THE EXPEDITO MASSIVE SULFIDE DEPOSIT, MATO GROSSO

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ABSTRACT The Expedito massive sulfide Pb-Zn deposit is located 14 Km north of the Aripuanã town, in the northwestern portion of the State of Mato Grosso, western Brazil. The deposit occurs within a thick pile of acid to intermediate volcanic rocks and co-genetic intrusions of the Uatumã Group. These rocks are believed to be related to Mesoproterozoic intracontinental rift, supported by U-Pb zircon age of dacitic volcanics (1,762 ± 6 M.y.) and of a granite (1,755 ± 5 M.y.). The deposit is hosted by a horizon of dacitic lapilli and crystal tuff interlayered with massive dacitic porphyritic flows and carbonate and chert layers. The deposit consists of several discordant and discontinuous lenses of massive to semi-massive pyrrhotite, pyrite, sphalerite, galena, chalcopyrite, and arsenopyrite. Sulfides also occur disseminated or in veins. There are two types of ores: sphalerite-rich, more prominent, and chalcopyrite-rich with high Cu-Au grades. These deposits are enveloped by a hydrothermal alteration halo consisting of chlorite, biotite, and a peculiar assemblage of calc-silicate minerals associated with carbonate. Magnetite-rich zones overprint the massive sulfides and suggest post-depositional sulfide replacement. The ore lenses are intimately associated with the volcanic rocks, suggesting an exhalative origin. However, the absence of typical exhalative textures, intense calc-silicate alteration, and syn-deformational character of the deposits do not fit the classical VMS model. Therefore, an intrusion-related, epizonal hydrothermal replacement model is proposed.

Keywords:

INTRODUCTION The Expedito Deposit is located in the Aripuanã District, western Mato Grosso State, Brazil, approximately 700 km northwest of Cuiabá (Fig. 1). The deposit was discovered through the drilling of a gold quarry worked since the early '80s by *garimpeiros*. It includes three orebodies named Valley , Massaranduba e Babaçu, set along a 4 km long NW-SE trending sigmoidal fold belt, plunging northwestwards. The orebodies crop out as gossans formed by oxidation of the primary sulfide lenses (Fig. 2). Total resources of the Valley Deposit are 11.65 million metric tons @ 6.29% Zn, 2.25 wt% Pb, 0.07 wt% Cu, 65 g/t Ag, 0.25 g/t Au. (Ambrex, Public News Release 1998).

The deposit occurs at the western portion of the Guaporé Shield, and is related to plutonic and volcanic rocks of the Uatumã Group, which possibly accumulated in an intra-continental rift (Almeida 1974). Volcanic activity was accompanied and followed by the deposition of a thick shallow marine to fluvial sedimentary sequence.

U-Pb Shrimp dating of zircon from volcanic and intrusive rocks, both related to the mineralization, yield ages of 1,762 ± 6Ma and 1,755 ± 5Ma respectively.

The Expedito deposit consists of an unique economic concentration of Zn-Pb-(Cu-Ag-Au) hosted by the acid volcanic rocks of the Uatuma Group. The purpose of this study is to describe the geologic environment and main features of the Valley Deposit orebody.

LOCAL GEOLOGY The Expedito deposit is hosted by unmetamorphosed acid volcanic rocks and minor chemical and epiclastic sediments of the Iriri Formation, which belongs to a part of the Uatumã Group. The volcanic succession is dominantly pyroclastic, and includes rocks of rhyolitic, dacitic and rhyodacitic composition.

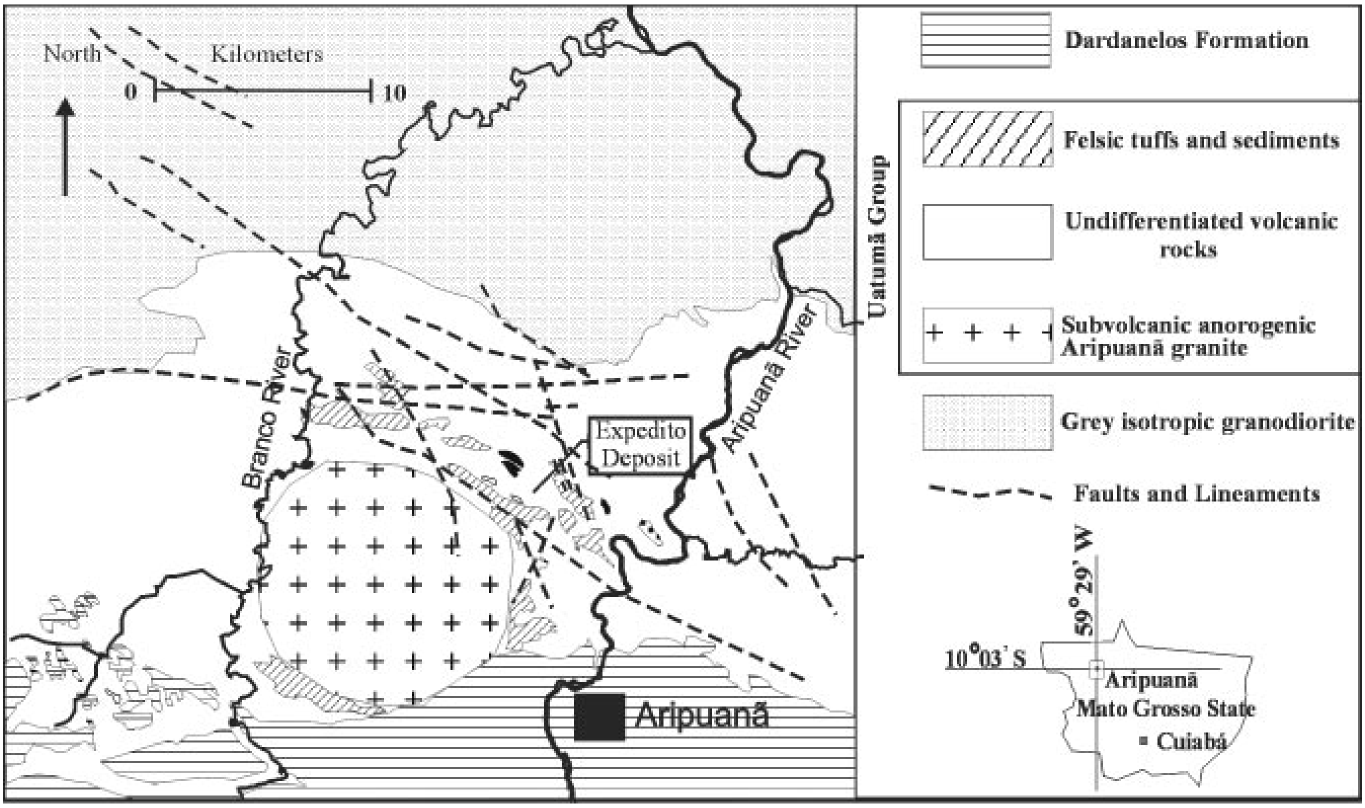

Figure 1. Location map and regional geology of the Aripuanã Region

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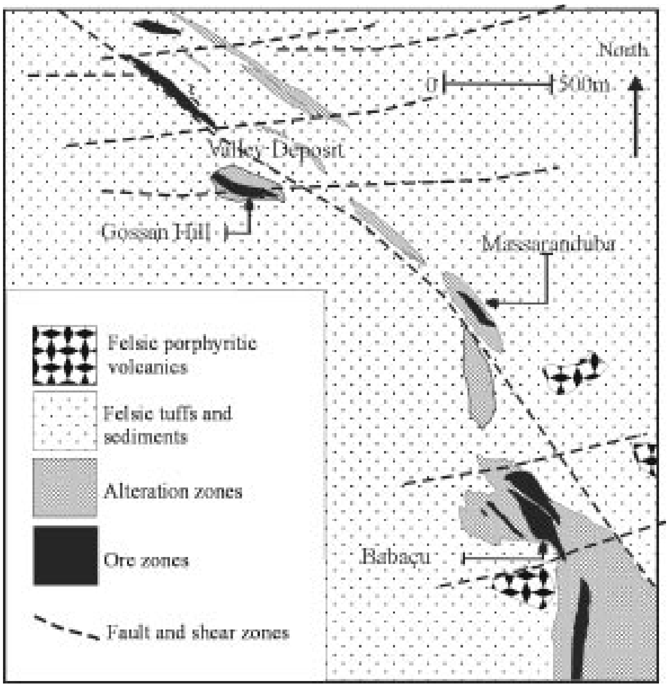

Figure 2. Simplified Geology of the Area of the Expedito Deposit (modified from Collins et al. 1998)

Table 1- Average chemical composition of least altered rocks. (n) = number of samples

	Basalt (5)	Dacite (25)	Rhyolite (30)
SiO_2	48.68	68.71	73.40
TiO_2	0.80	0.43	0.19
Al_2O_3	15.29	13.77	11.10
Fe_2O_{3T}	12.94	4.03	2.05
MnO	0.24	0.21	0.08
MgO	8.50	1.44	1.14
CaO	11.26	1.32	0.86
Na_2O	2.01	1.92	2.23
K_2O	0.81	4.45	3.81
P_2O_5	0.08	0.10	0.04
LOI	1.52	1.28	1.08
Total	100.22	99.26	99.53
Ba	273	1057	890
Rb	55	135	97
Sr	205	72	31
Nb	1.3	14.5	11.4
Zr	40	264	169
Y	23	39	35
Th	1.14	4.54	5.19
Cr	267	2	1
Ni	1	2	0
V	5	19	1
Cu	12	3	4
Pb	15	2	3
Zn	10	11	3

Towards the northwest of the deposit, the host sequence strikes N55W, inflecting to N15W in the southeastern portion, and dips usually moderate to steep to southwest. Minor folds have an axial plane trending EW and dipping moderately to the north, with axis plunging moderately to northwest. Only one phase of deformation is evident in the area and its intensity increases towards the proximity of the major faults that host the deposit. Although orebodies and host rock have similar strike, the former dip crosscutting the host rocks. This discordant relation is better observed at the contact between ore and less deformed laminated rocks.

The dominant host-rock of the orebodies is a fine to coarse-grained ash, lapilli, and crystal tuffs with minor intercalation of sericitized feldspatic siltstone. All rock types are grayish-green to brownish-red and are composed mainly of quartz and feldspar with rare lithic fragments, ranging from fine grained to lapilli. Rounded quartz are frequent may have formed by filling vesicles of pumice fragments. Crystal tuffs are porphyritic, with millimetric euhedral feldspar crystals and centimetric rounded quartz set in an ash size and sericitized groundmass, occasionally with microspherulites.

A chemical sedimentary unit occurs along the strike of the Expedito deposit. The horizon consists of chert and carbonate with subordinate silty and clayey laminae suggesting subaqueous deposition. The extension of this unit outside the prospect area is still unknown.

The felsic massive volcanic rocks are silicified and their composition falls within the range of rhyolite and dacite. They are characteristically yellow and porphyritic. Phenocrystals include corroded and euhedral quartz, sericitized orthoclase, plagioclase and chloritized biotite within a sericitized and recrystallized quartz-feldspar groundmass.

Sub-alkaline (tholeiitic) basalts occur regionally in close association with quartz and feldspar porphyry and rhyolitic volcanics, suggesting a bimodal volcanism.

Geochemical data of local and regional rocks indicate the immobility of Ti, Zr, Nb and Y as predicted in literature (e.g. Pearce and Cann 1973, Floyd and Winchester 1975). Chemical classification of weakly altered rocks (LOI < 2%) based on the relationships between these elements (Table 1, Fig.3), corroborates the presence of a bimodal volcanic pile. Figure 4 indicates that these rocks are not only sub-alkaline but also co-magmatic.

THE VALLEY DEPOSIT

The Gossan Hill is an exposure of oxidized ore more than 40m thick. The soil anomalies have more than 500 ppb Au and 0.5% of Pb. Underground, deposit consists of several discordant tabular bodies enveloped by shear and breccia zones. In general, the most significant ore zones are rimmed by a breccia, suggesting that a fault controlled the mineralization. Unlike barren and unaltered country-rocks, the orebodies and the alteration zone are intensely deformed.

The massive sulfide bodies consist of pyrite, sphalerite, pyrrhotite, and galena, disseminated or in bands, together with minor amounts of chalcopyrite. Semi-massive bodies have a compositional banding given by the alternation of zones rich in pyrite or pyrrhotite and sphalerite-rich levels. Although resembling a syngenetic feature, no primary sedimentary textures or structures were observed within the sulphide zones. Disseminated sulfides occur as veinlets, stringers, and open-space filling, including boxwork and crustiform veins.

Selected ore samples with Zn > 3% and Cu > 0.3%, show that there is a high positive correlation between Pb and Ag, a moderate positive correlation between Zn and Pb and Au and Cu, and a negative correlation between Cu-Zn, Cu-Pb and Cu-Ag. This suggests a metallogenetic relationship common to Archean VMS deposit (Knuckey et al. 1982, Piché and Guha 1991) (Table 2).

In decreasing order of abundance, the ore minerals are pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, carbonates, magnetite, arsenopyrite, and cassiterite. Fine-grained sphalerite presents a distinct metallic luster, while less frequent coarse-grained crystals are brown with a glassy luster and suggest two generations. Galena occurs in veins, segregation, or inclusion in sphalerite. The majority of the galena crystals are fine-grained, but coarse crystals also occur in veinlets or in cavity-fillings. Electron microprobe analysis indicated that galena contains trace amounts of silver. Chalcopyrite is rare in the Zn-rich ore. In the Cu-rich zones, chalcopyrite occurs associated with pyrrhotite, filling dilatational fractures and rimming pyrite. Pyrite is fine-grained and subhedral, and when euhedral, displays corroded boundaries. Pyrrhotite occurs either as granular crystals or as linear

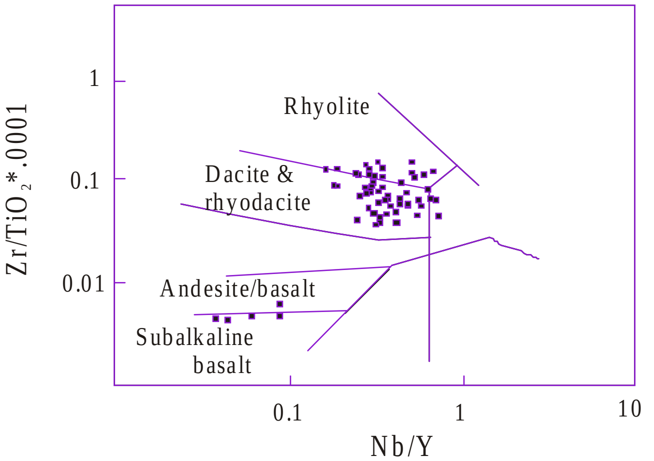

Figure 3-Winchester and Floyd 1977, discriminant plots for representative volcanic rocks of the Expedito District.

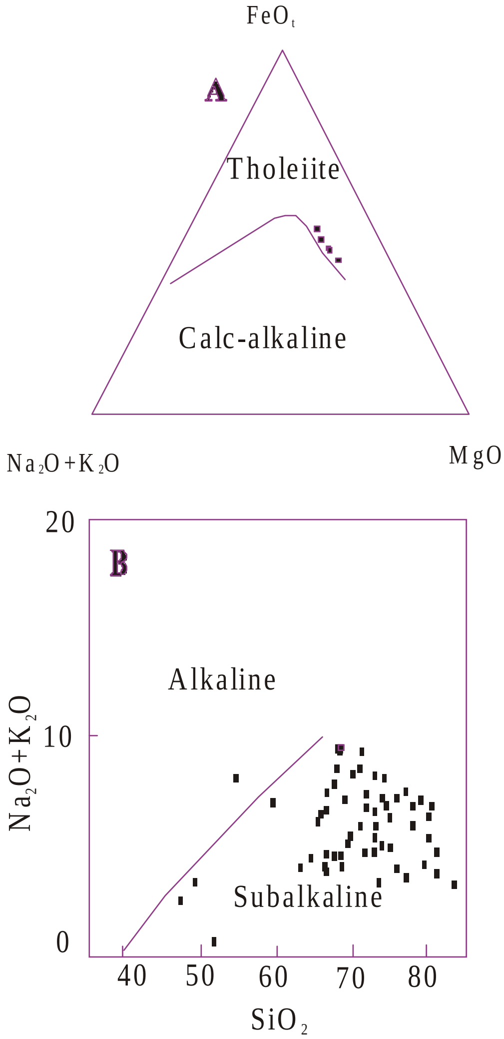

Figure 4 - Magmatic affinity of volcanic rocks: (A) AFM diagram for basalts and (B) Total Alkali X SiO2 diagram of basalts and felsic rocks (Fields according Irvine and Baragar 1971)

Table 2 – Correlation matrix of ore samples (288 Samples)

	Cu	Pb	Zn	Ag
Au	0.42	-0.07	-0.12	-0.03
Ag	-0.14	0.92	0.41	
Zn	-0.29	0.53		
Pb	-0.24			

Table 3 – Isotopic composition of galena crystals

Sample	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
F16/219	15.861	15.414	35.575
F19/257	15.835	15.440	35.685
F25/207	16.004	15.652	36.302

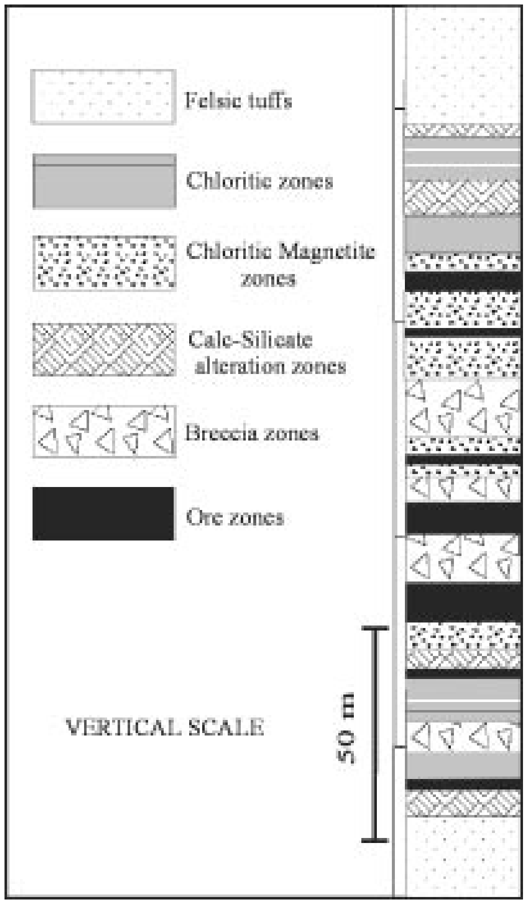

Figure 5 - Sketch of relationship of mineralization and alteration zone

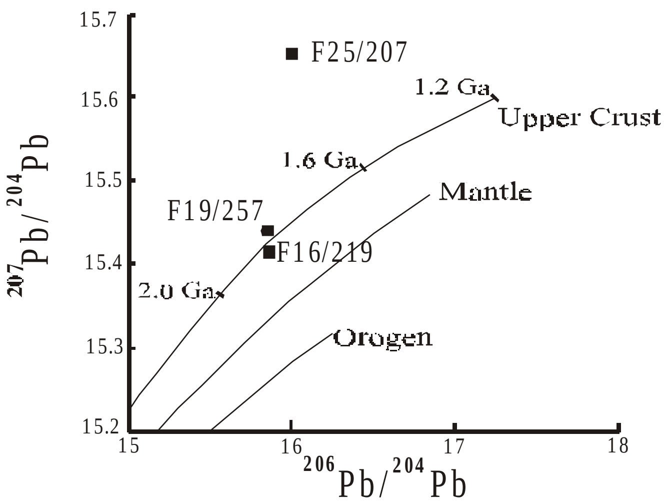

Figure 6- Pb isotopic reservoir growth curves of the plumbotectonic model (Zartman and Doe 1981) (Version II), applied to the Expedito sulfide deposits

blebs in sphalerite. Magnetite is subhedral and replaces sulfides in a characteristic "porphyroblastic" texture. Carbonates fill fractures and post-ore veins. Cassiterite is rare and occurs as microcrystalline grains recognized only in SEM analyses.

A widespread alteration zone, reaching up to 200 m, resulted from the channeling of hydrothermal fluids through the shear and fault zones (Fig.5). The zones are concordant with the sulfide lenses, and consist of chlorite with variable proportions of biotite, tremolite-actinolite, magnetite, and carbonates. Alteration is zoned and consists of:

1)-An outer shell with porphyroblastic biotite in a fine grained chlorite-biotite groundmass;

2)-Calc-silicate alteration (tremolite-actinolite) coupled with carbonatization and silicification. In hand specimens, this zone is mottled, occasionally brecciated, and contains granoblastic and acicular amphibole. Rocks from this zone have locally a talk-like appearance;

3)-A distinctive chlorite-magnetite halo with porphyroblastic magnetite, partially replacing sulfides;

4)-A core of breccia hosting the major Zn-(Pb) lenses.

Lead isotopes of galena from the Valley deposit (Table 3), when interpreted under the Stacey and Kramers two-stage model, yield model ages of 1.76, 1.82 and 1.99 M.y. The first two agree with the ages of zircon from barren igneous country rocks. These data adhere to the upper crust evolution curve of Zartman and Doe (Version II) (1981) (Fig.6).

DISCUSSION The general lack of detrital sedimentary structures and the widespread occurrence of cherts suggest that the host rock accumulated in a sub-aqueous environment. The intercalation of thinly and rhythmically laminated tuffs within thick homogeneous intervals of pyroclastic rocks may have resulted from oscillating intensity of the volcanic activity. Laminated intervals may represent reworked tuffs and exhalites.

The clear association of the orebodies with a brittle deformation zone ant the lack of consistent evidence of sea-floor discharge of sulfides, preclude the syngenetic models. The filling of the breccia matrix by hydrothermal minerals is characteristic of hydraulic explosion breccias, formed during fluid expansion triggered by underground phase separation (Hedenquist et al. 1985). Likewise, crustiform veins and veinlets are typical of the same conditions. This evidence suggests that the mineralization took place at shallow crustal levels, possibly connecting to the surface.

Satellite image interpretation together with regional mapping and field and petrographic observation show that the circular structure (Fig. 1) represents a multiphase granitic intrusion emplaced in epizonal conditions. The deposition and preservation of a thick tuffaceous sequence requires topographic depressions, which could represent subsidence structures resulting from magmatic evacuation. The structure could possibly represent a caldera intruded by shallow pluton(s) during the resurgent stages, as suggested by the intimate spatial and chronological association of the volcanic pile with granites.

The orebodies are associated with zones of hydrothermal alteration controlled by syn-deformational faults, which, together with the isotopic data, indicates that accumulation of the host volcanic sequence deformation, granite emplacement, mineralization, alteration, and the fault system was contemporaneous. The overprinting of distinct alteration assemblages could be explained by successive reactivation of the synvolcanic faults, which in their turns would control the variable intensity of the hydrothermal alteration indicated by different styles of metassomatic replacement.

Under this interpretation, one single volcanic episode could, during early stages, chloritize and develop carbonate open-space filling during faulting, in a typical propylitic process. Later stages would be represented by a more intense reactivation and high temperature reactions, resulting in a calc-silicate assemblage, typically stable at temperatures above than 350°C (Winkler 1974). High-temperature alteration could also explain the magnetite-chlorite association that replaces the sulfides.

The calc-silicate alteration assemblage is intimately associated with the orebodies, as indicated by their simultaneous occurrence at the intersection of syn-volcanic faults with a carbonate-rich chemical-sedimentary unit. In spite of being volcanic-related deposits, they are probably not exhalative. They may have formed by reaction of acid magmatic-hydrothermal fluids released from a coeval granite and flushed along faults formed by accommodation of the country rocks during the final stage of emplacement of the intrusion. Even not being exhalative, the Valley Deposit, the synchronism between volcanism, sedimentation, granite emplacement, faulting, alteration, and mineralization in a sub-aqueous environment favors the occurrence of syngenetic volcanic-associated deposits in this region.

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