XLIII Congresso Brasileiro de Geologia
Aracaju, 3 a 8 de setembro de 2006

Gold mineralization in the Crixás greenstone belt, GO: characteristics of the Palmeiras-type oreshoots

B.S. Almeida[1], H. Jost[2], J.C. Frantz[1] & M.R. Bennell[3]

1 Universidade Federal do Rio Grande do Sul (brunasaar@ibest.com.br, jose.frantz@ufrgs.br)
2 Universidade de Brasília (hjost@opengate.com.br)
3 Anglogold Ashanti Brasil (MRBennell@AngloGoldAshanti.com.br)

Abstract The palmeiras-type oreshoot is located in the Crixás Greenstone Belt, to the northwest of Goiás. The supracrustal rocks of the Crixás belt are divided into the following formations: Córrego Alagadinho, Rio Vermelho and the Ribeirão das Antas. The gold mineralization at Palmeiras orebody occurs at the contact between metabasalts and the underlying metasedimentary rocks marked by a reverse fault that hosts the hydrothermal alteration. Values of magnetic susceptibility average 300×10^{-3} in the hydrothermalized zone, confirming the presence of an anomalous magnetic signature. Three different zones of hydrothermal alteration have been identified An external, characterized by the presence of phyllic alteration; an intermediate zone, characterized by the increase in the content of white mica and the disappearance of chlorite; an internal zone, characterized by an assemblage of chlorite+magnetite+garnet±tourmaline±pyrite. The gold particles vary from 25 to 200µm, and commonly occur filling fractures in magnetite, pyrite or garnet. The development of magnetite in the internal alteration zone implies that geophysical ground magnetic methods can be used in the exploration for Palmeiras-type gold deposits in the Crixás area.

Keywords: Crixás Greenstone Belt, hydrothermal alteration, Palmeiras-type gold deposits.

The Crixás Greenstone Belt is located in the Tocantins Province (Almeida *et al.* 1968), to the west of the San Francisco Craton. This province is made up by the Neoproterozoic Brasilia, Paraguai and Araguaia fold belts, the Neoproterozoic Goiás Magmatic Arc and the Archaean Goiás Massif. The Archaean terrains, consisting of a typical association of granite-gneiss complexes and greenstone belts, are situated to the southern sector of the Goiás Massif, in the central portion of Goiás (Almeida 1968; Fuck *et al*, 1993 and Fuck 1994). The granite-gneiss complexes, with compositions varying from tonalite, granodiorite to granite, cover 80% of the Archaean areas and are represented by the Tapir, Anta, Caiamar, Moquém, Hidrolina, Caiçara and Uvá Complexes (Pimentel *et al*, 2000). The supracrustal rocks, making up the remaining 20%, occur in the greenstone belts of Crixás, Guarinos and Pilar of Goiás to the north, and the Santa Rita and Faina belts, to the south.

The Crixás Greenstone Belt, in the north of the Goiás Massif, is bounded by the Anta and Caiamar Complexes, located to the west and east, respectively, and by supracrustal metasedimentary rocks attributed to the Proterozoic Santa Terezinha Sequence to the northeast. Sabóia *et al.* (1981) classified the supracrustal rocks of Crixás belt into the following formations, from the base to the top: Córrego Alagadinho Formation (komatiite), Rio Vermelho Formation (tholeitic basalt), both with rare sedimentary intercalations (BIF and chert), and the Ribeirão das Antas Formation (greywacke, arenite and carbonaceous siltite and shale). Preserved thicknesses for each formation are estimated at 600, 800 and 300 meters, respectively. Volcanic and primary sedimentary structures are common throughout. These rocks had been variably deformed and metamorphosed by at least three major tectonic-metamorphic events, with metamorphic grades ranging from conditions of lower greenschist to lower amphibolite facies (Massucatto 2004).

The main occurrences of gold mineralization in the region are in the greenstone belts. The main gold deposits are hosted in metasedimentary units intercalated with metabasalts, however, there are deposits hosted in ultramafic rocks (Mina Inglesa deposit) and the Palmeiras mineralization, described in this study, hosted within the base of a thick sequence of pillow–bearing metabasalts. Mina III is the main gold deposit at Crixás, which is situated to the southeast of the city and the different orebodies are mined by underground methods by Mineração Serra Grande S.A., since 1989. The main orebody is hosted in the detrital clastic rocks of the Ribeirão das Antas Formation at the contact with metabasalts of the Rio Vermelho Formation (Yamaoka & Araújo 1988). The main mineralization types are (i) quartz lodes (Inferior Zone) enveloped by carbonaceous schists, and (ii) lenses of massive sulphide (Upper zone) associated with zones of hydrothermal alteration (Fe-dolomite, quartz-chlorite-carbonate-sericite schist,

M.G. Silva & W.J.S. Franca-Rocha (org.). *Coletânea de trabalhos completos*, Salvador: SBG, 2008.

pyrrhotite-magnetite-biotite schist, garnet-chlorite-schist, garnet-rocks, muscovite-schist, muscovite-chlorite-schist (Fortes 1996). Both zones, forming sub-parallel bodies plunging 20-25 degrees to 275-295, are controlled by recumbent folding with axial planes dipping between 290 and 320º (Fortes 1996). An exploration program that has been carried out in order to increase the mining reserves resulted in the discovery of several new mineralized zones in the Palmeiras orebody located to the south of the Mina III. The oreshoots, outlined by grid diamond drilling, have strike widths up to 50m and down plunge extents between 100 and 300m. The plunge is consistently 10-30º to the WNW. The distribution and intensity of the hydrothermal alteration of the Palmeiras orebody has many similarities with the Upper Zone of Mina III. The gold mineralization at Palmeiras is hosted at the contact between metabasalts and the underlying metasedimentary rocks. This contact is marked by an N-S trending, 30º west dipping reverse fault (Massucatto 2004). The metabasalts are massive, green, fine grained rocks with intervals containing pillow lavas and vesicle-amygdaloidal textures. The metasedimentary rocks schistose rocks have protoliths interpreted as carbonaceous pelites with subordinate greywacke, arenite and siltite of probable turbiditic origin.

The main objective of this study is to characterize the hydrothermal alteration haloes and the style of gold mineralization in the Palmeiras orebody and to establish parameters that can be utilized for systematic exploration work at this deposit and in the search for similar deposits in the Crixás area. In this study three representative drill holes, all intersecting the ore horizon at about 520m below the surface, were selected and the study concentrated on describing the mineralogical associations of a well mineralized hole (SGCG-106) in one of the ore shoots and two sub-grade/barren holes (SGCG-105 and 107) located either side of this ore shoot.

The diamond drill cores were geologically logged and magnetic susceptibility readings were made at 10-cm intervals in the alteration zone and mineralized zone and at 1-m intervals either side of it. Values of magnetic susceptibility averaged 0.6×10^{-3} in the carbonaceous schist, 0.8×10^{-3} in the metabasalt and 300×10^{-3} in the hydrothermalized zone, confirming the presence of a distinct anomalous magnetic signature in the hydrothermalized alteration zones.

Review of the company data base (susceptibility values for each meter of core) for the rest of the drill core in the Palmeiras area indicated that the susceptibility anomaly in the hydrothermalized zone occurs throughout the area irrespective of the gold grades.

Petrographic studies were carried out on 45 samples representative of the alteration zone and the wall rocks. Three characteristic zones of alteration are identified: external, intermediate and internal.

The external zone is present both in the metabasalts and in the underlying metasedimentary rocks. In the metabasalts this zone is represented by centimeter-wide zones of strong shearing with an increase in width of shearing downwards, towards the intermediate zone. These sheared zones are rich in chlorite, with subordinate biotite and veinlets of quartz and carbonate. A zone of banded rocks, up to 3m wide, characterized by the association of chlorite+biotite±epidote, cm- to dm-wide veinlets of quartz and carbonate occurs inward from the zone of shearing. Disseminated pyrite and chalcopyrite are common but never form more than 1% by volume of the rock. In the metasedimentary rocks, the external zone is characterized by a fine dissemination of chlorite as alteration of biotite in the meta-arenites and carbonaceous pelites. This external zone is characterized by the presence of chlorite as the dominant alteration mineral.

The intermediate zone, from 2 to 9 meters thick, is characterized by the increase in the content of white mica (± roscoellite) with subordinate biotite and the disappearance of chlorite. Locally, cm-size aggregates of epidotized rock and dm-size veins of quartz and carbonate are present. Amphiboles are present in the drill core closer to the contact with the internal zone. The abundance of white mica allows the interpretation of this zone as one characterized by phyllic alteration.

The internal zone, averaging approximately 4m in thickness, consists of rocks with a varied association of chlorite, garnet, amphibole, magnetite, apatite and tourmaline. The characteristic assemblage contains the minerals chlorite + magnetite + garnet ± tourmaline. Garnet and tourmaline occur in centimetric bands as garnetites and tourmalinites. The sulfide content increases in this zone with the pyrite being most characteristic. Pyrrhotite is subordinate occurring as fine disseminations or in irregular aggregates within carbonate and tourmaline veins. Hematite and chalcopyrite also occurs as fine disseminations in this zone.

The gold mineralization in the Palmeiras oreshoots occurs in narrow dm-wide bands with high gold grade (several tens of grams per ton) limited to the internal zone of hydrothermal alteration. Scanning electron microscopy (SEM) on selected polished sections has indicated that individual gold particles vary from 25 to 200 µm and commonly occur as fillings in fractures in the magnetite, pyrite or garnet. Ilmenite and scheelite have also been identified filling fractures in magnetite and amphibole, respectively.

The distribution and intensity of the hydrothermal alteration in the metabasalts and the metasedimentary rocks associated with the Palmeiras oreshoots suggest that this alteration resulted from a regime of a high fluid/rock ratio. The abundance of chlorite in the external zone with its gradual substitution by white mica in the intermediate zone probably resulted from either: (i) a gradual increase of the leaching capacity of the fluid phase of probable acidic character, or (ii) a greater volume of fluid passing through the intermediate and central zones. The presence of magnetite in the internal zone would suggest that the fluids had reached conditions around neutrality or slightly alkaline. The presence of amphibole in the contact between the intermediate and internal zones the abundance of chlorite in association with the amphibole suggests the presence of a hydrothermal fluid rich in iron.

The development of abundant magnetite in the internal alteration zone means that geophysical ground magnetic methods can be readily used in the exploration for Palmeiras-type gold deposits in the Crixás area.

References

ALMEIDA F.F.M. 1968. Evolução tectônica do centro-oeste brasileiro. *Anais Academia Brasileira de Ciências*, **40**:280-296.

FORTES P.T.F.O. 1996. *Metalogenia dos depósitos auríferos Mina III, Mina Nova, e Mina Inglesa, Greenstone Belt de Crixás, Goiás*. Tese de Doutorado. Brasília, UnB, 177p.

FUCK R.A. 1994. A Faixa Brasília e a compartimentação tectônica na Província Tocantins. SBG, Simpósio Geologia Centro-Oeste, 4, Brasília, *Resumos Expandidos*, p.184-187.

FUCK R.A., JARDIM DE SÁ E.F., PIMENTEL M.M., DARDENNE M.A., PEDROSA-SOARES A.C. 1993. As faixas de dobramentos marginais do Cráton do São Francisco: síntese dos conhecimentos. *In:* J.M.L. DOMINGUEZ & A.MISI (eds.) *O Craton do São Francisco.* SBG, Núcleos Bahia e Sergipe, p. 161-185.

MASSUCATO A.J. 2004. Aspectos estruturais do *Greenstone Belt* de Crixás. Anglogold Ashanti Mineração Ltda, Relatório Interno. 30p.

PIMENTEL M.M., FUCK R.A., JOST H., FERREIRA FILHO C.F., ARAÚJO S.M. 2000. The basement of the Brasília Fold Belt and the Goiás Magmactic Arc. In: U.G CORDANI, E.J MILANI, A. THOMAZ FILHO, D.A. CAMPOS (Eds.*). Tectonic Evolution of South America.* Rio de Janeiro: 31st International Geological Congress, 2000, pp.:195-229.

SABÓIA L.A., TEIXEIRA N.A., CASTRO J.H.G., TEIXEIRA A.S. 1981. Geologia do "Greenstone Belt" de Crixás (GO) e suas implicações geotectônicas *In:* Simpósio sobre o Cráton São Francisco e suas faixas marginais, 1, Salvador, 1981. *Anais* Salvador, SBG, Parte II, Núcleo Bahia, p. 39-50.

YAMAOKA W.N. & ARAÚJO E.M. 1988. Depósito de Ouro Mina III, Crixás, Goiás, *In:* C. Schobbenhaus & C.E.S. Coelho (Eds.) *Principais Depósitos Minerais do Brasil, v. III*, Capítulo XXXIV. Brasília, DNPM/CVRD, p. 491-498.