THE CHAPADA Cu-Au DEPOSIT AND GUIDELINES FOR MINERAL EXPLORATION PROGRAM IN THE GOIÁS MAGMATIC ARC

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Abstract This paper presents an integrated study based on geologic and mineral prospecting data from the Chapada deposit, Alto Horizonte, GO, located in the Neoproterozoic Goiás Magmatic Arc, Central Brazil. Guidelines for characterization of targets for metals in the arc, and for programs of mineral prospecting and exploration are: (i) frequent occurrence of mineral deposits in arc geotectonic unit; (ii) association of the mineral deposits with calc-alkalic provinces; (iii) occurrence of Brasiliano regional and local fracture systems; (iv) associated hydrothermal alterations; Neoproterozoic as an Era of great importance for the metallogeny of the State of Goiás. Geochemistry, remote sensing, magnetometry and gamaspectrometry are useful exploration techniques to evidence gold-base metals mineralizations in the Goiás Magmatic Arc.

Keywords: mineral exploration, Chapada, Goiás Magmatic Arc.

Resumo O DEPÓSITO DE Cu-Au DE CHAPADA E DIRETRIZES PARA A EXPLORAÇÃO MINERAL NO ARCO MAGMÁTICO DE GOIÁS A análise integrada de dados geológicos e de prospecção mineral da região do depósito de Chapada, Alto Horizonte-GO, no Arco Magmático de Goiás, permitiu estabelecer guias prospectivos regionais e locais. A freqüente associação dos depósitos e ocorrências minerais a magmatismo cálcio-alcálico e sua ocorrência em rochas submetidas a alteração hidrotermal no âmbito de fraturas regionais e locais, constituem guias prospectivos para programas de exploração mineral no arco magmático. Dados geocronológicos confirmam a importância do Neoproterozóico como época metalogenética no estado de Goiás. A análise integrada de dados geológicos de campo, imagens de satélite e magnetometria aérea, evidenciam o arcabouço estrutural da região e definem um controle estrutural para o depósito de Chapada e demais ocorrências minerais. Dados terrestres da magnetometria e gamaespectrometria indicam assinatura geofísica anômala para o depósito.

Palavras-chave: exploração mineral, Chapada, Arco Magmático de Goiás.

INTRODUCTION The volcanic-sedimentary sequences of the Goiás Magmatic Arc, central Brazil, hosts gold and base metal deposits, the most important one being the Chapada gold-copper deposit, located in the Alto Horizonte-Mara Rosa region, State of Goiás. The deposit was discovered by stream sediments prospecting in the 1970s and early 1980s (Silva and Sá 1988) which led to a major research effort carried out in programs related to mineral deposits by universities and companies (Richardson 1983, Arantes *et al.* 1991, Kuyumjian 2000, Oliveira *et al.* 2000, Ramos Filho 2001 and Ramos Filho *et al.* 2003). This paper summarises geologic and mineral prospecting data from the Chapada deposit, based on the published papers and recent work carried out by the present authors.

THE CHAPADA COPPER-GOLD DEPOSIT The Mara Rosa volcanic-sedimentary sequence, present in the north part of the magmatic arc and containing the Chapada (Cu-Au), Posse (Au) and Zacharias (Ba-Ag-Au) deposits and several gold and gold-copper occurrences (Lacerda 1986), comprises an eastern metasedimentary unit (metagreywacke, staurolite-kyanite schist, feldspathic garnet-quartz-biotite schist, metachert, banded iron formation, exhalite and interlayered calc-alkalic amphibolites), central metavolcanic unit (tholeiitic pillowed amphibolite and garnet amphibolite) and western metasedimentary unit (staurolite-kyanite schist, metagreywacke and calc-silicate rocks). The plutonic rocks constitute tonalite, granodiorite, gabbro,

pyroxenite and hornblende. The copper-gold Chapada deposit is associated to feldspathic garnet-quartz-biotite schist, calc-alkalic amphibolite and hydrothermal alteration zones. The ore body (134 Mt of 0.44 % Cu and 0.35 % Au) coincides with the structural trends of major NE-trending axes and W-dipping limbs of isoclinal fold and consists of pyrite-chalcopryrite-magnetite-sphalerite-galena-pyrrotite-molibdenite disseminated in biotite-rich schist, sericite-rich schist, gedrite-anthophyllite schist and subordinated silicified zone. Gold is very fine-grained, included in chalcopryrite, and less commonly occurs as coarse-grained gold in between sulphide grains. The sulphide minerals are frequently elongated, bent and boudinaged together with mica, and also occur as inclusions in metamorphic minerals, which indicate the sin- or pre-metamorphic nature of the Chapada deposit (Kuyumjian 1995). Based on S isotope composition of pyrite and chalcopryrite, Richardson *et al.* (1986) proposed a wall-rock porphyry copper model for the origin of the Chapada deposit. Kuyumjian (2000) speculates that the Chapada, Posse, Zacarias and Bom Jardim de Goiás deposits may represent metamorphosed porphyry-epithermal systems related mineralizations, and Oliveira *et al.* (2000) suggest that the origin of gold and/or copper deposits in the Goiás Magmatic Arc are related to magmatic evolution of a collisional belt.

EXPLORATION TOOLS The main guidelines for exploration of the Chapada Cu-Au deposits in the Goiás Magmatic Arc are:

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summarized in Table 1. Located in a deep weathering area the deposit was first evidenced by copper anomalous concentration from a stream sediment sample and soil geochemistry was used routinely to define copper and gold anomalies.

The fact that the Mara Rosa sequence hosts deposits and several gold and gold-copper occurrences emphasises the good potential of the Goiás Magmatic Arc as an important target for mineral exploration programs. Most of the copper/gold deposits and occurrences from the Goiás Magmatic Arc are restricted to those parts of the volcanic-sedimentary sequences, where metavolcanics and plutonics have calc-alkalic and alkalic chemical affinities. In the Chapada-Mara Rosa region, the calc-alkalic and alkalic magmatism are restricted to the eastern metasedimentary unit, which hosts the Chapada and Posse deposits (Kuyumjian 1989, Palermo *et al.* 2000).

U-Pb zircon data for diorite and tonalite from Chapada indicate crystallization of the protolith at 856 Ma, and amphibolite facies metavolcanic rock from the Mara Rosa sequence has U-Pb sphene age of c. 590 Ma (Pimentel *et al.* 1993, Pimentel *et al.* 2000). Isotopic analysis for Pb in galena from the Chapada deposit indicate a 1.0 Ga age for the extraction of the Pb from a mantle source (Ramos Filho 2001). Araújo Filho and Kuyumjian (2000) show that the Goiás Magmatic Arc deposits, as well as most of the gold deposits in central Brazil, are controlled by shear zones originated by the Neoproterozoic Brasileiro Orogeny. These data indicate that the Neoproterozoic constituted an important metallogenic epoch in central Brazil.

The Chapada deposit occurs very near the major Rio dos Bois fault and is controlled by splays of this. The main structural lineaments in the region strikes N20-40E, but subsidiary N50-

70E, N10E, N20-40W and NS are important also, for they host the gold or copper-gold deposits and occurrences. The major faults are marked by mylonite, alignments of intrusions, hydrothermal alteration and gold deposits and occurrences (Ramos Filho *et al.* 2003). The geology sketch and the cross section of the Chapada deposit evidence that the products of the hydrothermal alteration include biotite schist, quartz-magnetite-sericite schist and staurolite-gedrite-anthophyllite-schist (Kuyumjian 1995). Although outcrops are very limited and mapping of alteration zones is very difficult in the Chapada region, exposures of sericite-rich schist correlate with proximity to the deposit.

Remote sensing images and airborne magnetic survey data were interpreted aiming to identify the main structural lineaments in the region and also to detect areas of hydrothermal alteration related to the Chapada deposit. The produced images evidenced a complex geometric array, showing structures in the NE, that controls the Chapada deposit, and NW directions (Ramos Filho 2001). The presence of hydrothermal alteration zones with strong potassic enrichment suggested the use of gamma-ray spectrometric data. Airborne gamma-ray data available in the area were interpreted based on the areal superposition of the K and Th channels images, and the use, together, of the two criteria: low Th/K ratios and anomalies of K normalized to Th (Pires 1995). The low Th/K ratios brought into evidence the contrast of potassic alteration zones closely associated to the Chapada deposit when compared to the surrounding geologic environment. Ground magnetometry and gamaspectrometry data indicate anomalous geophysical signatures for the Chapada deposit (Ramos Filho 2001). Ground geophysics profile across the Chapada deposit showed a remarkable increase in potassium values associated

Table 1- Guidelines for copper and gold mineral exploration program in the Goiás Magmatic Arc.

REGIONAL MINERAL EXPLORATION PARAMETERS	
Tectonic Setting	Island arc.
Chemistry	Calc-alkalic and/or alkalic magmatism.
Structural Control	Brasiliano shear zones and associated hydrothermally altered rocks.
Geologic Time	Neoproterozoic: metallogenic Era in the Província Tocantins.
Genetic Model	Epithermal - porphyry copper mineralizations
Tools for mineral exploration	
Geochemistry	Reconnaissance stream-sediment prospection.
Geophysics	Airborne regional survey with line spacing of 500 meters, at most. Ground survey in anomalous areas identified by the airborne survey and/or by field geology. .
Magnetometry	Important in understanding the regional structural framework through the extraction of magnetic lineaments. Identification of mineral deposits with contrasting magnetic susceptibility and support to geologic mapping.
Gamma-ray Spectrometry	Identification of radioactive elements halos, specially potassium, associated with deposits related to hydrothermal processes and support to geological mapping.
Remote Sensing	Use of satellite images for extracting structural lineaments and identification of hydrothermal alteration zones in areas of known geology. Radar images, although not used in this work, can be helpful to the geological mapping.

Figure 1 – Gammaspectrometric (K %, Th cps and Th/K) and Residual Magnetic Field (nT) responses in the Chapada deposit.

with a magnetic low (Fig. 1).

FINAL REMARKS Concentration of exploration effort for gold and/or base metals in the Goiás Magmatic Arc is amply justified by discoveries at Chapada, Posse, Zacarias and Bom Jardim de Goiás. These deposits emphasize the potential of subduction-related settings worldwide. The -80 mesh fraction of stream-sediment samples was an effective medium for detection of the Chapada deposit. The deposit occurs associated to calc-alkalic magmatism and maximum exploration potential exists within Brasiliano orogeny shear zones, which are best evidenced by remote sensing imagery. Hydrothermal alteration overprinting or alongside the deposits enable detection by remote sensing images and gamma-spectrometric and magnetic surveys. The authors believe that the available data suggest that the origin of the Goiás Magmatic Arc gold and copper mineralizations are probably related to porphyry-epithermal systems.

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