THE DISCOVERY OF EPITHERMAL Au-Cu-Mo PROTEROZOIC DEPOSITS IN THE TAPAJOS PROVINCE, BRAZIL

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INTRODUCTION Following a simple principle that a world class deposit should have a world class signature, in 1997 the author and a group of Rio Tinto exploration geologists selected five outstanding gold bearing structural-anatomical anomalies on the Tapajos Province, the Amazon region, northern Brazil. This simple procedure triggered the discovery of several Au-Cu-Mo-Ag mineralized Proterozoic epithermal deposits. The first discovery was a large, low-grade epithermal gold deposit called V3.

THE TAPAJOS PROVINCE Tapajos is amongst the largest gold provinces in Brazil. The region is producing gold since 1958. More than 90% of the gold was extracted from thousands of alluvial deposits spread over large areas. A significant number of alluvial districts have produced more than 3Moz of gold during their mining history. Garimpos like Cuiú-Cuiú, Canta-Galo, Abacaxis, and Patrocínio are classical examples of quite large sedimentary systems. Alluvial gold deposits are scattered everywhere over a large area in the province. In spite of being a world class, gold producing region, mineral exploration efforts started only at the beginning of the 90's and not a single medium to large sized primary gold deposit was known to occur before. The abundance of gold-bearing alluvial deposits make it very difficult for geologists to believe that they result from the erosion of former primary deposits. Lack of basic and reliable geological maps, geophysical, geochemical and exploration data contributed to the absence of important primary discoveries in the Tapajos.

Regional geology The Tapajos Province is situated in Central Amazon and is a part of the large Amazon Craton. In the North, it is bounded by the Arariboia Basin near the town of Itaituba, and in the South by the Cachimbo Graben. The main rock units of the Province are attributed to events that took place during the Archaean, Proterozoic, and Phanerozoic. Archaean rocks are represented by a few preserved supracrustals. Proterozoic rocks are represented by a huge volume of anorogenic granites and co-magmatic lava flows and pyroclastic rocks belonging to the Uatumá Supergroup. Subordinate granites are formed in shallow environments, intruding the Paleozoic/Mesozoic sedimentary rocks of the large intracontinental Amazon Basin and to the Cachimbo Graben. Phanerozoic units belong to the Paleozoic/Mesozoic sedimentary rocks of the large intracratonic Amazon Basin and to the Cachimbo Graben.

The main Proterozoic felsic rocks comprise the Paraúara granitoids, the Iriri volcanics and late stage granitic intrusions. The Paraúara granitoids (1961, apatite Bezzera et al. 1991), subordinant granites intruded sedimentary rocks and mafic, sometimes layered intrusions. Phanerozoic units belong to the Paleozoic/Mesozoic sedimentary rocks of the large intracratonic Amazon Basin and to the Cachimbo Graben. The Tapajos epithermal systems

THE V3 DISCOVERY The V3 target sustains a hill that is 300 m above the surrounding topography. The V3 area is part of a large alluvial deposit known as V3. The V3 epithermal system occurs near the rim of a large collapsed caldera filled with volcanics and sediments, a structure that has never been described before in the Province. Like other epithermal/orogenic gold deposits, V3 has a conspicuous chemical fingerprint. The most important elements are Au, Cu, Ag, Mo, Zn, Pb, As, Bi, Sn, Au, and Cu, thus playing an important role in the Tapajos Province mineral economy. No major thermal metamorphism affected the Tapajos Proterozoic units.

The V3 discovery V3 is a large epithermal system containing gold and traces of copper, and lead to the discovery of more than five additional mineralized similar systems in the Tapajos Province. The discovery of V3 started by selecting a conspicuous NE-SW structure almost 5 km long, almost alluvial occurrences for field investigation. Preliminary exploration consisted of geological mapping and soil geochemistry. At a first interpretation, the results were disappointing because a few samples from a large grid were anomalous in gold. This fact led to consider the area as of lower potential. However, one unaltered sample of rock changed the whole exploration strategy. The sample consisted of a gossan-like, mica-rich rock that, tested by panning, in the bush yield more than 2 g/t of Au. The soils near the sample's site just yield background values. A decision was taken to review the area to better understand the discrepancy. During the subsequent follow-up, a large outcrop of a quartz-pyrite, pyrrhotite-pyrite Au-bearing acid breccia was found. The higher Au values occurred in goethite gossan fragments of the soil's coarser fraction, the -80 mesh fraction being barren.

These results determined to change the sampling procedure and bulk soil analysis resulted in the outlining of a wide soil anomaly where previous sampling did not have any success. Subsequent detailed mapping evidenced a large volcanic center containing silicified, brecciated, intensely altered, and sulfide-rich rocks, becoming the first gold-copper-silver Proterozoic epithermal deposit of the Province.

GEOLOGY AND MINERALIZATION OF THE V3 EPITHERMAL SYSTEM The V3 target sustains a hill that is 300 m above the local regional surface, a feature that also occurs in the other epithermal deposits discovered in the Province. The topographic anomaly is due to the intense silicification of the upper portion of the volcanic centers by hydrothermal acid leaching and destruction of most of the pre-existing minerals and forming a characteristic paragenesis. The interaction between hydrothermal fluids and meteoric water caused the precipitation of a widespread siliceous zone. Silica sealed the fractures and open spaces of the volcanic/pyroclastic pile trapping the remaining hydrothermal solutions underneath the silicified horizon. Latter volatiles and fluids developed several stages of brecciation and stockwork. The silicified upper portion is also characterized by the abundance of gold-bearing breccias filled with quartz, hematite, carbonate, and sulfides. These volcanic centers are likely related to deep porphyry intrusions, as interpreted in figure 1.

The deposits frequently originate a conspicuous U/K anomaly, reflecting the intense hydrothermal alteration. On the other hand, alteration destroyed the original magnetite resulting in weakly or non-magnetic core. Altered rocks are mainly rhizohylt and dactile flows and lapilli and ash-flow tuffs. Amigdaloidal andesite and dacite flows and tuffs, as well as sedimentary rocks, in spite of frequent are not related to the mineralization event. Deposits such as the V3, as well as its similar V6 formed in a very shallow environment, near the Proterozoic land surface. Their preservation is due to the silica-rich capping, or to the sedimentary cover that resisted to erosion during later uplift of the region.

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Hydrothermal alteration styles The Tapajos epithermal systems are characterized by a widespread and intense multistage hydrothermal alteration that resulted from fluid percolation through a dense array of stockworks. Argillic to advanced argillic alteration is followed by a phyllic alteration that resulted from fluid percolation through a widespread siliceous zone. Silica sealed the fractures and open spaces of the volcanic/pyroclastic pile trapping the remaining hydrothermal solutions underneath the silicified horizon. Latter volatiles and fluids developed several stages of brecciation and stockwork. The silicified upper portion is also characterized by the abundance of gold-bearing breccias filled with quartz, hematite, carbonate, and sulfides. These volcanic centers are likely related to deep porphyry intrusions, as interpreted in figure 1.
Figure 1 - Sketch section of the V3 epithermal deposit.

**SULFIDE-SILICA-PYROPHYLITE RICH BRECCIAS** These breccias (Fig. 3) occur underneath the hematite-bearing breccias after a few-meters transition zone, and are characterized by an intense silicification and sulfidation of the clasts. After initial sealing, late stage fluids broke trough the rock developing a typical crackle breccia with unusual amounts of gold and some silver. Pyrite (10-60%) occurs disseminated as individual crystals, blebs, and fine-grained masses. Other minerals comprise andalusite, ilmenite, chalcocite, covellite, and rare rutile, apatite and chalcopyrite.

Most of the epithermal deposits of the Tapajos Province occur within a volcanic center with a core made up of brecciated and intensely hydrothermally altered quartz porphyry. The core is rimmed by ash flow tuffs and ignimbrites frequently brecciated and altered. Dacite and andesite flows and pyroclastics are widespread in the region but are unrelated to the mineralized volcanics.

**SEDIMENTARY ROCKS** The volcanic pile frequently contains intercalations of Proterozoic sedimentary rocks. These comprise arkoses and sandstones, such as those of the V6 target and likely represent intra-crater sedimentary fades. However, the relationships between some of these rocks and the underlying volcanics are difficult to determine. Sedimentary units may host copper-gold mineralization.

**GRANITOIDS** Red granites and gray granodiorites constitute the "basement" of most volcanic centers. These rocks have been eroded and appear to be unconformably capped by the ash flow tuffs. Red granite intrusions may have porphyry-like texture and potassic alteration consisting of an assemblage of quartz, K-feldspar, chlorite, and green mica in general restricted to fracture selvages. Veinlets of K-feldspar and masses of chlorite probably formed after biotite represent the alteration style in V6. Fluorite and calcite in fracture fillings are interpreted as the result of the circulation of late-stage hydrothermal fluids. So far, not a single typical porphyry intrusion was detected in association with one of these shallow epithermal systems.

**MINERALIZATION** Until today the Tapajos epithermal deposits were not properly tested. Just a few were drilled by Rio Tinto. Economic concentrations of Au, Cu, Ag, and Mo were found in at least three (V3, V6, and V7) volcanic centers. Other targets as V4, V8, V9,
VI2 and VI3, have, so far, not been detailed. Apparently, these targets group into two categories of deposits. The V3-type, which has economic grades of Au-Ag and sub-economic grades of Cu, Zn, and Mo, and the V6-type, a low-grade Cu deposit with Mo, Au and Ag as by-products. Galena and sphalerite were recorded as rare dissemination. Data about grade and tonnage of both types are not available for publication yet.

The main gold and copper reserves of these targets are supergene. The primary Tapajos deposits underwent deep rain forest weathering during the Cenozoic, developing a large Cu-Au-Ag rich supergene blanket.

At V3, the blanket is sub-horizontal and sustains the topography roughly at an altitude of 300 m. The primary mineralization was intersected in the deeper portions of the volcanic center and correlates well with the pyrite-rich zones. Estimated reserve is larger than 100 Mt of low-grade ore that may be mined as an open-pit as soon as infrastructure and prices rise to profitable levels.

At V6, a chalcocite rich blanket was developed. However, this target differs from V3 in its prevailing potassic alteration, lesser amounts of pyrite, lower gold grades, and higher Cu and Mo grades. The V6 chalcolite supergene enrichment zone is a classic example of oxidation of primary disseminated Cu-sulfide deposit. From the surface to deeper levels, the supergene blanket consists of an iron oxide rich zone overlying a copper-rich zone. Primary sulfides include chalcopyrite, pyrite, rare galena, and sphalerite. Molibdenite was not recorded during the early exploration stages, but soil geochemistry indicate sub-economic to economic grades of the metal within areas that do not coincide with the main copper anomaly.

**CONCLUSIONS**

The Tapajos epithermal deposits have several features in common to the Proterozoic Iron oxide-Cu-Au deposits such as Olympic Dam, as described by Roberts and Hudson (1983), Einaudi and Oreskes (1990), Hauck (1990), Oreskes and Einaudi (1990), and Reeve et al. (1990). The most important features are:

- the geochemical fingerprint: Au, Cu, Ag, Pb and As, Mo, Bi, Sb, Y, La, Zr, Ba, U, REE and Te, age(LSGa),
- geological control by major intracratonic extensional structures, the considerable volume of hematite-bearing breccias, alkaline affinity of the volcanic rocks, hydrothermal alteration styles, and proximity to a magnetic, deeper source.

The V3 target has also similarities to other iron oxide epithermal deposits as Igarape Bahia, Candelaria, and Ernest Henry. Its discovery opens completely new horizons for the exploration of other large epithermal Au deposits in the Tapajos Province, as well as in the Amazon region. It is the author's feeling that some will be mined in the forthcoming decade. It also clearly renews the economic potential of some Brazilian areas that have not merited reliable basic mapping and proper geochemical and geophysical exploration.

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**References**


NOTÍCIAS

SÍTIOS GEOLÓGICOS E PALEONTOLOGÍCOS DO BRASIL

O Brasil e signatário do PATRIMÔNIO MUNDIAL - WORLD HERITAGE - da UNESCO, Convenção Internacional para a proteção de sítios culturais e naturais. For essa convênio as Nações reconhecem que mantêm sob sua responsabilidade a conservação, para a Humanidade e as gerações futuras, aqueles bens de valor universal excepcional, são considerados Patrimônio Mundial, localizados dentro de seus limites territoriais.

A Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP) está encarregada de preparar uma base de dados dos sítios brasileiros dessa natureza que mereçam receber proteção, destacando-se como principais finalidades dos mesmos, entre outras, o uso para:

a - pesquisa científica básica e aplicada;
b - difusão do conhecimento científico na área das Ciências da Terra;
c - atividades educacionais e recreativas;
d - criação e fortalecimento de uma consciência conservacionista;
e - referenciais em guias turísticos, estimulando, por meio do ecoturismo, a participação e desenvolvimento sócio-econômico das comunidades locais.

Os sítios aceitos para a base de dados serão objeto de uma publicação bilingüe (português e inglês) denominada SÍTIOS GEOLÓGICOS E PALEONTOLOGICOS DO BRASIL (GEOLOGICAL AND PALEONTOLOGICAL SITES OF BRAZIL). Os sítios brasileiros estão relacionados e parte deles já disponível, juntamente com um mapa índice, no endereço http://www.unb.br/ig/sigep/. A seleção dos sítios mais importantes será encaminhada à World Heritage Committee da Unesco que, por sua vez, poderá definir alguns como Patrimônio da Humanidade.

Novos sítios podem ser propostos mediante o encaminhamento à Comissão Brasileira de um formulário disponível no endereço eletrônico acima e, se aceitos e descritos, serão integrados à base de dados existente na Internet.

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