Porphyry or Not Porphyry: That´s Not The Only Question

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Abstract

Tapajós (PA) and Alta Floresta (MT) gold areas form one large (1,900 km long and 280 km wide) Paleoproterozoic gold province named Tapajós – Alta Floresta Gold Province (TAFGP). Gold deposits from the TAFPG are divided into two major groups: (1) Epithermal and pluton-related high grade quartz vein deposits ±(Zn-Pb-Cu-Fe) with restricted sericite, chorite and carbonate alteration; and (2) Low grade disseminated deposits ±(Ag-Bi-Te-Pb-Zn) with "phyllic" fault-controlled alteration (muscovite-quartz-pyrite) and strong to moderate silicification. Early k-feldspar alteration is pervasive and not related to gold grades. TAFGP deposits are not porphyry-type or intrusion related *strictu sensu* gold deposits. Additionally, TAFGP gold deposits are not related to subdution zones. Seismic thomography revealed that the TAFGP sits over a rifted SCLM keel (Amazon archean craton). TAFGP gold deposits represent a new type of gold mineralization related to intracratonic A-type volcanic-subvolcanic-plutonic system generated by large underplate-plume Paleoproterozoic event.

Introduction

The Tapajós and Alta Floresta regions are responsible for the majority of the Brazil´s recent gold production. Despite of the mineral importance of the area basic geological and geochronological knowledge is still poorly developed. Several different deposit types have been inaccurately described at the TAFGP (e.g. porphyry, epithermal, orogenic, intrusion, related). Part of the difficulty of classifying such deposits comes from the complexity and uncertainties of classical definitions. For example, defining an orogenic gold system requires a previous definition of the regional geotectonic setting. Although a correct categorization of TAFGP mineral deposits may be fundamental for both scientific and industry communities, it should be considered that currently known deposit models may not meet particular characteristics and features of the TAFGP. Thus, the need to use current models may be hindering the identification of new gold deposit types at the TAFGP.

It is undeniable that recent academic studies conducted on the TAFGP deposits have contributed to advance on the understanding of the gold and polymetallic veins province. However, operational difficulties of working on the Amazon region together with the lack of good exposures contribute to the absence of major mineral discoveries. Most of the scientific and exploration work carried out in the area is limited to high grade artisanal mining sites. This fact can explain the large amount of vein-hosted deposits described when compared to documented disseminated low grade mineralization. The characterization of V3 in Tapajós as high sulfidation epithermal deposit by Juliani (2002) opens new possibilities for the understanding of the TAFGP mineralizations. The characterization of porphyry copper deposits in the TAFGP followed, almost compulsorily, this epithermal definition (Jacobi 1999, Juliani *et al.* 2014). This work provides a review of the mineralization characteristics and proposes a distinct interpretation for the TAFGP deposits.

Tapajós-Alta Floresta Gold Province (TAFGP)

Biondi (2003) understands that Tapajós (PA), Alta Floresta (MT), Uaimiri (AM) and Parima (RR) gold areas are one large (1,900 km long and 280 km wide) metallogenetic and petrologic

provinces with different ages. In the Tapajós region, three main types of gold mineralization can be described: (1) Compressional shear veins associated to the Jacareacanga and Cuiú-Cuiú units with restrict sericite, carbonate and chlorite alterations (Espírito Santo, Bom Jesus, Pepeu, Chico Torres, Jerimum de Cima). These mineralizations are not considered as orogenic gold type (Assunção and Klein 2014), althought Jacareacanga and Cuiú-Cuiú units seems to be related to orogenic events; (2) Extentional epithermal high grade quartz veins with comb texture and adularia indistinctly hosted by the three plutonic-volcanic sequences: Creporizão-Riozinho, (2,000 to 1,968 My), Parauarí-Moraes de Almeida, (1,898 to 1,880 My) and Maloquinha-Iriri (1,890 to 1,864 My) (e.g. Carneirinho, Goiano, Pison, Abacaxis); and (3) High sulfidation low grade gold deposits (e.g. V3). Two gold mineralizing events have been documented (1.95 and 1.88 Gy, Assunção and Klein 2014). The youngest is probably related to the calc-alkaline Parauari (± alkaline Maloquinha) granitoid suite (Coutinho 2008).

In the Alta Floresta region, gold mineralization shows the same characteristics of those in the Tapajós area, except by slightly younger ages (1,70 Gy, Xavier et al., 2013). There are two main types of gold mineralization in the Alta Floresta area: (1) Small disseminated and structurally-controlled Au ± Cu -(Bi, Te, Ag, Mo) deposits associated to pervasive silicification and sulphidation; and (2) Structurally-controlled vein-type Au + Zn + Pb ± Cu deposits. Both deposit types are hosted in oxidized I-type, calc-alkaline to sub-alkaline, medium to high K, metalluminous to slightly peralluminous granites (Assis 2015). Additionally, Serrinha and Juruena deposits have been considered as porphyry type sited in volcanic arc setting (**Figure 01**).

Geotectonics of the Tapajós – Alta Floresta Gold Province

Seismic tomography (Assumpção *et al.* 2013) revealed that the Central Amazon Province is located over thick (>150 km) lithospheric keel. Conversely, the TAFGP occurs where seismic velocities (v_p) attenuate at depths of less than 100 km indicating the presence of a thinner lithosphere. TAFGP mineralization is hosted by Creporizão, Parauari, Maloquinha, Iriri, Matupá, Nhandú, Juruena, Paranaíta, Colider plutonic-volcanic sequences. They cover an area of approximately two million km^2 forming an extensive intra-continental anorogenic magmatic event. The Amazon keel show evidences of deep fertilization and to have been rheologically weakened during the Paleoproterozoic, allowing infiltration of magma and hydrothermal fluids at the edge of the Amazon Craton. The TAFGP geological framework seems to be a consequence of intracratonic magma underplating not related to the formation of convergent margin plate. Although Juliani (2014) considered that the TAFGP would have evolved under a continental arc setting during the Paleoproterozoic, we consider that TAFGP is the result of an intra-continental magmatism at the edge of a rifted SCLM keel. The large majority of felsic magmas, and its huge volume (2000 km^2), can be explained by a megaplume impact.

Is it Porphyry, Is It Not Porphyry?

The mineralization described in Alta Floresta and Tapajós as porphyry-type (Moura 1998; Juliani *et al.* 2014) does not fit in any conventional style of magmatic-hydrothermal disseminated gold deposits. This should not be an exploration concern as the discovery of new types of mineral deposits is possible to happen at any time. As a distinct feature of the porphyry-type deposits, we can mention: (1) The absence mineralized sinuous A-type veins; (2) Au mineralization is hosted in magnetite-destructive pyrite-rich phyllic alteration rather

than in magnetite-constructive pyrite-poor potassic alteration; (3) Pphyllic alteration is carbonate-rich and is not associated to D-type veins; (4) The precense of spiky high gold grades instead of long and sustained low grade intersections; (5) No sulphates are present (anhydrite, gypsum); (6) Some of the mentioned deposits do not show porphyry type fluid inclusion (>25% NaCl); and (7) Fluids are $C0_2$ rich (Espada 2015).

Disseminated gold mineralization from Alta Floresta region displays strong phyllic alteration envelope (sericite+quartz+pyrite) spatially and genetically related to acid porphyritic dykes. This intrusive rocks display granophyric texture indicating that their emplacement occurred at shallow crustal levels. TAFGP deposits show three main differences from typical porphyry-type gold mineralization: (1) Geotectonic setting in which they are located; (2) Type and sources of magmas; and (3) Volcanism dynamics. Fluids responsible for the formation of gold and pollymetalic mineralization at Alta Floresta were exsolved form underplated magmas on a rifted cratonic margin, more likely associated to a megaplume impact than to slab subduction. This may be the reason for the absence of calc-alkaline granites and low base metal endowment. The initial metallic content of magmas is directly related to their source and to processes such as metasomatism of the mantle by subducted ocean plate, mantle partial melting, fractionation and assimilation. Metal partition towards fluid phase depends on factors such as oxigen fugacity and magma composition. Volatile rich fluids are necessary for efficient metal transport, hydraulic brecciation and hydrothermal alteration. The sum of factors such as enriched sources, efficient metallic concentration, transport and deposition conditions are essential for the formation of world class deposits. Some of these factors were not identified in the TAFGP.

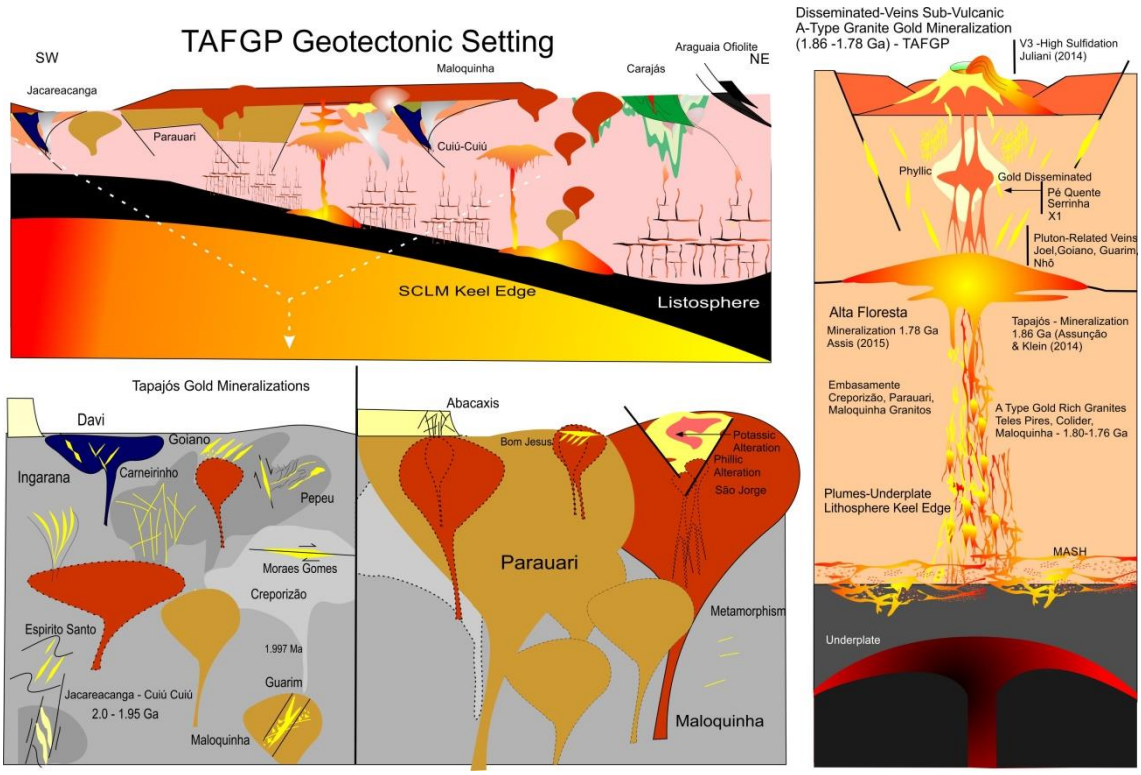

Figure 01: Geotectonic setting of the TAFGP and gold mineralization styles.

Conclusion

Discussions about formation conditions of a large mineral province such as the TAFGP may not be restricted to mineral deposit typology or whether classical porphyry-type mineralization is present or not. Nonetheless, recognizing regional and local control of the mineralization, as well as their specificities regarding the current models, may bring a sound contribution to the ongoing exploration programs. On the other hand, metallic endowment is directly related to mantle-crustal scale geological processes. Defining which geotectonic process was responsible for the formation of the TAFGP has a direct impact on the selection of exploration strategies and new mineral discoveries. We conclude that the TAFGP mineralizing fluids originated from magmas generate by underplate in thick SCLM keel rifting. There is no evidence for oceanic plate subduction during the TAFGP mineralizing events (1.88 and 1.78 Ga). The several small gold deposits (<2 million ounces) from the TAFGP should be considered to represent a new deposit type. The gold deposits from the TAFGP has the following characteristics: (1) Disseminated gold in phyllic alteration envelope, associated to acid subvolcanic dikes and plugs; (2) Massive quartz veins and stockworks with epizonal to mesozonal tectonic fabrics and restrict wall rock alteration ±(adularia, sericite, k-feldspar, chlorite); and (3) Spatial and temporal association to A-type granites. The gold system from the TAFGP is not related to neither subduction processes (Porphyry-type) nor S-type granites (Intrusion related).

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