	0.10	0.01	0.10	0.01	0.10	0.01
CaO	0.63	0.26	0.14	0.10	<0.1	<0.1	0.51	0.09	0.10	0.09	0.10	0.18
Na_2O	4.01	4.05	3.68	2.59	1.55	3.04	2.96	3.98	4.09	4.1	0.69	0.37
K_2O	4.72	5.26	4.37	8.33	4.76	4.54	5.31	3.16	3.82	3.16	0.38	0.22
P_2O_5	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01
L.O.I.	1.06	0.75	3.78	0.60	4.57	2.28	1.61	3.01	1.55	2.4	2.73	5.07
Total	99.20	100.50	100.60	100.20	99.90	100.30	99.20	99.50	100.90	100.60	99.60	99.20
F	n.a.	n.a.	0.30	0.30	0.74	1.07	1.02	0.85	n.a.	n.a.	3.77	4.47
ppm												
Zn	111	83	173	99	196	151	384	196	201	238	61	1675
Li	13	3	3	70	300	700	1090	1050	620	0	1	160
Rb	690	580	750	1120	1380	1250	1560	1380	1320	1070	6	100
Ba	21	46	83	96	22	<15	15	15	15	15	15	<15
Sr	22	41	32	6	<5	<5	10	6	5	5	5	<5
Th	28	31	21	10	10	28	27	34	48	34	33	17
Ta	13	10	45	33	34	34	17	46	36	44	14	25
Nb	56	55	66	40	74	47	46	45	45	66	14	41
Y	200	130	69	40	30	47	220	5	63	7	76	40
Zr	72	54	51	39	51	28	67	29	26	33	28	43
Sn	29	6	190	31	180	230	170	240	280	200	410	>5000
In	n.a.	n.a.	15	n.a.	n.a.	n.a.	n.a.	n.a.	13	n.a.	39	1113
W	30	31	29	20	14	22	37	37	27	27	63	26
La	33.53	14.60	32.18	n.a.	20.85	31.01	n.a.	n.a.	n.a.	n.a.	n.a.	33.22
Ce	92.51	39.30	69.36	n.a.	55.05	67.47	n.a.	n.a.	n.a.	n.a.	n.a.	85.83
Nd	42.08	13.08	27.06	n.a.	16.74	24.58	n.a.	n.a.	n.a.	n.a.	n.a.	25.97
Sm	14.70	4.40	8.41	n.a.	3.15	5.51	n.a.	n.a.	n.a.	n.a.	n.a.	6.51
Eu	0.22	0.08	0.13	n.a.	0.08	0.12	n.a.	n.a.	n.a.	n.a.	n.a.	0.14
Gd	11.59	3.45	5.06	n.a.	2.02	4.59	n.a.	n.a.	n.a.	n.a.	n.a.	4.64
Dy	20.33	9.70	9.76	n.a.	2.77	8.27	n.a.	n.a.	n.a.	n.a.	n.a.	7.82
Ho	4.46	2.41	2.18	n.a.	0.63	1.93	n.a.	n.a.	n.a.	n.a.	n.a.	1.76
Er	13.99	8.86	7.06	n.a.	2.10	6.55	n.a.	n.a.	n.a.	n.a.	n.a.	5.70
Yb	19.86	14.01	12.98	n.a.	3.80	9.98	n.a.	n.a.	n.a.	n.a.	n.a.	9.97
Lu	2.41	1.76	1.63	n.a.	0.48	1.15	n.a.	n.a.	n.a.	n.a.	n.a.	1.26

n.a. = not analyzed

DISCUSSION The topaz-albite granite is the most evolved granitic facies of the g2 series in Mangabeira Massif. Its mineralogy, chemistry and genetic association with Sn mineralization allow classify TAG as a special granite.

In spite of its Nb/Ta ration normally >1, TAG is similar to the class of Ta-bearing granites with normal SiO_2 and low P_2O_5, defined by Raimbault *et al*. (1991), which have 71<SiO2<76wt%, P_2O_5<0.15wt.%, A/NK=1.2-1.53, Na/K>1.4 and high Ta and Nb contents. P-poor granites also have flat REE patterns and a deep Eu anomaly, in contrast to the low and moderately fractionated patterns with no Eu anomaly of the P-rich granites (Raimbault *et al.* 1991, Taylor 1992). TAG has simultaneous decrease in Nb/Ta and FeO/MnO ratios, similar to the results obtained by Raimbault *et al.* (1991) for Ta granites from several regions of the world (Fig. 5). However, besides the Ta enrichment of the Mangabeira topaz-albite granite and its similarities with some Ta-bearing granites, TAG is related to NYF (Nb, Y, F) association, while the main Ta-bearing granites are Li-Cs-Ta-rich (Cerný 1991), belonging to the LCT association.

Other nomenclatures are used for topaz-albite granite in the literature, as topaz granite (Pichavant and Manning 1984, Taylor and Fallick 1997), Li-F rare metals granite (Kovalenko and Kovalenko 1984) or topaz - Li-mica granite (Pollard and Taylor 1991). This

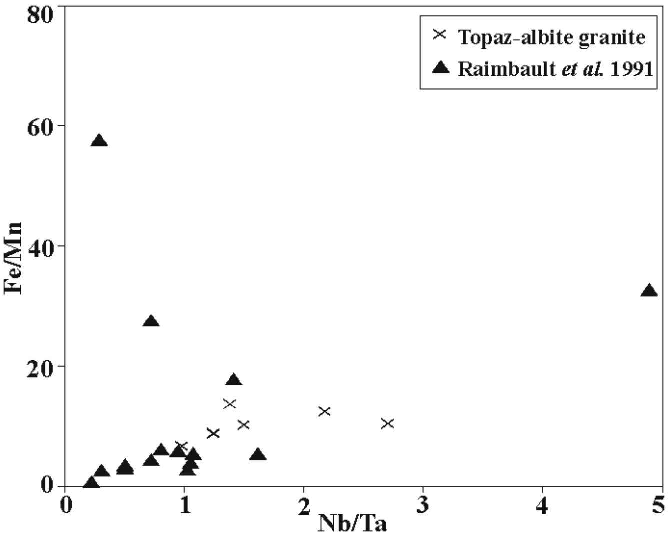

Figure 5–Fe/Mn vs. *Nb/Ta plot for topaz-albite granite samples in comparison to Raimbault et al.(1991) data.*

granite type is considered special by its rare occurrence, unusual mineralogy and for being genetically related to mineral deposits of the type Sn-W and Ta-Sn. They are emplaced at shallow levels in the crust (Pichavant and Manning 1984).

The genesis of those unique granites has been ascribed to: a) metasomatic origin, by post-magmatic fluids (apogranites) and b) magmatic origin – fractionated crystallization under high activity of F, allowing magmatic processes to persist up to temperatures lower than 630°C. The homogeneous mineralogy, chemistry, the Qz-Ab-Or relation of the MGZ topaz-albite granite and its igneous texture constitute important criteria to designate such rock as igneous. On the basis of chemical data, TAG can be characterized as part of g2 family, being the product of g2d magmatic differentiation.

The evolution of TAG may be approximated by Taylor and Fallick (1997) suggestion for low-P_2O_5 topaz granites, which have many similarities with TAG. The unusual high F contents of the granitic magma facilitate extreme differentiation in topaz granite magmas and force the production of a group of granitic rocks with near-minimum compositions so enriched in lithophile elements (Li, Nb, Ta, Sn) that economic mineralization often results.

The quartz-topaz rock has peculiar mineralogy, besides special textural and chemical characteristics. Chemically, QTR is distinguished from MGZ granites and greisens for its high SiO_2, Al_2O_3, F and Cu and low contents of Na_2O, K_2O, Rb and Li (Table 1). QTR resembles New England (Australia) topazites, described by Eadington and Nashar (1978) as magmatic rocks, composed mainly by quartz, 18-27% topaz and with almost 5% of miarolitic cavities. Other minerals reported are wolframite, muscovite and tourmaline. Fluid inclusion studies in topaz from New England indicated crystallization temperature between 570-620°C. Similar rocks were described elsewhere, as the quartz-topaz-loellingite rocks of Victoria, Australia (Birch 1984), the topazite dykes of Arizona, USA (Kortemeier and Burt 1988), and North Queensland's topazites, Australia (Johnston and Chappell 1992).

Besides greisens and topaz granites, other rocks with topaz include ongonites or topaz rhyolites, probably the volcanic counterparts of topaz granites. Kortemeier and Burt (1988) described ongonite dykes and topazites occurring together. The presence of one or another rock was explained in function of the HF concentration in the dykes. High HF would have favored the exclusive crystallization of quartz + topaz, because the alkalis would partition to the aqueous fluid, while ongonite would crystallize in conditions of low HF. Kortemeier and Burt (1988) concluded that a rock without feldspars and composed fundamentally by quartz can have a low *solidus* temperature, smaller than 650°C, and that topaz can then occur as a *liquidus* phase.

In MGZ, the quartz-topaz rock is always associated with TAG. Considering the hypothesis of magmatic origin, it could be called a topazite and its crystallization could be related to high HF concentrations in the magma. If of metasomatic origin, the Mangabeira quartz-topaz rock is the product of topaz-albite granite extreme greisenization.

CONCLUSIONS

The Main Greisenized Zone (MGZ) of the Paleoproterozoic Mangabeira granitic Massif is composed of two different evolved granite facies (Li-siderophyllite g2d and topaz-albite granites), Sn-mineralized greisens and of a special In-bearing quartz-topaz rock.

The granites distinction can be done on the basis of petrographic and chemical data. The micas study is also fundamental in the characterization of the different types of rocks of MGZ, in which those phylossilicates could be divided in three groups, defining the phengite-zinnwaldite series.

The pink g2d granite is the less evolved granite from g2 family in the area. The topaz-albite granite (TAG) has derived from g2d granite by magmatic differentiation and corresponds to topaz granites described in the literature, which are rare, have uncommon mineralogy and are genetically associated to mineral deposits of the type Sn-W and Ta-Sn. The Mangabeira topaz-albite granite is an example of extreme fractionation from an igneous source. The high F contents facilitated the differentiation until low temperatures and the economic Sn and In concentrations.

The topaz-albite and g2d granites were submitted to strong infiltration metasomatism, caused by the intrusion of the F-rich TAG, resulting in the greisenization of those granites, in the local albitization of g2d granite and in the economic Sn concentration.

An unusual rock described in MGZ is the quartz-topaz rock, composed of quartz, topaz, zinnwaldite, arsenopirite, cassiterite, sulphides, In-minerals and several secondary arsenates. Topaz occurs as submillimetric to millimetric euhedral crystals or as small crystals (30 µm) included in quartz and in the larger topaz crystals. QTR has chemical and petrographic similarities with topazites, described by Eadington and Nashar (1978) as magmatic. However, additional studies are required to corroborate the magmatic hypothesis for the Mangabeira quartz-topaz rock.

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