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The Cumaru mesothermal granodiorite-hosted gold mineralization, Amazon craton, Brazil

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ABSTRACT: A new type of gold metallotect is described for the Amazon craton, in southern Para State. Instead of being hosted in hydrothermally altered mylonites along transtension domains of shear zones like in most other reported gold districts, the Cumaru deposit is hosted by a 2.543 F 53 Ma granodiorite pluton. The Cumaru Granodiorite, like the nearby Maria Bonita pluton is intruted in the dilatation zones of the horse-tail termination of a shear zone that crosscuts the rock units of the Archean Gradaus greenstone belt. Its skarn rocks with a wollastonie-diopside / hedenbergite-grossular-honblende-epidote mineral association were developed. The skarn is formed within an ignimbritic sequence of dacite composition of the Gradaus greenstone belt where mylonitization followed by widespread carbonate alteration took place. The Cumaru mineralization lies along a stockwork array of fractures at the western edge of the granodiorite pluton where saussuritization and albitization of the plagioclase and cloritization of the biotite and amphibole are widespread. Mesothermal gold deposition is associated to late sulfide formation that followed or accompanied the sericitization of albite and recristalization of quartz. Native gold occurs within pyrite, chalcopyrite and quartz grains. The gold ore is often brecciated with minor amounts of molybdenite and sphalerite.

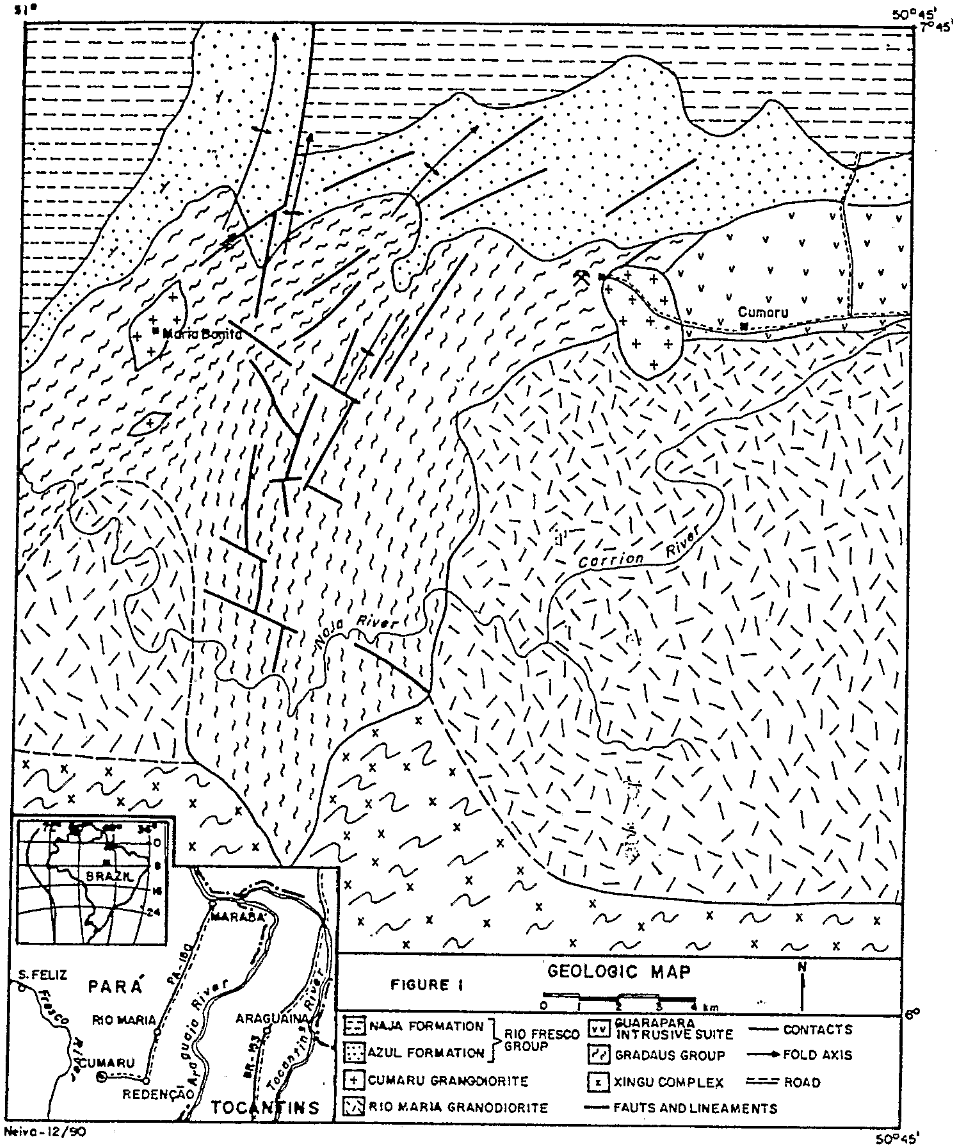
1 INTRODUCTION

The primary gold deposits that have been described up to now in the Amazon craton are directly related to shear zones that were installed along or that cut across greenstone belt type sequences and their country rocks. These deposits are all hosted by a hydro thermally altered mylonites that have been derived from a large variety of protolites (Leonardos et al., 1988) and they are similar to deposits that have been described in shield regions elsewhere (Hodgson, 1989).

In the southeastern part of the Amazon craton, the classics examples are those associated to the greenstone belts of Andorinhas (Huhn et al. 1988) and Sapucaia (Oliveira and Leonardos, 1990). The Cumaru deposit is an exception to that model, for the gold deposition lies within a granitoid intrusion that postdates both the Gradaus greenstone belt and the shearzones within that belt.

2 GEOLOGICAL SETTING

The Cumaru gold deposit lies 100km to the west of the city of Redencao in the south of the state of Para (fig 1). It is one of several deposits that are associated to small late Archean granitoids that were emplaced in the dilatation zones of a major horse-tail shaped shear zone that cut across the southern flank of the Gradaus greenstone belt. This belt is structured as a large synclinorium with its axis



dipping to the west and outcrops at the base of the well marked scarp formed by overlying sandstones of the Rio Fresco group. To the east of the Cumaru granitoid the Gradaus belt is formed by a undeformed plutonic sequence of olivine gabbros and diabase and small serpentinized ultramafic bodies with cummulitic stuctures (Macambira et al., 1986) while to the west the greenstone is represented by a typical meta volcanic-sedimentary sequence metamorphased and deformed under greenschist facies conditions (Gradaus group, Macambira et al. op. cit.), along conjugated sets of transcurrent shear zones with north and northeastern directions marked by a strong mylonitic foliation. In this area, the major rock types are formed by flow tuffs and ignimbrites of dacitic to riodacitic composition with little or no deformation, intercalated by centimetric and metric bands with a variable degree of mylonization. Mafic to ultramafic rocks are minor and occur in the zones of intense deformation as actilonite schists and talc-chlorite schists. Metassediments like banded iron formations (BIF) and clastic sediments though of minor occurence near the Cumaru deposit form a major rock unit to the southwest in the Serra Ruim, together with acid metavolcanics.

3 CUMARU GRANODIORITE

Under the term Cumaru granodiorite Macambira et al. (1986) included three granitoid plutons with 1 to 2km in diameter that were intruded in the Gradaus greenstone belt. The main stock that lies under the alluvial workings of the Cumaru "garimpo" and host in the main mineralization has an eliptical shape elongated in the N-S direction and being limited in its southern border by a slightly older granodiorite of the Rio Maria type (Rb/Sr age of 2,660 $\pm$ 40 Ma, Montalvão et al., 1984). The other granitoid stocks outcrop under the workings of the Maria Bonita garimpo (within the area of Indian Reservation), west of Cumaru. A brief survey of the Maria Bonita area has shown a remarkable similarity between the stocks of Cumaru and those of Maria Bonita despite the strinking sigmoidal shape of the later. Rb-Sr age determinations for the Cumaru Granitoid indicated and absolute age of 2,543 $\pm$ 53 Ma with a Sr^{87}/Sr^{86} ratio of 0,70311 (Lafon et al.,1990).
The Cumaru stock is made up by a dominant grey granodiorite intrusion and a late-formed irregularly distributed small bodies of a red monzogranodiorite restricted to its northwestern border. These rocks show a characteristic isotropic texture formed by euhedral crystals of biotite, hornblende and zoned plagioclase and sphene sitting on a late formed mass of anhedral quartz and microcline, often showing graphic intergrowth.
The geological, petrographic and petrochemical characteristics of the Cumaru Granitoid point out to an origin from melting of plutonic rocks (I type). Following Pitcher (1983), its metalogeny (Au-Co- Mo-Ag) and its low Sr^{87}/Sr^{86} initial ratio is further suggestive of a mantle derivation (M-type) or of a short crustal residence (Cordilleran I-type).

4 SKARNS

Because the Cumaru Granitoid emplacement postdates the strong carbonate alteration that were developed along the shear bands within the dacitic volcanics of the Gradaus group, the resulting carbonate bearing mylonites were transformed, by thermal effect, into banded skarns with a striking mineralogy. Bands of quartz-carbonate, tremolite/actinolite-diopside/hedenbergite and epidote-zoisite-grossular-sphene-apatite-scheelite suceeds on another, closer to the contact with the Cumaru pluton.

5 HYDROTHERMAL ALTERATION AND NATURE OF FLUIDS

The early stage of alteration of the Cumaru sock is marked by a pervasive and widespread saussuritization of the plagioclase and chloritization of both the biotite and horblende. The fisrt process is often complete and grains with borders of white clear albite that envelopes nucleii clouded by newly formed epidote crystals while the chloritization may be incomplete. Along a stockwork array of fractures where circulation was much greater, the early alteration is followed by late stage destructive and phyllic alteration, patircularly where the original granitic texture has been fully destroyed yielding a quartz-muscovite-

carbonate brecciated rock.
The majority of fluid inclusions associated with the gold and the base metal sulphide mineralization within quartz grains are secondary in origin. Three broad types of inclusions were distinguished:

Type 1. Three-phase (liquis-vapor-halite) or multiphasic solid-fluid inclusions (L + V + halite + sylvite) distributed in planar arrays or outlining healed fractures. The vapor phase occupies 10-20% of the cavity volume and the crystals about 5% of the total volume. Total salinity is estimated to be greater than 30%NaCl>=200^{0}C.

Type 2. Three-phase (L_{H2O} + L_{CO2} + V_{CO2}) or two phase inclusions (infilling degree greater than 50 and less than 90), corresponding to H_2O-CO_2-NaCl fluids with $ThCO_2$ >18^0 and <27^{0}C and $TmCO_2$ ~= -56.6^{0}C.

Type 3. Late fluid inclusions that crosscut grain boundaries with a highly variable gas/liquid ratio.

Type 1 and 3 are the dominant flincs whereas type 2 amounts to no more than ten percent of the fluid inclusion population. Type 1 fluid inclusions are consistent with a cooled orthomagmatic fluid or a mixed meteoric-orthomagmatic origin. They are clearly contrasting with the low salinity fluids characteristic of the vast majority of the shear zone iode deposits.

6 THE ORE

Two main ore types are distinguished within the Cumaru deposit: the primary ore formed by gold-pyrite-chalcopyrite-sphalerite-molybdenite association with a quartz-sericite-carbonate-epidote-chlorite-albite-leucoxene gangue and the oxydized ore formed by the oxydation of the former by laterization and supergene enrichment processes. The primary ore lies within a milimetric to metric stockwork array of quartz veins with varrying orientation and thickeness; the thicker veins with a N 40^0 E / 50^0 NW preffered orientation (fig 2).

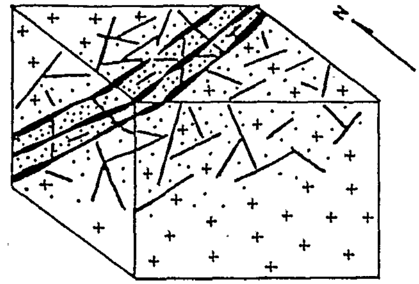


FIGURE 2 - STOCKWORK VEINS OF THE CUMARU GOLD DEPOSIT

Though ore grades are usually found within the thicker quartz-pyrite veins, the mineralization has a disseminated character along microfissures in between the thicker quartz lodes. Thus, we can subdivide the primary ore into two main domains: the domain of the high grade ore shoots (average grades around 10g/ton) and the disseminated ore along micro-cracks (usually with grades of tenths of 1g/ton). Though some lodes are definetly formed by quartz vein introduced along the granodiorite fracutring, most ore shoots are formed by fragments of primary quartz (quartz 1) plus a secondary quartz (quartz 2) formed through the recrystallization of the brecciated fragments with little or no introduced quartz. Breccias are thus often common along the ore shoots and are formed by angular fragmments of quartz and early pyrite (pyrite 1) cemented by quartz 2, carbonate and sericite; bands of quartz 1 plus pyrite alternates with bands of quartz 2 plus sericite (fig 3).

Muscovite flakes are local products of sericite recrystallization in a last stage of hydrotermal alteration associated with carbonization. In the ore shoots, pyrite occurs both in enhedric milimetric to centimetric crystals or in

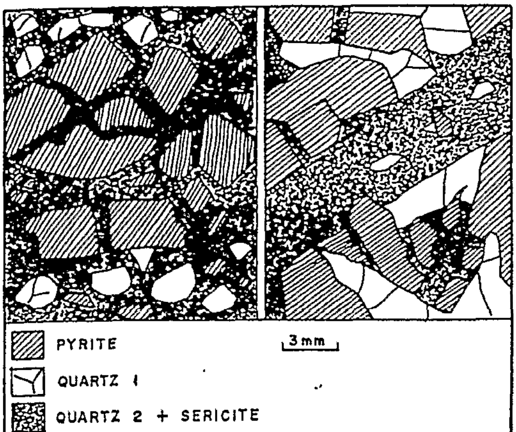


FIGURE 3 - BRECCIATED ORE

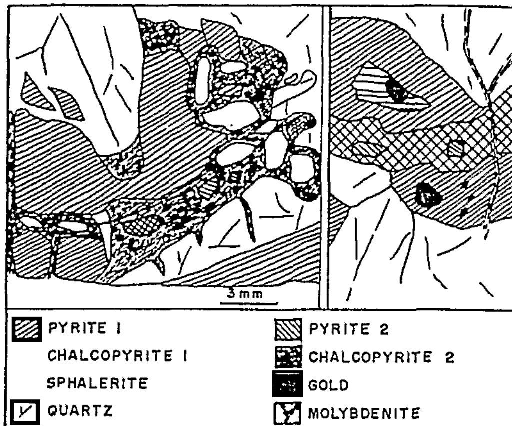


FIGURE 4 - PRIMARY SULFIDE ORE

shapeless aggregates of anhedral and often brecciated grains. The gold is unevenly distributed in small (0.02 to 0.08 mm) grains within pyrite and chalcopyrite crystals or is associated with quartz filled microffisures on the borders of sulphyde crystals and aggregates. Interstitial aggregates of late chalcopyrite, pyrite 2 and sphalerite fill the space between the fragments of pyrite 1. Molybdenite is restricted to late fractures in elongated flat crystals (fig 4). The ore shoots grades into the disseminated ore, represented by the hydrothermally altered granodiorite. This has also and often brecciated aspect and it is formed by fragmentsof primary quartz in a sericitic matrix with subordinated amounts of albite, chlorite,recrystallized muscovite and milimetric ehedral crystals of pyrite and late formed veinlets of calcite and pyrite.
The oxydized ore due to laterite and/or supergene enrichment. Free gold grains derived from primary crystal are dispesed within an iron oxyde/hydroxyde brownish red earthy crust, containing pods of kaolin, quartz fragments and locally impregnated by manganese oxydes. Botryoidal gold nuggets are also found on high grade ores, being apparently derived from the gold dispersed within the sulphyde structure. The main ore shoots show grades in the range of 2 to 50 g/ton; pyrite rich pods within the oxydized ore may show local values up to 500g/ton.

7 ORE GENESIS AND TIPOLOGY

Though the Cumaru gold deposit is associated to Archean granite - greenstone terrains it does not fall in the category of the shearzone Archean lode deposit as stated by Macambira et al.(1986). The disseminated stockwork vein geometry, the I-type calco-alkaline nature of the host granodiorite, the tectonic environment, and the high salinity nature of the mineralizing fluids point out to a mesothermal origin for the mineralizing fluids point out to a mesothermal origin for the deposit. These characteristics are remarkably similar to the features that are found in the Au-Cu-Mo porphyry of the Andean Cordillera and in the classic mesothermal deposits of the West Pacific Island Arcs such is described by Sillitoe (1989). This suggests that we have a new type of metallotect for the Amazon craton. It also points out that subduction zones may have been already active in the late Archean as has been suggested by Ludden et al.(1986) for the Abitibi belt and by Barley and Groves (1990) for the Norseman-Wiluma belt (Yilgarn Craton).

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