Sn-polymetallic deposits associated with Proterozoic rapakivi granites from Rondônia Tin Province and Itu Rapakivi Province, Brazil

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1. Introduction

Proterozoic rapakivi granites of Brazil range in age from 1.88 Ga to 0.59 Ga, and are 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 (~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 in the Amazonian craton are responsible for major Brazilian tin production with a total output of 400,000 t/Sn in-concentrate.

Despite the progress achieved in the last few years, the magmatic-metallogenic 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 present a comparative study between selected Sn-polymetallic deposits from Rondônia Tin Province (Amazonian craton) and Itu Rapakivi Province (Mantiqueira Province).

2. Rondônia Tin Province (RTP)

According to Bettencourt et al., (1999), seven an-orogenic rapakivi granite suites, with ages between 1.60 and 0.97 Ga, have been distinguished in the RTP (Fig. 1). Important Sn-polymetallic deposits are asso-

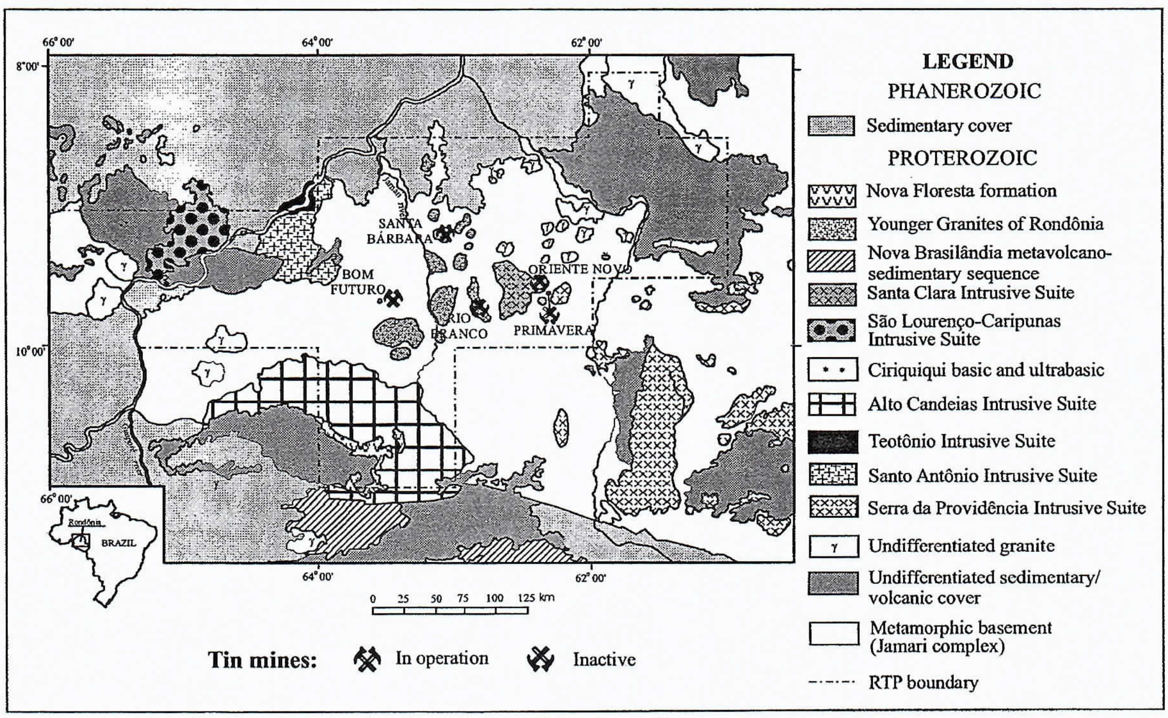

Fig.1. Simplified geological map of the Rôndonia Tin Province (RTP) and adjacent areas (modified after Bettencourt et al., 1999)

ciated with at least the three youngest suites: the São Lourenço-Caripunas Intrusive Suite (~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 (SISC) and Younger Granites of Rondônia (YGR) have shown that both suites have petrographic, geochemical and metallogenic similarities (Leite Júnior et al., 2000). These suites are composed of several early and late-stage intrusions. The early-stage intrusions are dominant, 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 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; and (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 SISC, and Potosi (Sn, W, Zn, Cu, Pb), Santa Bárbara (Sn, W), and Bom Futuro (Sn, W, Zn, Cu, Pb) in the YGR.

In the SISC, Sn-polymetallic deposits comprise magmatic cassiterite and columbite-tantalite disseminated in the Li-mica alkali-feldspar granite, greisen pods (endogreisen), veins and lenses with cassiterite, quartz veins and veinlets with cassiterite and wolframite, and quartz veinlets with sphalerite, chalcopyrite, galena, pyrite, marcasite, and pyrrhotite. The greisen and quartz veins and veinlets constitute stockwork and subparallel systems, and subparallel and subhorizontal greisen lens systems are also observed. At least two hydrothermal phases of oxide mineralization are recognized. The early phase is interpreted to be related to the biotite alkali-feldspar granite and alaskite, whereas the late phase is thought to be related 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, that occurred between 370–240 °C, and 2.4–1.0 kbar.

In the YGR, the Santa Bárbara deposit covers a 500 m by 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 temperatures of 500 °C for the bed-like greisen bodies, and 400 °C for the cassiterite-quartz veins. 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, save for late phengite ($\delta^{18}O_{H2O}$ = -8.1 ‰ at 300 °C) and quartz (II) ($\delta^{18}O_{H2O}$ = -8.2 ‰ at 250 °C) which suggest mixture with meteoric waters (Sparrenberger and Bettencourt, 2002a, b). In the Bom Futuro deposit, two domains have been observed: the Palanqueta stock (cupola) in which greisen bodies with pyrite, chalcopyrite, bornite, sphalerite, galena, cassiterite, and wolframite are hosted mainly by topaz-bearing Li-mica-albite granite, and the Bom Futuro hill in which pegmatite and quartz veins with topaz, cassiterite, sphalerite, galena, chalcopyrite, and pyrite are disposed mainly in a ring pattern, and spatially associated with breccia pipe, microsyenite, syenite porphyry, and topaz-bearing granite and rhyolite porphyry dykes (Villanova and Franke, 1995; Silva et al., 1995, 1997; Leite Júnior, 2002; Souza and Botelho, 2002). Fluid inclusion studies in greisen and quartz veins 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 and Botelho, 2002).

3. Itu Rapakivi Province (IRP)

The batholiths and stocks of the IRP (Fig. 2) are mainly composed 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 the Itu complex (W) and the 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 ‰;

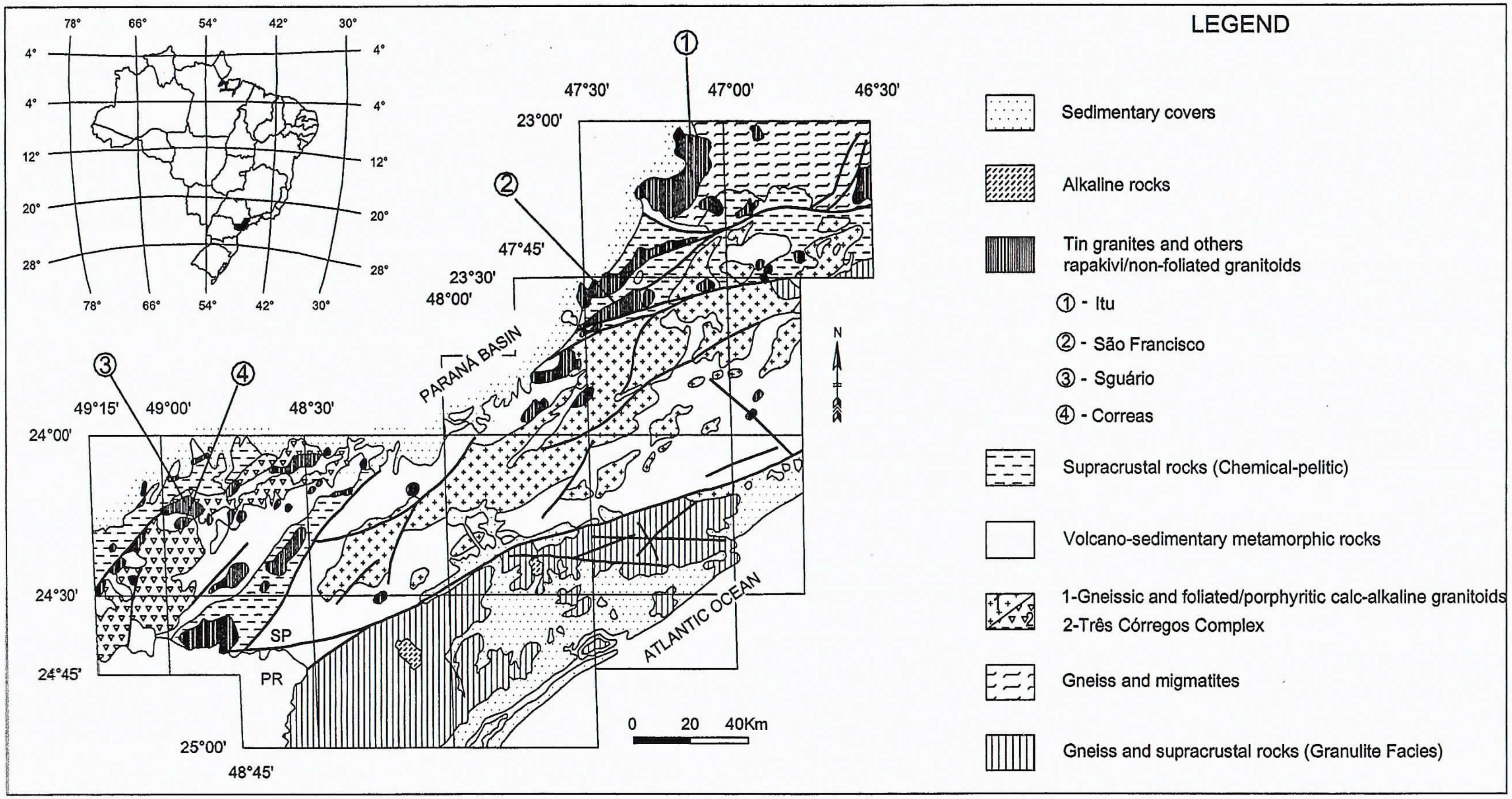

Fig. 2. Simplified geological map of the Ribeira Fold Belt (southeastern part of the State of São Paulo, Brazil) showing the main rapakivi granite massifs (after Goraieb, 2001).

$\delta^{18}O_{H2O}$ = 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 were in the range of 330 to 460 °C and 210 to 440 °C (at 0.8 to 2.6 kbar), as deduced from quartz-cassiterite/quartz-wolframite pair and fluid inclusions, respectively.

4. Main similarities and contrasting features

- 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) and highly evolved.
- In the RTP deposits, topaz-granites and rhyolites are associated with syenite and peralkaline granites, whereas in the IRP the deposits are rarely associated with volcanic and basic members.
- In both provinces the tin-bearing granite hosts are characterized by high values of SiO_2 and F, incompatible lithophile elements, and rare-metals such as Nb, Ta, Sb, W, thus being compatible with the low P_2O_5 topaz-granite sub-type of Taylor's 1992 classification.
- Differences in morphologic-genetical types of tin-deposits might reflect the erosion level prevailing in each province or mining district, and depths of magma emplacement, mainly based on detailed mining geology and fluid inclusions.
- Mineralization is dominantly stanniferous.
- The early magmatic fluids are rich in CO_2 and CH_4 and show moderate salinities, later fluids are generally water rich and less saline, even though in some deposits moderate salinities are observed. These results suggest mixing of meteoric and magmatic fluids, and effervescense processes.
- Variation in oxidation state of the fluids may be consistent with the lack of sulphide in Santa Bárbara, the common occurrence in Correas deposit, and less amounts in Oriente Novo and Rio Branco. Also the presence of sulphide at shallow levels may reflect the influence of near-surface processes or enhanced magmatic degassing.

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