Sn-POLYMETALLIC DEPOSITS FROM RONDÔNIA TIN PROVINCE AND ITU RAPAKIVI PROVINCE, BRAZIL: FLUID INCLUSIONS AND STABLE-ISOTOPE CONSTRAINTS

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INTRODUCTION

Proterozoic rapakivi granites from Brazil range in age from 1.88 Ga to 0.59 Ga, and are to be found in anorogenic tectonic settings of the Amazonian craton (1.88 - 1.00 Ga) and Tocantins Province (1.77 - 1.55 Ga), and in post-orogenic tectonic settings as those of the Mantiqueira Province (ca. 0.59 Ga) (Dall'Agnol et al., 1999). Important Sn-polymetallic deposits are spatially and temporally associated with some of them. The Rondônia and Pitinga provinces situated in the Amazonian craton are responsible for major Brazilian tin production with a total output of ~500.000 t/Sn in-concentrate.

Despite the progress achieved in the last few years, the magmatic-metallogenetic history of the rapakivi granites from Brazil is far from being fully understood. Many fundamental questions still require answers before serious attempts to elucidate their origin, evolution, and relation with associated mineral deposits can be satisfactorily undertaken. The aim of this work is to give an overview of the present knowledge regarding the metallogeny of selected Sn-polymetallic deposits from Rondônia Tin Province (Amazonian craton) and Itu Rapakivi Province (Mantiqueira Province).

RONDÔNIA TIN PROVINCE (RTP)

According to Bettencourt et al. (1999), seven anorogenic rapakivi granite suites have been distinguished in the RTP (Fig. 1), showing ages between 1.60 Ga and 0.97 Ga.

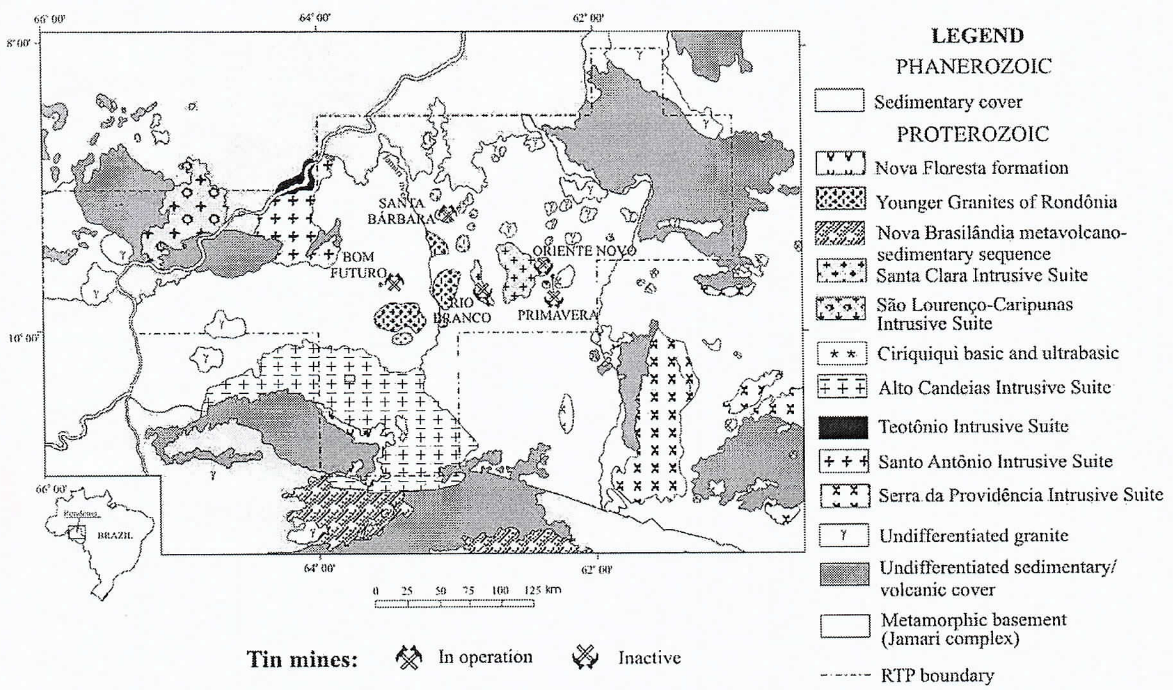

Figure 1. Simplified geological map of the Rondônia Tin Province (RTP) and adjacent areas (after Bettencourt et al., 1999).

Important Sn-polymetallic deposits are associated with at least the three youngest suites: the São Lourenço-Caripunas Intrusive Suite (ca. 1.31 Ga), the Santa Clara Intrusive Suite (1.08 – 1.07 Ga), and the Younger Granites of Rondônia (0.99 – 0.97 Ga). Detailed studies in the Santa Clara Intrusive Suite and Younger Granites of Rondônia have shown that both suites have petrographic, geochemical and metallogenetic similarities (Leite Júnior et al., 2000). These suites are composed of several early, and late-stage intrusions. The early-stage intrusions are dominant in area, exhibit a metaluminous to slightly peraluminous character, and are formed mainly by biotite (± hornblende) monzogranite and syenogranite, showing rapakivi textures. The late-stage intrusions are volumetrically smaller and comprise two compositional rock groups: (1) a metaluminous to peralkaline group composed mainly of hornblende (± pyroxene; ± biotite) alkali-feldspar syenite and microsyenite, trachyandesite and trachyte, as well as biotite (± sodic amphibole) alkali-feldspar microgranite and rhyolite; (2) a peraluminous group formed by biotite alkali-feldspar granite, alaskite, Li-mica (± topaz) alkali-feldspar granite and topaz-bearing rhyolite porphyry (ongonite). The Sn (W, Nb, Ta, Zn, Cu, Pb) deposits are closely associated with these late-stage peraluminous rocks in both suites, such as: Primavera (Sn, Pb), Oriente Novo (Sn, W, Nb, Ta), and Rio Branco (Sn, W, Zn, Cu, Pb) in the Santa Clara Intrusive Suite, and Potosi (Sn, W, Zn, Cu, Pb), Santa Bárbara (Sn, W), and Bom Futuro (Sn, W, Zn, Cu, Pb) in the Younger Granites of Rondônia.

In the first suite, the Sn-polymetallic greisen and vein-type deposits are spatially and temporally associated with biotite-alkali feldspar granite and alaskite, as well as with Li-mica-alkali feldspar granite and rhyolite porphyry (Leite Júnior & Bettencourt, 1995; Leite Júnior, 2002). Major styles of Sn (W, Nb, Ta) mineralization in the Oriente Novo massif can be divided from the oldest to youngest, into three groups: (1) stockwork vein/veinlets of greisen with cassiterite, and of quartz with cassiterite and wolframite hosted within older porphyritic biotite syenogranite; (2) disseminated cassiterite and columbite-tantalite in the Li-mica alkali-feldspar granite with greisen pods with cassiterite; and, (3) sub-parallel vein/ veinlets of greisen bearing cassiterite and of quartz with cassiterite and wolframite, having a general strike of N30-50E, and dipping 50-80 SE. The stockwork mineralization is interpreted to be genetically related to the biotite-alkali feldspar granite and alaskite, whereas the disseminated and sub-parallel vein/veinlets mineralization system, to the Li-mica-alkali feldspar granite and rhyolite porphyry. Both were formed by similar magmatic aqueous-carbonic fluid with minor meteoric hydrothermal water input. Effervescence and greisenization are the principal processes responsible for Sn and W mineralization. Oxygen isotope geothermometry coupled with fluid-inclusion data suggest that mineralization took place between 370 – 240°C, at 2.4 to 1.0 kbar. The $\delta^{18}O_{H2O}$ = (+7.4 to + 8.4 ‰) is consistent with an origin as magmatic fluid that equilibrated with a granitic magma (T=700-650 °C). However the δD_{H2O} of the fluids (-91 to -112 ‰) indicates mixing with meteoric water, with temperature decrease and vapor decompression.

In the Younger Granites of Rondônia, the Santa Bárbara deposit occurs in a 500 x 150 m zone and shows two principal structural types, both hosted by peraluminous siderophyllite-albite-microcline granite: horizontal and lensoid cassiterite-bearing topaz-siderophyllite-quartz greisen bodies, up to 40 m thick, and stockworks of cassiterite-bearing topaz-siderophyllite-quartz greisen veins, and/or of quartz veins and veinlets with cassiterite (± wolframite). Oxygen-isotope geothermometry indicates crystallization temperatures, calculated from the oxygen isotopic composition of mineral pairs, of quartz-pods (570 °C), bedded-greisen (495°C), and greisen-vein (416°C), consistently higher by 46 to 170 °C than fluid inclusion trapping temperatures. The calculated isotopic composition of water in equilibrium with host metasomatites ($\delta^{18}O_{H2O}$ = 3.8 to 10.4‰) is consistent with a magmatic origin for the fluids, exception made to late muscovite ($\delta^{18}O_{H2O}$ = -8.1‰ at 300°C), and late-quartz ($\delta^{18}O_{H2O}$ = -8.2‰ at 250 °C) which suggest mixture with meteoric waters (Sparrenberger & Bettencourt, 2002a, b). Fluid inclusion studies in greisen and quartz veins, from the Bom Futuro deposit, indicate that cassiterite was formed by effervescence processes of an aqueous carbonic fluid characterized by low salinity and density, at homogenization temperatures between 420 and 320°C, and lithostatic pressure of approximately 1 kbar (Souza & Botelho, 2002).

ITU RAPAKIVI PROVINCE (IRP)

The batholiths and stocks of the IRP (Fig. 2) are composed mainly of subalkaline biotite syenogranite and monzogranite, with minor granodiorite, quartz syenite, quartz monzonite, tonalite, quartz diorite, and topaz-bearing granite sometimes spatially associated to mineral deposit as in Itu complex (W), and Correas massif (Sn, W, Zn, Cu, Pb) (Wernick et al., 1997; Goraieb, 2001). The Correas deposit comprises lode/stringer, pods, stockworks (exocontact), and their greisen border encompassing mica-topaz-quartz greisen and mica greisen, accompanied by breccia. The most abundant ore minerals are cassiterite and wolframite, followed by pyrite, sphalerite, and chalcopyrite. Successive phases of fluid evolution are mainly depicted from trapping of heterogeneous fluid inclusions as a result of partial mixing of magmatic and meteoric fluids, in the two-phase subsolvus region of the fluid system under variable pressure. A typical magmatic fluid, partly mixed with meteoric fluids (CO_2 ± CH_4, H_2O, NaCl, KCl, $FeCl_2$; $\delta^{18}O_{quartz}$ = 9.9 to 10.9‰; $\delta^{18}O_{H2O}$ = 4.13 to 6.95‰; $\delta^{18}O_{mica}$ = 4.7 to 5.2‰) was involved in the genesis of this deposit.

The depositional temperatures are in the range of 330 to 460°C, and 210 to 440°C (at pressure conditions from 0.8 to 2.6 kbar) obtained from quartz-cassiterite/quartz-wolframite pair and fluid inclusions, respectively.

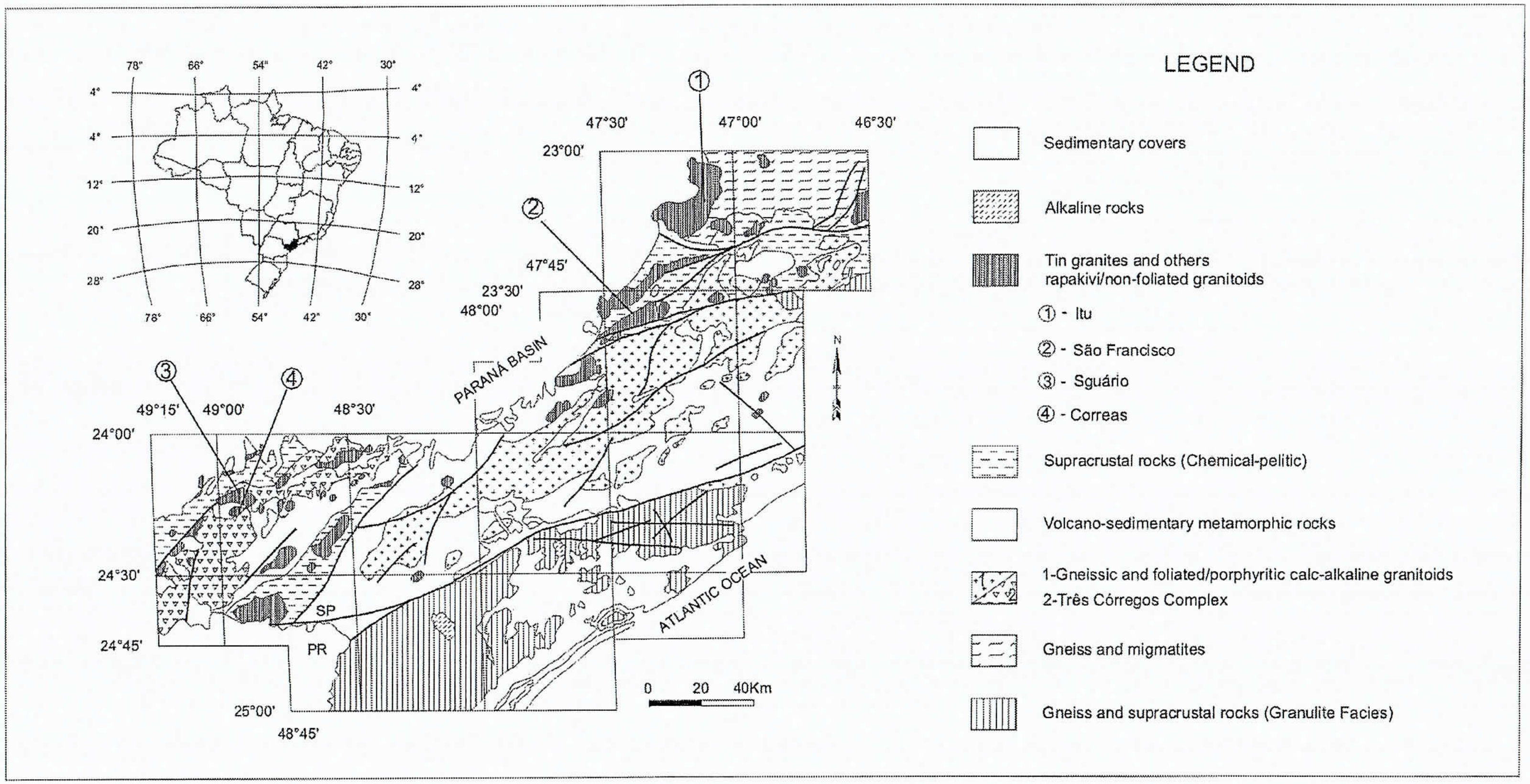

Fig. 2. Simplified geological map of the Ribeira Folf Belt (southeastern part of the State of São Paulo, Brazil) showing the main rapakivi granite massifs (after Goraieb, 2001)

DISCUSSION AND CONCLUSIONS

The tectonic settings are of importance for the formation of the mineralized granites: 1- post-collisional setting (e.g. IRP), and 2- anorogenic setting (e.g. RTP). All the tin-bearing granites are Neoproterozoic in age (1.31 to 0.59 Ga). In the (RTP), the intrusions that hosts rare-metal mineralization are highly evolved A-type, P-poor reduced peraluminous granites, whereas in the Correas massif (IRP) they are slightly peraluminous A-type transitional or mixed I-A-type granites. In both provinces the rare-metal mineralization is closely related to strongly fractionated peraluminous granites characterized by high values of SiO_2, FeO/FeO+MgO and Ga/Al ratios, F, Li, Rb, Ga, Sn, Ta, Nb, U, and Th, and low Mg, Ti, Ba, Sr, Eu. These studied granites show similarities and geochemical features to those of rare-metal peraluminous granites (Pollard, 1989).

The Correas and Oriente Novo deposits show the predominance of two fluids, which could be derived from a common late-stage parental magmatic hydrothermal fluid phase, which was separated into two immiscible fluids involving mixture-immiscibility and progressive decrease in temperatures. The data suggest that the mineralization in these deposits occurred at temperatures variable from 240 to 400°C under peak fluid pressures between 0.8 to 2.6 kbar. In the Santa Bárbara a quasi-continuous fluid evolution is depicted from an initial immiscible closed system (T=390 to 400 °C), which changed into a immiscible system (T=350-370 °C). The overall evolution of the fluid system, accompanied by immiscibility at lower temperatures, is represented by primary fluid inclusions from bedded greisen (T=350-370°C, at P~200 bar), and topaz-siderite-quartz greisen (T=350-370°C, at P variable from 200 to 250 bar. These suggest peak-fluid pressures during hydrothermal activities, at the post-magmatic late-stage of the deposit, between hydrostatic and near hydrostatic. The late fluid-type is either low-salinity or high-salinity low-temperature Ca-enriched solutions.

A typical magmatic fluid partly mixed with meteoric water is largely confirmed, in all deposits, by oxygen and hydrogen stable isotope studies. Hydrofracturing, boiling, immiscibility and greisenization, and loss of CO_2 (CH_4) with falling temperature, are the principal processes responsible for Sn-W deposition.

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