

Contrasting Archean-Proterozoic-hosted gold deposit types and associated gold-bearing fluids

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ABSTRACT : The study of fluids from four contrasting Archean-Proterozoic-hosted Brazilian gold deposits shows their very distinctive composition, significative of contrasting physical-chemical conditions during gold deposition. At the Pontal mine, fO_2 was slightly above and below the QFM buffer at the time of gold precipitation, and above the hematite-magnetite buffer at Costa Sena occurrences. The H_2O -NaCl-KCl fluids found in the Crixás Mine III deposit indicate the trapping of a probable very high salinity magmatic fluid which mixed with a cooler CO_2 -rich aqueous fluid. At Santa Rita occurrences, the highly saline fluids result from the leaching of evaporitic beds hosted in the Paranoa sequence by H_2O - CO_2 - N_2 -rich fluids.

1 INTRODUCTION

The Archean granite-greenstone belt terranes of Brazil define several important gold provinces. The major part of these gold deposits are spatially and/or genetically related to shear zone structures which show intense hydrothermal alterations (Leonardos & al. 1988). In the shear zone model, the origin of the associated metasomatic and/or mineralizing fluids, remains in debate : syngenetic versus epigenetic, metamorphic or magmatic (Keays & Skinner 1989).

Many factors operate in controlling ore deposition such as structural traps, or the kind of rock association, but the nature of the hydrothermal solutions transporting and depositing gold and the nature of the gold complexes in the ore fluids are the most important.

The study of four Brazilian gold deposits hosted in Archean-Proterozoic rock units and occurring in very different regional and geological settings, allows us to characterize the hydrothermal fluid chemistry and to check, to some extent, the main factors controlling gold mobilization transport and deposition.

2 GEOLOGICAL SETTING OF THE GOLD DEPOSITS

The four investigated auriferous districts are located in the Tocantins State (Pontal mine), Goiás State (Mine III Crixás deposit and Santa Rita occurrence) and Minas Gerais State (Costa Sena occurrence).

2.1 The Pontal Mine : It consists of an auriferous quartz vein hosted in tonalitic orthogneisses deformed by ductile shear and metamorphosed in the amphibolite facies (Santos 1989). The vein is generally concordant with the mylonitic foliation of the surrounding gneisses, exhibiting a tabular aspect and boudinage structures. Its mineral assemblage consists of oligoclase, actinolite, biotite and less than 2 % sulfides (Po, Py, Sph, Cpy). Native gold occurs as disseminated particles in the quartz crystal interstices or sometimes in irregular fractures.

2.2 The Mina III Crixás deposit : This gold deposit occurs within an Archean metamorphosed greenstone belt sequence bordered by a complex granite-gneiss terrane

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(Saboia 1979). Two main mineralized zones occur : the upper and lower ore zones (Yamaoka & Araujo 1986). Processes of hydrothermal alteration, such as carbonatization, silicification, sericitization and sulfidization were recognized and assumed to post-date the peak of the epidote-amphibolite metamorphism (Thomson & Fyfe 1990). The upper ore zone consists of an irregular massive sulphide body (Aspy, Po, Cpy) associated with sericite-schist, biotite-garnet schist and massive magnetite in a sequence of interlayered dolomitic rocks and Fe-dolomite-chlorite schists. The lower zone is represented by a concordant quartz vein syntectonically introduced in carbonaceous schists. Both ore zones are structurally controlled by a N 75W/15 lineation, parallel to shear-fold axis (Fortes & Nilson 1990).

2.3 The Santa Rita occurrence : It is hosted in the Middle to Upper Proterozoic carbonate-pelite sequences of the Paranoa group, that have been metamorphosed in the greenschist facies grade (Olivo & Marini 1988). The ore is contained in sulphide-bearing quartz-carbonate veins. The mineralization is structurally controlled by WNW-ESE high angle faults and fractures resulting from the reactivation of older NE-SW lineaments. Pyrite is the main sulphide and exhibits growing zones enriched in Co and/or Ni and As (up to 4%). Hydrothermalized zones are enriched in Co, Ni, As and are characterized by diffuse albittization, carbonatization, silicification and pyritization.

2.4 The Costa Sena occurrence : This free-gold mineralization occurs in specularite-bearing quartz veins located in a shear zone affecting the Archean volcanosedimentary series of the Rio Paraúna Supergroup. The quartz lodes are enclosed in quartz-sericite chloritic schists.

3 FLUID INCLUSIONS DATA

3.1 Pontal mine : Microthermometry and Raman studies on quartz (Santos 1989; Guilhaumou & al. 1990; Santos & al. 1990) identified primary S-type and V-type fluid

inclusions which are geometrically related to gold particles. S-type inclusions (H₂O-CH₄ and H₂O-CO₂-CH₄ systems) are multiphase solid inclusions containing siderite-calcite-graphite as daughter phases. They are often associated with solid inclusions of biotite and actinolite. V-type are gaseous CH₄-H₂O fluids whose relation with S-type is not yet understood. Homogenization temperatures (Th) for S and V, respectively, range between 300 to 460°C, in the liquid and/or the vapor phase. Other late type inclusions are secondary and contain low salinity aqueous solutions with variable amounts of CO₂, CH₄ and N₂.

3.2 Mina III Crixás mine : Preliminary microthermometry was carried out on quartz associated with the massive sulphides of the upper gold ore zone. All the inclusions are secondary and distributed along trails. Two kinds of fluid inclusions are recognized : S-type and M-V-type. S-type are multiphase fluid inclusions with halite, sylvite and other anisotropic solids. Their Th ranges from 276 up to 600°C and the temperature of fusion of halite varies from 296 up to 494 °C. Type M and V fluid inclusions are monophasic dark or vapour-rich carbonic fluids, having TfCO₂ between -58.6 to - 57.3°C and Th between 245 to 376°C.

3.3 Santa Rita occurrence : Fluid inclusion studies on quartz veins led to the identification of two kind of fluids : - a highly saline CO₂-rich aqueous fluid with halite and sylvite daughter minerals; - a CO₂-rich aqueous fluid with moderate to high salinity. The two types of fluids occur in the same portion of quartz grains displaying great variation of the degree of infilling and notable dispersion of the microthermometric parameters. Heterogeneous trapping is suspected for these fluids. On heating, all inclusions decrepitated between 250 and 300°C. Raman probe indicated a high concentration of N₂ in the gas phase, with a CO₂/N₂ ratio between 1 and 19, and a small concentration of CH₄.

3.4 Costa Sena occurrence : Microthermometry and Raman studies in quartz, led to the recognition of both CO₂-rich aqueous (C₂ and C₁) and aqueous (L) fluids, presumably responsible for the mineralizing event. The

early stage C₂ fluid (composition : 82.8 mole % H₂O; 16 mole % CO₂; 1.8 mole % NaCl) was probably diluted by an H₂O fluid (L) at around 350°C and 2.0-2.5 Kb, with an increase of the CO₂ density phase (fluid C1 composition : 94 mole % H₂O; 3.8 mole % CO₂; 2.2 mole % NaCl).

4 CONDITIONS OF GOLD DEPOSITION

4.1 In the Pontal mine, the presence of primary H₂O-CH₄ and H₂O-CO₂-CH₄ fluids (with $f_{CO_2}/f_{CH_4} = 4$) in equilibrium with graphite at high temperatures ($T > 450^\circ C$), reflects fluctuations in the redox state of the fluids. f_{O_2} plots near the QFM buffer with variations above and below the curve depending on pressure (Guilhaumou & al. 1990; Santos & al. 1990). In such reducing conditions, the significant f_{O_2} reduction would cause the precipitation of gold by destabilization of Au(HS)₂- complexes. In the absence of a C-bearing lithology in the Pontal basement, the origin of the methane-rich fluids can be attributed to a deep source. The low T-reducing f_{O_2} conditions for gold deposition are compatible with boundary metamorphic conditions between greenschist and amphibole facies in the Pontal region, and allows us to ascribe the deposit as a high temperature metamorphic type (Guilhaumou & al. 1990).

4.2 The origin of the gold-bearing massive sulphide Mina III Crixás ore bodies is not yet entirely understood. There is no unequivocal chemical evidence to consider them as products of intense metasomatism of metabasic rocks. The absence of primary structures is not sufficient to exclude the possibility of an iron-rich level of sedimentary-exhalative origin, though irregular shape and geometry of the ore bodies and coarse grain size of arsenopyrite favour an epigenetic origin. Preliminary fluid inclusion data show the coexistence of two fluids syntectonically introduced in the hydrothermal system : type S fluid may have been originated from saline brines derived from metamorphosed carbonate-rich sediments. These saline fluids are atypical of syngenetic exhalative deposits, and in the absence of

evaporitic layers in the Crixás sequence, a probable orthomagmatic origin may be inferred. Type M and V fluids may be due to the liberation of CO₂ and H₂O and carbon oxidation reactions during metamorphism. In this way, gold may have been transported as AuCl₂- by saline fluids and/or Au (HS)₂- by aquocarbonic fluids. The mixing of these two different fluids would contribute a possible genetic mechanism for gold precipitation.

4.3 In the Santa Rita occurrence, a mechanism of heterogeneous trapping at 250-300°C is suspected for the CO₂-N₂-rich and H₂O-NaCl-KCl-rich fluids. The entrapment of compositionally variable fluids may result from the mixing of high salinity fluids with cooler meteoritic waters and CO₂-N₂ produced by the reaction with carbonate and phyllic host rocks. Considering the absence of spatially and temporally related igneous activity and the low P-T regional metamorphism in the Paranoa group, the highly saline fluids are inferred to be the product of leaching of evaporitic beds which are known to occur in the lower part of the Paranoa lithostratigraphic column. Gold was probably initially transported as a AuCl₂- complex ($T > 300^\circ C$, low pH, moderate f_{O_2} -pyrite field stability). As temperature decreased and mixing proceeded below 290°C, the "switch-over" process described by Large et al. (1989) would lead to the predominance of Au(HS)₂- in the fluid. Pyrite precipitates in this interval of low temperature. The oscillatory zoning of the As-Ni-Co-bearing pyrite grains indicates episodic fluctuation of the fluid composition, and is similar to pyrites found in geothermal systems or in stratabound and stratiform gold deposits such as those of Carlin type (Fleet et al. 1989). A model of a Proterozoic geothermal system involving the regional thermal gradient is presented. This gradient remained high in the interior of the belt and slowly decreased following the compressive phases of the Brasiliano cycle, and would be responsible for the hydrothermal gold mineralization.

4.4 In the case of Costa Sena, the evolution of the hydrothermal system (C₂ -> C₁ -> L fluids) is characterized by a progressive increase of

H₂O. The absence of CH₄, N₂ or H₂S in the volatile phase, the presence of specularite and the absence of pyrite in the vein, indicate that the fO₂ conditions of the fluids were closed to the magnetite-hematite buffer. Under these oxidizing conditions, the transport of gold would take place within the stability field of the HSO₄⁻/SO₄⁻⁻ pair, gold being soluble as AuCl₂⁻. Gold precipitation is attributed to a pH increase which is favoured by the evidenced fluid dilutional process.

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REFERENCES

- Fleet, M.E. Mc Lean, P.J. & Barbier, J. 1989. Oscillatory-zoned As-bearing pyrite from stratabound and stratiform gold deposits : an indicator of ore fluid evolution. *Econ. Geol.*, Monograph 6 : 356-362
- Fortes, P.F.T.O. & Nilson, A.A. 1990. Geologia dos corpos de minério do depósito de ouro Mina III, Crixás, Goiás. *Resumo XXXVI Cong. Bras. Geol., Natal* : 146-147.
- Guilhaumou, N.; Santos, M.M., Touray, J.C., Beny, C & Dardenne, M.A. 1990. Multiphase methane-rich fluid inclusions in gold-bearing quartz as illustrated at Pontal (Goiás, Brazil). *Mineralogical Magazine* : 257-266.
- Keays, R.R. & Skinner, B.J. 1989. Introduction on the Geology of gold deposits : the perspective in 1988. *Econ. Geol.*, Monograph 6 : 1-8.
- Large, R.R., Huston, D.L., Mc Goldrick, P.J., Ruxton, P.A. & Mc Arthur, G. 1989. Gold distribution and genesis in Australian volcanogenic massive sulfide deposits and their significance for gold transport models. *Econ. Geol.*, Monograph 6 : 520-536.
- Leonardos, O.H., Jost, H. & Veiga A.T.C. 1988. Brazilian gold districts : how many are not associated with shear zones ?. *Extended abstract Gold 1988, Melbourne* : 611-613.
- Olivo, G.R., & Marini, O.J. 1988. Ouro no grupo Paranoá : distribuição, tipos e controles das ocorrências. *Congr. Bras. Geol.*, 35, V.1 : 93-106.
- Saboia, L.A. 1979. Os "greenstone belts" de Crixás e Goiás- Go. *Bol. Inf. SBG-Goiânia*, Nº9 : 43-72.
- Santos, M.M. 1989. Contribuição à geologia e à geoquímica do depósito Pontal, Tocantins. *Mestrado Thesis, University of Brasília*, 150 p.
- Santos, M.M., Dardenne, M.A, Giuliani, G., Guilhaumou, N., Touray, J.C. & Beny, C. 1990. Características do veio de quartzo aurífero do depósito Pontal, Tocantins. *XXXVI Cong. Bras. Geol.*, V.1
- Thomson, M.L. & Fyfe, W.S. 1990. Crixás gold deposit, Brazil : thrust-related, post-peak metamorphic gold mineralization of possible Brasiliano cycle age. *Econ. Geol.*, V.85 : 928-942.
- Yamaoka, W.N. & Araujo, E.M. 1986. Mineralização de ouro da Mina III. *Roteiro das excursões Congr. Bras. Goiânia* : 77-78.