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The Correas massif and associated greisen-hosted tin-tungsten mineralization, State of São Paulo, southeastern Brazil

C.I. Goraieb[1] and J.S. Bettencourt[2]

(1) Institute for Technological Research of São Paulo State, Brazil, (2) Institute of Geosciences, University of São Paulo, São Paulo, SP, 05422-970, Brazil

The Correas massif is a small (5 km^2) granite pluton which is located at the southwestern part of the State of São Paulo, southeastern Brazil, emplaced into medium-grade Proterozoic supracrustal metamorphic rocks of the Ribeira Fold Belt, intruding the Itu Belt[1] and/or the Itu Rapakivi Province[2].

The lack of foliation, emplacement relationship with host-rocks and age (whole-rock Rb-Sr age is 603 ± 7 Ma; Ri=0.7228 ± 0.0057, MSWD=1.21) indicate post-orogenic nature for this pluton. The high uncertainty of the Sr initial ratio can be explained by the low dispersion and high $^{87}Rb/^{86}Sr$ values of the analyzed samples (albite granite). The massif is highly differentiated and together with several other Neoproterozoic post-tectonic and anorogenic granitoids with rapakivi characteristics, represents a late silicic magmatic episode of the Brasiliano Orogenic Cycle (0.8 - 0.5 Ga).

The granitic rocks of the Correas massif are characterized by high SiO_2 (72.28 - 75.70%) and K_2O (4.55 - 5.68%), as well as low CaO (4.55 - 5.68%), FeO (0.53 - 1.60%), MgO (0.03 - 0.25%) and TiO_2 (0.03 - 0.14%). They also exhibit high Sn, F, Li, and Rb contents, strong negative Eu anomalies (0.8 - 0.44 ppm) and high $^{87}Sr/^{86}Sr$ ratio (0.7228 ± 0.0057), features that indicate a geochemical fractionation trend typical of tin-bearing granites.

Four main lithofacies are recognized in the massif: biotite granite, biotite-muscovite granite, microgranite and topaz-muscovite-albite granite, that have subalkalic and metaluminous to weakly peraluminous A-type geochemical signatures.

The upper contact of the stock is marked by the development of a marginal barren pegmatite, composed of topaz, quartz, feldspar and Li-mica crystals, interlayered with fine-grained granite. A vertical zoning is also observed through the late stage fine-grained porphyritic, granophyric and pegmatitic rocks within small cupolas, grading downwards into medium to coarse-grained granitic rocks. This vertical textural zoning indicates an important concentration of volatiles and ore elements in the roof of the rare metal-bearing plutons from the earliest stages of crystallization[3].

Different types of late to post-magmatic hydrothermal alteration affected the intrusive body and the host rocks as well. Microclinization, albitization and greisenization processes were identified in most of the studied granitic facies, except in the albite granite, which was only affected by greisenization. In the host rocks, greisenization is the main hydrothermal process observed.

In the northeastern albite granite exocontact, an extensive greisenization resulted in several greisen bodies, mineralized in cassiterite and wolframite, also containing sulphide minerals such as sphalerite, chalcopyrite and pyrite. These greisenized and mineralized rocks constitute a small primary deposit with high economic grade values.

The mineralization seems to be spatially and genetically related to the topaz-rich muscovite-albite granite end-member. Albite granite apophysis occurs cutting cassiterite-topaz greisen bodies developed within host rocks, as greisen veins also cut the albite granite. Such evidence suggests the coexistence of an immiscible fluid phase extracting tin from the Na and F-rich residual melt. This hypothesis is reinforced by depletion of tin content in the albite granite, if compared with the less fractionated facies of the stock, as well as the K-Ar age (593 ± 13 Ma) obtained in greisen from the primary deposit, which is very close to the whole rock Rb-Sr isochron (603 ± 7 Ma) of the albite granite.

Fluid inclusions data from quartz stockwork, topaz-quartz greisen and topaz greisen indicate the presence of two distinct inclusion types: (1) CO_2-rich inclusions with variable phase ratios V_{CO2}/V_{H2O} (10-90%), consisting of CO_2±CH_4-H_2O-$FeCl_2$-NaCl, with salinity ranging from 2 to 13% eq.NaCl and homogenization temperatures ranging from 410 to 250°C; (2) aqueous-rich inclusions with constant gas/liquid volume ratios (15%), showing lower homogenization temperatures (260 to 110°C), high variable salinity (1 to 20% eq.NaCl), and an aqueous solution composed by H_2O-$FeCl_2$-$CaCl_2$-NaCl. These results indicate that boiling and mixing of meteoric water may have occurred during trapping of immiscible fluids from a heterogeneous system.

The origin of the Sn-W mineralization can be related to the following stages:

(a) fluorine and tin-rich magma intrusion in a geologic/geotectonic environment favorable to a magmatic evolution marked by strong differentiation (fractional crystallization of feldspar, mica and accessory phases);

(b) enrichment and preconcentration of volatiles and metallic elements during magmatic/late-magmatic stages of crystallization;
(c) development of an immiscible aqueous fluid phase with low viscosity, silica and volatile rich, coexisting with a Na and F-rich residual melt (hydrothermal concentration);
(d) migration of enriched fluids throughout structural discontinuities, causing fissural hydrothermal alteration and propitiating pervasive hydrothermal alteration in low permeability host-rock zones (siliceous buffers, lithic contacts, etc.).

Fracturing followed by boiling, probably as result of hydraulic overpressure, must have been an important ore deposition mechanism. Immiscibility of compounds initially present in the fluid phase would be responsible for the origin of two distinct separated phases, one essentially constituted by volatile elements, and the residual aqueous-rich phase. Increase in concentration, pH and fO_2 of the aqueous phase would result from this process.

Additionally, mixing of water from dehydration of host-rocks and/or meteoric water would introduce a new aqueous phase in the hydrothermal system, changing the physical and chemical conditions, especially salinity fluctuation, abrupt decrease in temperature, instability of complexes and decrease in solubility, favoring silica, topaz, cassiterite and wolframite precipitation.

Further studies are required in order to constrain the metallogenetic model for the Correas deposit. However, the data and results already obtained give support to the proposed preliminary model, which is of great importance to the tin exploration models for the southeastern Brazil.

References

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