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THE IGARAPÉ BAHIA Au-Cu-(REE-U) DEPOSIT, CARAJÁS MINERAL PROVINCE, NORTHERN BRAZIL.

Edison Tazava & Claudinei Gouveia de Oliveira

Instituto de Geociências, Universidade de Brasília,
Brasília, DF 70910-900, Brazil
e-mail: tazava@unb.br

Abstract - The Igarapé Bahia Au-Cu-(REE-U) deposit is located in the Carajás Mineral Province - Northern Brazil - and is hosted by an Archaean low-grade metamorphosed volcanosedimentary sequence characterized by metavolcanic rocks of the footwall and metavolcanoclastic/metasedimentary rocks of the hangwall. An intense hydrothermal alteration occurred in this sequence, promoting intense chloritization, Fe-metasomatism, Cu-sulphidation (chalcopyrite and bornite), carbonatization, silicification, tourmalinization and biotitization.

The Cu-Au mineralization is hosted at the contact between meta-volcanic and meta-volcanoclastic/meta-sedimentary rocks and is divided into magnetitic/sideritic heterolithic breccias and hydrothermalized meta-volcanic rock, which are enriched in REE (monazite, alanite, xenotime, bastnäsite and parisite), Mo (molybdenite), U (uraninite), F (fluorite), Cl (ferropyrosmalite) and P (apatite). We believe that saline and F-Cl-rich fluids at high temperatures may have been responsible for carrying the REE, according to fluid inclusion and paragenetic studies.

C and O isotopic data from hydrothermal carbonates and fluid inclusion analyses from carbonate and quartz suggest the mixing of two fluids in both alteration and mineralization processes. Negative values of $\delta^{13}C$ (-9.3 to -5.8‰) indicate the presence of magmatic fluid with high salinity; moreover, the large variation of $\delta^{12}O$ (0.7 to 9.4‰) suggests a mixture between magmatic fluids of high T (higher isotopic values) and meteoric fluids (lower values).

On the basis of chemical and mineralogical composition, isotopic and fluid inclusion data, we propose in this paper a genetic model for the Igarapé Bahia deposit, that may be compared to the other intrusion-related hydrothermal Fe-oxide-(Cu-Au-U- REE) deposits.

Introduction

The Igarapé Bahia Au-Cu-(REE-U) deposit is located in the Carajás Mineral Province, Pará State, Northern Brazil and is related to an Archaean metamorphosed volcanosedimentary sequence of the Itacaiúnas Supergroup (Fig.1). This deposit was discovered by the Rio Doce Geologia e Mineração S.A.- Docegeo Company, during geological and geochemical exploration in 1974.

The Igarapé Bahia deposit is located on a plateau zone with an altitude of around 650m and with features of strong weathering which reached 200m in depth. According to CVRD company information and Huhn et al. (2000), in this supergene zone the Igarapé Bahia gold mine works at an approximate production rate of 10 t/year and a total reserve of 29 Mt at 2g/t Au in 1998 and is maintaining this production to the present time.

The aim of this paper is to present the geological characteristics of the Igarapé Bahia primary mineralization and to propose a genetic model on the basis of petrological and paragenetic studies, geochemistry, and oxygen and carbonate isotopes data.

Regional Setting

The Carajás Basin contains a large number of mineral deposits, including iron, manganese, gold, copper and nickel, which are stratigraphically associated with the Archaean metamorphosed volcanosedimentary sequence – the Itacaiúnas Supergroup (Fig.1). The Cu-Au deposits that define the Carajás Copper-Gold Belt include the Igarapé Bahia, Alemão, Salobo, Cristalino and Águas Claras deposits.

The basement of the Carajás Basin is mainly composed of gneisses and migmatites from the Xingú Complex (2.8 Ga - Machado et al., 1991) and orthogranulites from the Pium Complex (3.0 Ga - Rodrigues et al., 1992). The basement is overlain by the Carajás Basin that corresponds to volcanosedimentary rocks (Itacaiúnas Supergroup –

Docegeo, 1988) accumulated in the Late Archaean (2.7 Ga - Machado et al., 1991) and metamorphosed to greenschist -amphibolite facies. The Itacaiúnas Supergroup are overlain by siliciclastic rocks of marine origin representing the Águas Claras Formation (Araújo et al., 1991) or Rio Fresco Group (Docegeo 1988).

The Carajás Basin is intruded by granitic rocks of Archaean age that include granites and diorites from the Plaquê Suite (2.74 Ga - Huhn et al., 1999) and alkaline granites (2.5 Ga) like the Estrela Complex (Barros et al. 1992) and Old Salobo Granite (Machado et al., 1991). Other intrusions in the Proterozoic (1.88 Ga - Machado et al., 1991) include anorogenic granitic plutons like the Central Granite and Cigano Granite.

Geology of the Igarapé Bahia deposit

The Archaean meta-volcanosedimentary rocks, which host this deposit, were designated Igarapé Bahia Group, from the Itacaiúnas Supergroup. The Igarapé Bahia Group is divided into two units: Grota do Vizinho Formation (base) which is composed of meta-volcanic and meta-volcanoclastic rocks, banded iron formation (BIF), and fine grained sediments which underwent low grade metamorphism (greenschist facies); Sumidouro Formation (top) with a sedimentary origin, composed of metasandstones (Docegeo 1988). Radiometric dating by the Rb/Sr method gives an age of 2350 Ma for siliceous volcanoclastic/pyroclastic rocks and an age of 2577 Ma for basic granophyres. By K/Ar in amphiboles, the age 2270 ± 50 Ma was obtained (Ferreira Filho, 1985). Mougeot (1996), through U/Pb and Pb/Pb methods on sulphides (chalcopyrite, pyrite, galena and molybdenite) determined an age of 2850Ma for the Au-Cu mineralization of Igarapé Bahia deposit, but these authors also found remobilization ages for the Archaean mineralization of about 2060 and 1800 Ma.

On the surface, the rocks of the Igarapé Bahia Group are strongly weathered forming a thick Au-rich lateritic sequence and are surrounded by discordant sandstones from the Rio Fresco Group or Águas Claras Formation. All these rocks and the ore were cut by late dykes (gabbros, diorites and diabases) with nearly NS and NE-SW trends (Fig.2).

The Igarapé Bahia mine contains three orebodies named Acampamento, Furo Trinta and Acampamento Norte. The orebodies of the Igarapé Bahia mine are spatially disposed as a semi-circle feature characterized from the NW-SE trend of the Acampamento body, EW of Furo Trinta body and NE-SW at the Acampamento Norte body (Fig 2). These orebodies are near vertical, with a dip of 75° in the Acampamento orebody, south dip of Furo Trinta which show few local variations. The orebodies are situated at the interface between metamorphosed sedimentary/ volcanoclastic and volcanic rocks, commonly brecciated near the contact of the ore. High grade primary Cu-Au mineralization, the aim of this paper, occurs mainly in breccias with milimetric to centimetric fragments of varied composition (BIF, meta-volcanic, meta-volcanoclastic and meta-sedimentary rocks).

Relatively low grade copper mineralization is also found in the Igarapé Bahia deposit related to meta-sedimentary/ metavolcanoclastic host rocks like interbedded metasiltstones or tuffs, reaching values around 0.1-0.5% to 1.33% of Cu (Table 1). This subeconomic mineralization style is interpreted as stringer ore type by Ferreira Filho (1985).

The Alemão Cu-Au deposit which does not outcrop and shows the same trend as the Acampamento Norte Orebody was discovered near the Igarapé Bahia mine (Barreira et al., 1999; Soares et al., 1999; Ronzê et al in this conference).

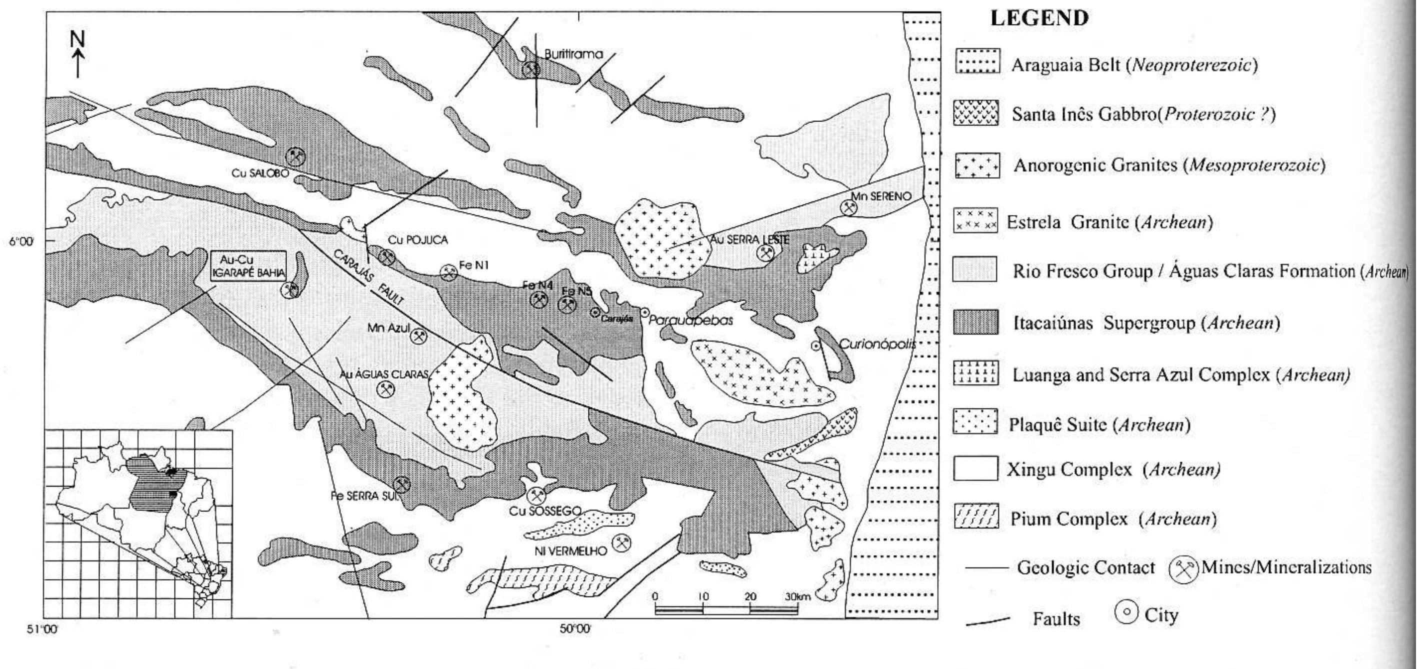

Figure 1 - Simplified map of the north region of Carajás (modified of Docegeo, 1988 and Barros et al., 1997).

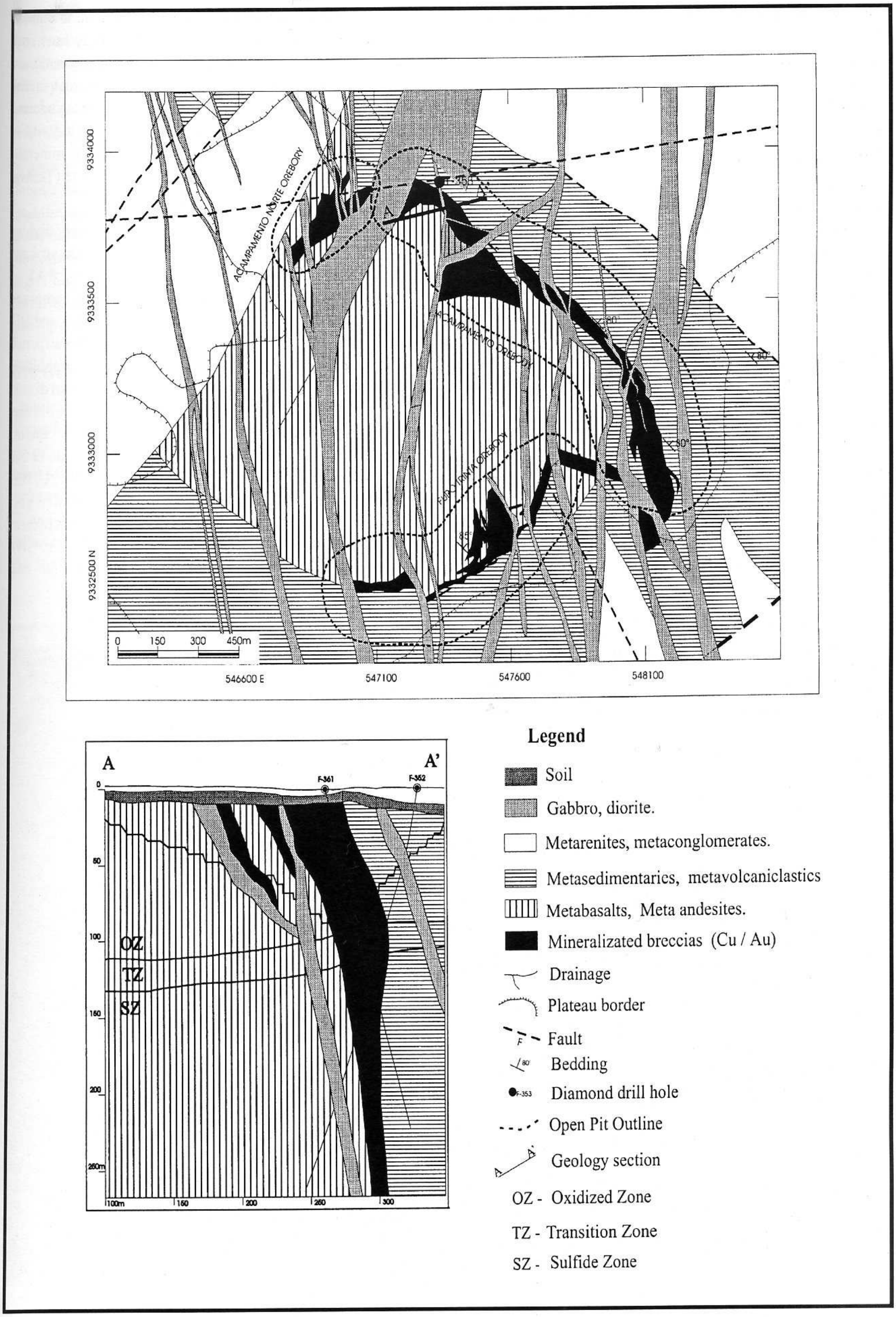

Figure 2 – Geological map of the Igarapé Bahia Copper-Gold mine and geological cross section A-A' through the Acampamento Orebody (simplified from Soares et al., 1999).

Mineralization

On the basis of the mineralogical composition of the different stages of ore oxidation processes, the Vale do Rio Doce Company-CVRD characterized three types of ore zone at Igarapé Bahia: oxidized zone, transition zone, and sulphide zone (Fig. 2). The later constitutes the aim of this work.

***Oxidized Zone*:** mineralization is generated by supergene enrichment with a high gold grade and low copper content due to leaching processes. The thickness of this zone reaches 200m in depth, and comprises hematite, goethite, gibbsite and quartz;

Transition Zone *(Cu-cemented):* reaches approximately 50m in thickness and is also mineralized by supergene enrichment. It is characterized by the presence of malachite, cuprite, native copper and goethite. Minor amounts of digenite and chalcocite associated with high grade Cu and Au are also characteristic features.

Sulphide Zone: corresponds to primary Cu-Au mineralization occurring at 200 to 250 m in depth. It is represented by hydrothermal breccias containing chalcopyrite, bornite, carbonate, magnetite and minor molybdenite and pyrite.

The primary Cu-Au mineralization consists of a broad range of heterolithic breccias, composed by host rock fragments (basic volcanic rocks, BIF, volcanoclastic and sedimentary rocks) enclosed in a hydrothermal matrix with Cu-sulphide (chalcopyrite, bornite and minor molybdenite, digenite and pyrite), magnetite, carbonate (siderite to calcite), fluorite, gold, uraninite, apatite, REE minerals, tourmaline, stilpnomelane and ferropyrosmalite (Tazava, 1999).

In this work, the primary mineralized rocks were divided into three main types, based on textural, mineralogical and geochemical characteristics: type 1 (Fig. 3A) — sulphidated magnetitic heterolithic breccia – is composed of centimetric fragments of meta-volcanic rocks and BIF cemented by variable amounts of hydrothermal matrix rich in chalcopyrite, bornite, magnetite, Fe-chlorite, amphibole (Fe-hornblende to actnolite) and subordinate ferropyrosmalite, molybdenite, digenite, cobaltite, stilpnomelane, quartz, uraninite, REE minerals, apatite, fluorite, biotite and tourmaline (Fig. 3C, D, E, F, G and H). This breccia exhibits an enrichment in Au, Fe, U, Mo, Ag, Cu, Pb, REE and P, Ca , W (Table 1). Native gold occurs as fine particles included in gangue minerals (quartz, siderite) and chalcopyrite (Fig.3E).; type 2 (Fig. 3B)- sulphidated magnetitic sideritic heterolithic breccia – this

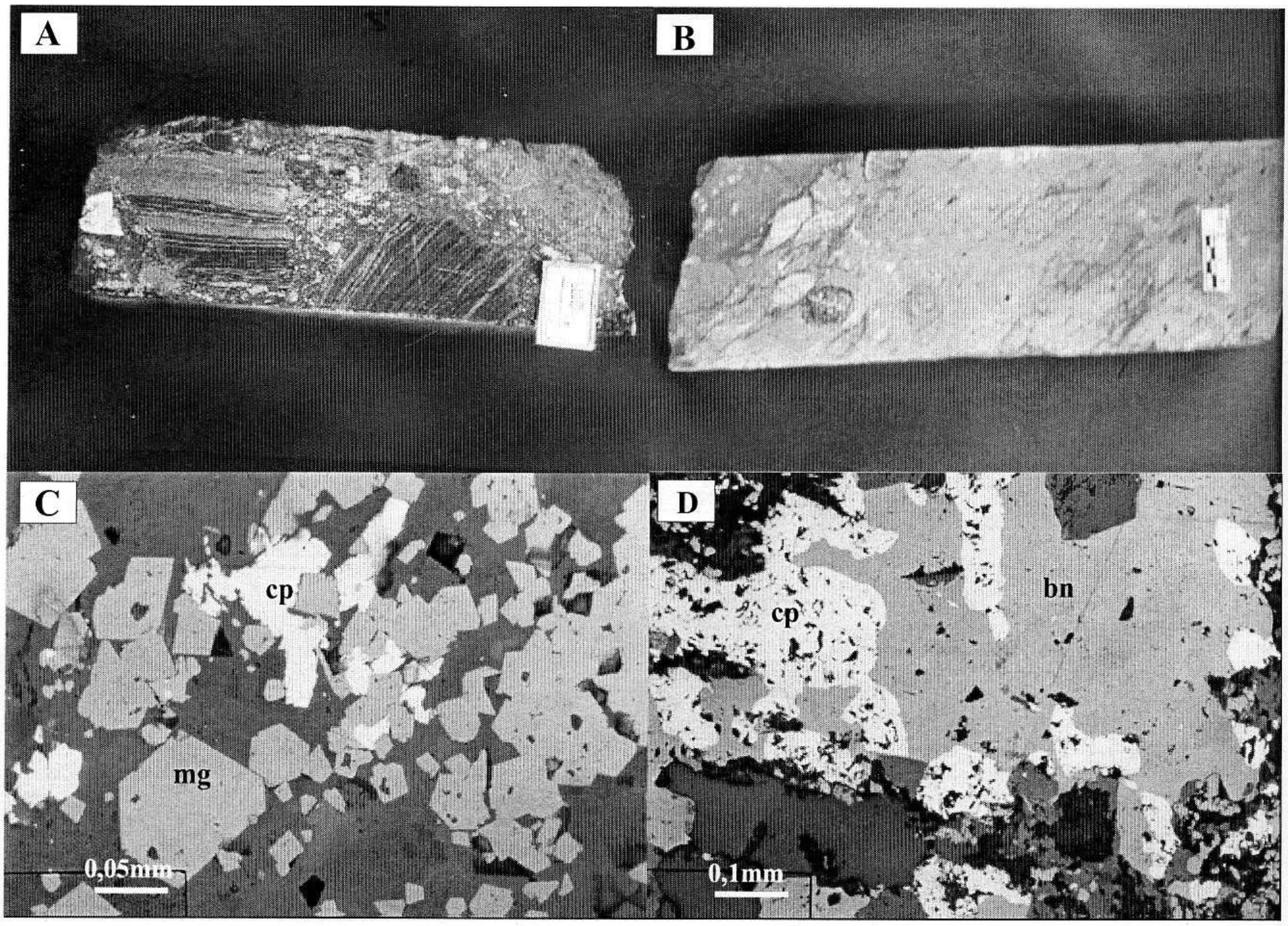

Figure 3 – A. and B. Photographs of drill core showing magnetitic and sideritic breccias, respectively, with fragments of BIF, metabasic and metasedimentary rocks. C. and D. Reflected light photomicrographs of magnetitic breccia. C. Euhedral magnetite (mg) associated to chalcopyrite (cp). D. Intergrowth bornite (bn) and chalcopyrite (cp).

breccia is different from the type 1 basically through the major amounts of siderite in the hydrothermal matrix; type 3 - intensely hydrothermalized metavolcanic rock with mainly chalcopyrite and chlorite, representing an enrichment of Au, Cu, U, Ca, Mo, Ag e Pb and consequently it does not show Fe and REE enrichment (Table 1).

In general, the spacial distribution of these breccia types doesn't have a defined boundary, but it is possible to establish approximately a trend of increase of iron content to the north of the Acampamento orebody, reflecting in a mineral change where the siderite and magnetite domains begin. Several milimetric to centimetric veins of calcite, siderite, quartz and fluorite, sometimes presenting chalcopyrite, cut the mineralized breccias and host rocks.

Ore Geochemistry

Chemical analyses of mineralized rocks reveal that the gold ranges from 0.98 to 7.73 ppm and the copper presents high values, reaching grades of 10% (Table 1). The contrasting ratios of copper, gold and iron between host meta-volvanic rocks and the mineralized zone can be observed in logs of Cu and Au content and magnetic susceptibility data. High values of Cu commonly correspond to high values of gold and magnetic susceptibility data, denoting a positive correlation (Fig. 4).

The mineralized breccias of Igarapé Bahia also contain anomalous concentrations of Fe_2O_3, Cu, U, Au, Ag, Mo, P_2O_5, REE, particularly Ce and La, CaO, W, and Pb if compared with host rocks (Table 1). The paragenetic mineral relations suggests a common metasomatic origin for these elements and shows the interaction of hydrothermal alteration like Fe-metasomatism, sulphidation, chloritization and carbonatization mainly.

The large enrichment in REE occurs in both magnetitic and carbonatic mineralized breccias, with values of normalized La reaching 2450. The La/Lu ratio of host rocks (<30) and mineralized breccias (>1300) indicate the preferential concentration of LREE by the hydrothermal solutions (Fig. 5a, b, c and d – Table 1). The REE minerals that are found in the Igarapé Bahia deposit are monazite, alanite, bastnaesite and parisite are related to hydrothermal alteration (Tallarico et al. 1998). Studies of REE mobility in hydrothermal environments are common, but no one reports high REE content transportation like that which occurs in the Olympic Dam deposit (Oreskes & Einaudi 1990) which has REE distribution patterns similar to the values obtained in mineralized heterolithic breccias of the Igarapé Bahia Au-Cu deposit.

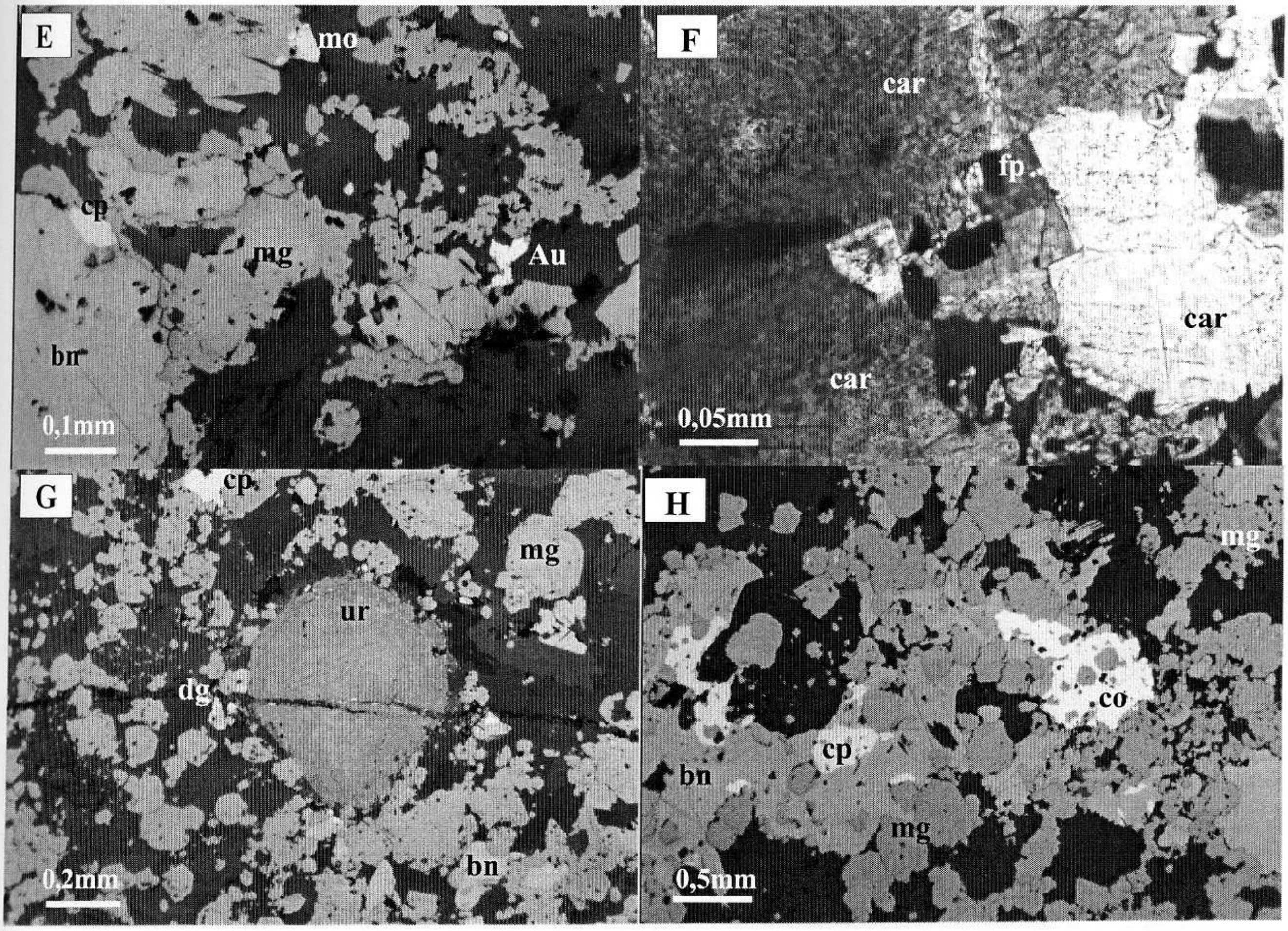

Figure 3 (*cont.*) - Photomicrograph E. Gold (Au), bornite (bn), chalcopyrite (cp) and molybdenite (mo) in a magnetitic matrix. Photomicrograph F. Ferropyrosmalite (fp) crystals associated with the carbonate (car), magnetite, chalcopyrite and bornite (opaques), NX. G. and H. Uraninite and cobaltite, respectively, in a matrix of magnetite, chalcopyrite (cp), bornite (bn), and digenite (dg).

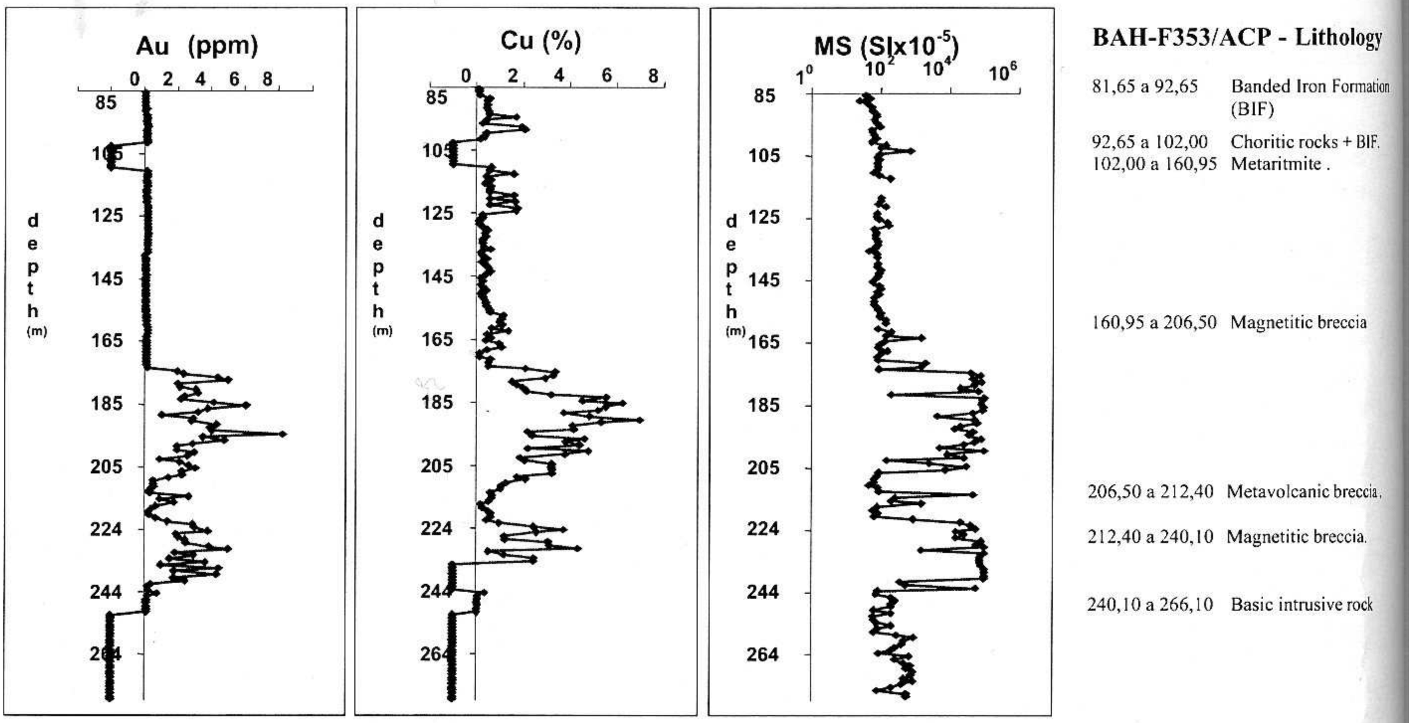

Figure 4 – Logs of Au, Cu contents and magnetic susceptibility (MS) in drill hole from Igarapé Bahia deposit.

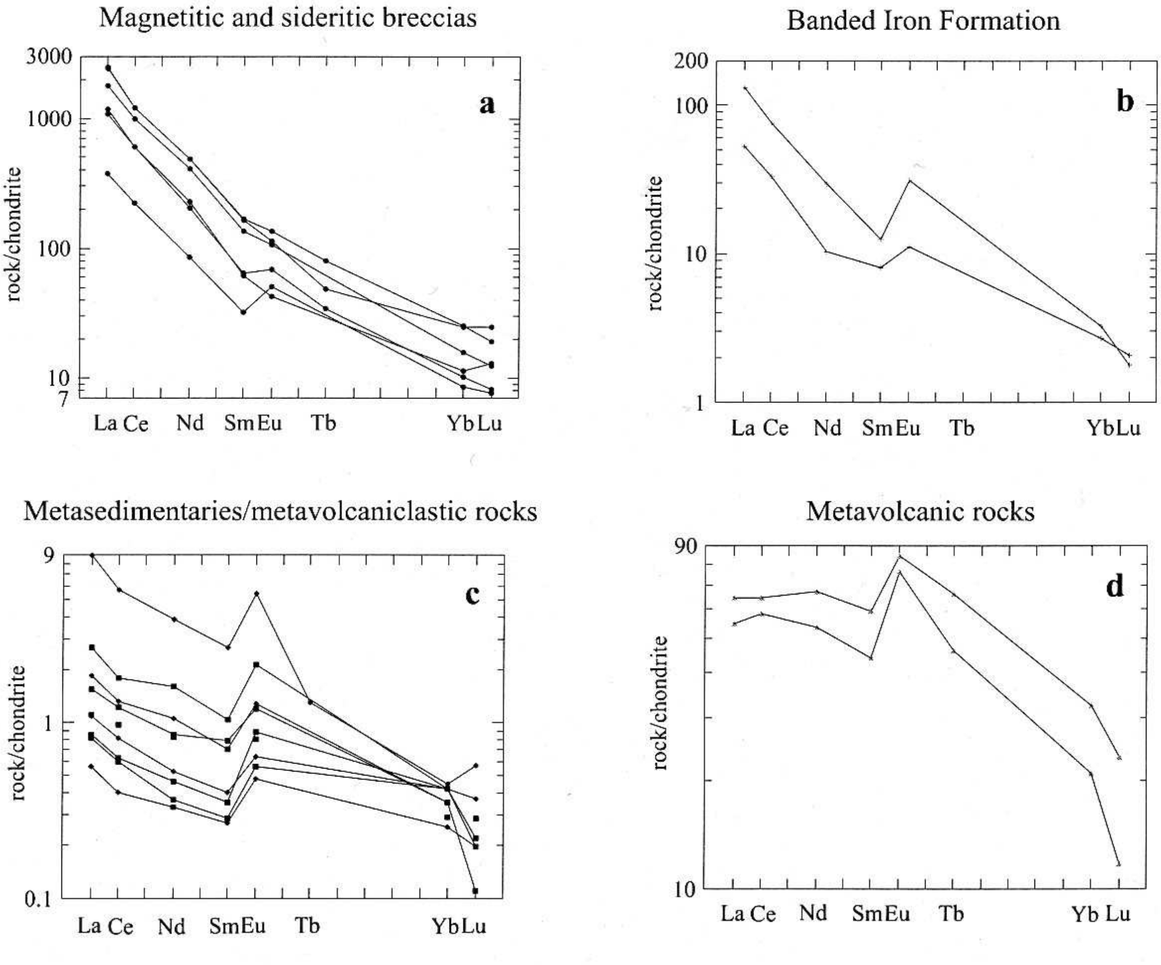

Figure 5 – Rare earth element distribution in magnetitic and sideritic breccias (a), banded iron formation (b), metasedimentary/metavolcanoclastic rocks (c) and metavolcanic rock (d) from the Igarapé Bahia deposit. (a), (b) and (d) chondrite composition according to Haskin et al. (1968) and (c) chondrite composition (NASC) according to Gromet et al. 1984.

Table 1- Chemical composition of Igarapé Bahia rocks. Major elements (wt.%) and trace elements (ppm). Sample identification by drill core and depth (m), ACP = Acampamento orebody, FT = Furo Trinta orebody. Lithology: RIT = Metarithmite, TF = Metatuff, SB = Sideritic breccia, MB = Magnetitic breccia, MH = Metabasic hydrothermalized, BIF = Banded Iron Formation (data from Tazava, 1999).

Sample	349ACP 489	365FT 143	384FT 290	9ACP 164	348ACP 128	352ACP 127	353ACP 178	353ACP 184,7	391FT 404.20	357ACP 119	348ACP 82
Lithology	RIT	RIT	TF	TF	SB	SB	MB	MB	MH	BIF	BIF
SiO_2	52.5	61.3	74.5	61.1	27.2	18.4	37.4	21.2	29.1	61.1	52.9
Al_2O_3	13.4	17.4	7.18	12.3	0.38	3.89	1.28	3.29	2.1	3.3	2.39
Fe_2O_3	23.6	10.1	13.4	14.9	47.3	42.7	52.1	55.5	16.4	31.7	41.6
MnO	0.16	0.06	0.06	0.05	1.91	1.43	0.53	0.47	0.24	0.24	0.15
MgO	4.35	1.47	1.58	1.22	1.58	2.11	0.83	1.79	1.2	0.47	0.02
CaO	0.22	0.04	0.1	0.75	0.71	4.04	2.13	4.6	19.6	0.61	0.08
Na_2O	0.02	0.09	<0.01	1.12	<0.01	<0.01	0.23	0.53	0.04	<0.01	<0.01
K_2O	0.25	3.78	0.43	2.57	<0.01	0.42	0.24	0.55	0.05	<0.01	0.05
TiO_2	0.54	0.66	0.32	0.67	0.02	0.33	0.1	0.24	0.12	0.1	0.09
P_2O_5	0.19	0.04	0.06	0.07	0.46	0.75	0.44	1.12	0.29	0.48	0.47
LOI	4.5	3.99	2.21	2.72	15.7	17.6	0.1	0.44	3.74	1.6	1.84
Total	99.7	98.9	99.8	97.4	95.2	91.7	95.4	89.6	72.9	99.6	99.5
Ba	55	442	92	602	10	68	36	91	23	<1	26
Sr	9	25	4	25	4	79	7	28	32	3	7
Y	12	16	8	17	40	63	25	73	101	11	12
Zr	127	136	119	284	9	60	22	44	21	25	27
Be	1	2	<1	1	<1	<1	<1	<1	<1	1	1
V	117	155	46	82	42	67	22	77	15	38	25
Au	0.03	0.04	0.03	0.28	4.01	2	3.73	7.73	1.58	0.07	0.02
As	24	130	4	<2	2	<2	8	59	5	5	35
Br	<1	<1	<1	<1	<1	<1	8	<1	<1	<1	<1
Co	64	22	31	30	37	74	61	94	55	26	69
Cr	98	130	63	140	8	21	10	26	10	28	29
Cs	<0.5	2.3	<0.5	2.1	<0.5	3.3	5.8	2.3	<0.5	<0.5	<0.5
Hf	3.3	3.9	2	7.2	<0.5	1.3	<0.5	<0.5	<0.5	0.8	0.6
Hg	<1	<1	<1	<1	<1	<2	<1	<1	<1	<1	<1
Ir	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Mo	<0.5	5	<0.5	34	86	<0.5	49	110	190	8	<0.5
Rb	<20	63	<20	78	<20	<22	<16	<20	<20	<20	<20
Sb	<0.2	1.1	0.3	0.5	0.5	0.9	1.4	0.9	0.5	0.8	1.4
Sc	20	25	7.2	15	1.4	9.7	4	6.6	5.7	4.4	3.8
Se	<3	<3	<3	<3	<3	<4	<3	<3	6	<3	<3
Ta	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Th	8.6	11	5.3	14	<0.5	3.4	<0.5	3.9	1.1	2.1	1.8
U	4.3	3.9	1.7	16	103	46	86.4	160	110	3.9	3.7
W	3	8	<0.3	<0.3	<0.3	27	50	<0.3	<0.3	4	<0.3
Cu	836	2135	3099	13278	23006	30386	16891	55127	76325	4980	706
Pb	<5	<5	<5	16	64	48	57	119	85	<5	<5
Zn	38	26	18	13	14	59	9	58	20	17	5
Ag	<0.4	<0.4	<0.4	2.8	4.4	23.7	5.6	29.3	8.2	1.6	<0.4
Ni	88	76	45	59	46	136	104	141	117	20	20
Cd	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	2.8	<0.5	<0.5
Bi	<5	10	6	22	<5	<5	<5	<5	11	<5	<5
La	26.5	82.9	17.4	278	575	784	374	777	20.7	42	17
Ce	42	120	27	381	772	940	476	940	51	60	26
Nd	14	49	10	118	236	280	130	280	39	17	6
Sm	2.1	6.2	1.6	16	24.9	30	11.5	31	11	2.3	1.5
Eu	1.1	2.7	0.6	6.8	7.6	8.1	3	9.6	6	2.2	0.8
Tb	<0.5	<0.5	<0.5	1.1	<0.5	2.4	<0.5	4	3.3	<0.5	<0.5
Yb	1.3	1.3	0.8	1.4	2.9	4.6	2.1	4.7	6	0.6	0.5
Lu	0.09	<0.05	0.09	0.26	0.42	0.85	0.44	0.65	0.79	0.06	0.07

Stable Isotopes

Carbon and oxygen isotope ratios were measured for 13 samples of Igarapé Bahia hydrothermal carbonate at the University of Brasília stable isotope laboratory. These analyses were performed on calcite and siderite from veins, disseminated in metabasic rocks and matrix of mineralized breccias (table 2).

Carbon isotopes data exhibited a narrow range of d^{13}C (-9.3 to -5.8‰), while oxygen isotopes presented a broad variation of d^{18}O (0.7 to 9.4‰). These results are plotted in Figure 6, and compared with others known reservoirs.

The narrow range of negative values of d^{13}C indicates the presence of magmatic fluid. The wide range of d^{18}O values is interpreted as resulting from the mixture of magmatic solutions (high values) with meteoric fluids (low values). Fluid inclusion studies of the Igarapé Bahia hydrothermal system reveal the existence of two inclusion types: (*i*) 100-400°C and up to 42% wt. eq. NaCl; and, (*ii*) 100-150°C and from 10 to 25% wt. eq. NaCl (Ribeiro 1989; Althoff et al., 1994; Lindenmayer et al., 1998), denoting the action

Table 2 – Carbon and Oxygen isotope analyses from Igarapé Bahia carbonates (data from Tazava 1999).

Sample	Description	δ^{13}C (PDB) (‰)	δ^{18}O (SMOW) (‰)
F350/ ACP – 278m	Disseminated and vein (calcite)	-6,78	+6,86
F350/ACP - 307,5m	Disseminated (calcite)	-6,42	+6,33
F346/ACP – 308m	Disseminated and vein (calcite)	-7,64	+4,72
F391/CT - 421,4m	Vein (calcite)	-7,82	+2,56
F356/ACP - 402,9m	Disseminated and vein (calcite)	-6,67	+5,66
F384/ACP - 392,6m	Vein (calcite)	-7,90	+1,84
F350/ACP – 376m	Disseminated (calcite)	-7,90	+5,73
F340/ACP - 186,7m	Vein (calcite) with chalcopyrite	-9,30	+0,70
F349/ACP - 333,6m	Dissem.(calcite) with chalcopyrite	-5,83	+9,42
F349/ACP - 434,05m	Matrix (siderite) with chalcopyrite	-7,63	+8,12
F361/ACP - 110,90m	Matrix (siderite) with chalcopyrite	-6,46	+9,25
F352/ACP - 126,90m	Matrix (siderite) with chalcopyrite	-8,02	+1,90

of two distinct fluids in the Igarapé Bahia system. Then, on the basis of both stable isotope and fluid inclusion evidence, the most probable depositional mechanism for the Igarapé Bahia ore is the interaction between a hot saline and acid magmatic fluid with a low temperature and less saline meteoric solutions.

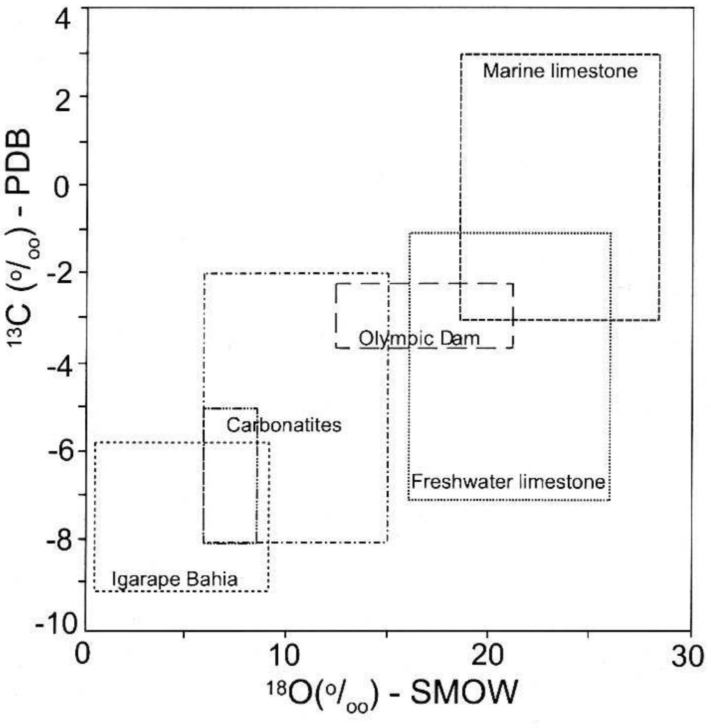

Figure 6 - d^{18}O vs. d^{13}C values for 13 samples of Igarapé Bahia carbonate, compared with carbonate values from carbonatites (Taylor et al., 1967; Deines and Gold, 1973; Pineau et al. 1973), limestone (Craig 1953; Keith and Weber, 1964) and Olympic Dam siderites (Oreskes and Einaudi, 1992).

Discussion and Conclusion

Fe-oxide Cu-U-Au-REE deposits are an important new type of ore deposit that has only been categorized in recent years. However, the large variations in their geological setting supports a wide range of views on the origins of these deposits, including sedimentary-exhalative, subsurface intrusion of immiscible Fe-oxide melts and hydrothermal replacement (Gow et al., 1994).

Several genetic models have been proposed for the Cu-Au (REE-U) Igarapé Bahia deposit. The first suggestion of a genetic model was published by Ferreira Filho (1985) and Ferreira Filho and Dani (1985), that interpreted this mineralisation as a stringer-type, formed according to the classical process which involves volcano-exhalative deposits. Ribeiro (1989) discussed the possibility of a multistage genesis involving remobilization of primary Archaean mineralization during Proterozoic time. To Sachs (1993) two main types of mineralization are striking: a volcano-exalative stratiform, and another formed by superimposed hydrothermal events. Althoff et al. (1994) concluded that the style of mineralization doesn't fit any classical models of sulphide deposits. The authors have proposed a model where mineralisation processes resulted from sea water circulation in response to the thermal energy dissipation from volcanic rocks. Cu and Fe were leached and re-precipitated as Au-containg sulphides, preferably in hydrothermal veins. Huhn (1996) and Huhn and Nascimento (1997) suggested that the Igarapé Bahia deposit is included among the Fe-oxide (Cu-Au-REE-U) class of deposits proposed by Hitzman et al. (1992). This hypothesis is confirmed by Tallarico et al. (1998) and by Tazava (1999). Lindenmayer et al. (1998) proposed an epigenetic mineralization related to anorogenic Proterozoic granitic plutons and Almada (1998) suggests a mineralization model of the Besshi type.

On the basis of the mineralogical characteristics, stable isotope and fluid inclusion analyses, the genetic model proposed in this paper for the Igarapé Bahia involves a mixture of magmatic fluids with meteoric solutions, that percolated the volcano-sedimentary sequence. This interpretation is analogous to the model proposed by Oreskes and Einaudi (1992) and Haynes et al. (1995) for the Olympic Dam deposit, Australia and may be compared to the other intrusion-related hydrothermal iron oxide (Cu-Au-U-REE) deposits.

The Igarapé Bahia deposit presents an anomalous enrichment in REE. Gieré (1996) proposes that wide amounts of REE (>100 ppm) can only be transported by magmatic fluids of high temperatures and salinity. According to Banks et al. (1994), in ancient hydrothermal systems, the largest amounts of REE (SREE = 1290ppm) have been found in very saline magmatic solutions, showing that saline solutions of high temperature are very effective for carrying large proportions of REE. In the Igarapé Bahia deposit, the evidence of high temperature saline fluids are supported by fluid inclusion data (Ribeiro 1989) with H_2O-$NaCl$-$CaCl_2$ composition and by the presence of ferropyrosmalite in the mineralized breccia matrix. Ferropyrosmalite in the Igarapé Bahia deposit show high contents of chlorine (2.77 to 5.38% wt. - Tazava et al., 1999) and has been related to high salinity subaquosus deposits. We interpret the large enrichment of REE in the Igarapé Bahia deposit, particularly La and Ce, is related to an intense hydrothermal activity with fluids of high temperature and salinity. The metal transport was dominated by chlorine complexes with high temperature and salinity, low pH and moderate to high $f(O_2)$ according to the characteristics suggested by Davidson and Large (1994) for Au-Cu-magnetite association.

In general, there is a common spatial and temporal relation between granite intrusion and ore formation. In the Carajás region, the two largest events of granite emplacements occur in Archaean and Proterozoic times. However, the timing of the complex events that produced the iron oxide – (Cu-Au-REE-U) mineralization are still unclear. It's possible that the Igarapé Bahia deposit constitutes a example of iron oxide – (Cu-Au-REE-U) deposit in the Archaean.

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