ISOTOPIC DATA FROM PROTEROZOIC SEDIMENT-HOSTED SULFIDE DEPOSITS OF BRAZIL: IMPLICATIONS FOR THEIR METALLOGENIC EVOLUTION AND FOR MINERAL EXPLORATION

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Abstract: Geological, petrographic, fluid inclusions studies and isotopic data of seven Proterozoic sediment-hosted Pb-Zn-Ag sulfide deposits of Brazil, permit the estimation of the age of the hosting sequence and the mineralization, the nature of the sulfur and metal sources, the temperature range of sulfide formation and the environment of deposition of the mineral deposits. The studies suggest that they were formed during periods of extensional tectonics: Growth faults or reactivated basement faults were responsible for localized circulation of metal-bearing fluids within the sedimentary sequences. In most cases, sulfides were formed by the reduction of sedimentary sulfates. Linear stuctures are important controls for sulfide concentration in these Proterozoic basins.

INTRODUCTION

Majority of the world class base metal deposits are present in the Proterozoic sedimentary continental basins, making them primary targets for exploration. Such deposits, with total reserve exceeding 250 million tons of metal content, are found in Australia, Canada and Africa. In contrast, no huge deposits have been found in South America, despite the favorable geological setting. This is all the more intriguing in the case of Brazil, which represents nearly half of continental area and has Proterozoic sedimentary basins extending more than 500,000 km^2. The major Pb-Zn mines are Morro-Agudo and Vazante in Minas Gerais, whose total metal content is 2 to 3 million tons. There is an urgent need to find new economic deposits. This can only be achieved through a concerted effort by geologists from mining companies and academic institutions, resulting in the development of satisfactory metallogenic models and employment of sophisticated exploration tools to locate high priority targets.

The present study reports geological, isotopic (Pb, S) and fluid inclusions data from seven sediment-hosted Pb-Zn-Ag deposits (from Archean-Paleoproterozoic to Early Paleozoic) of Brazil (Fig. 1). The data are employed to conceive a metallogenic model for these deposits and their possible application for mineral exploration strategies.

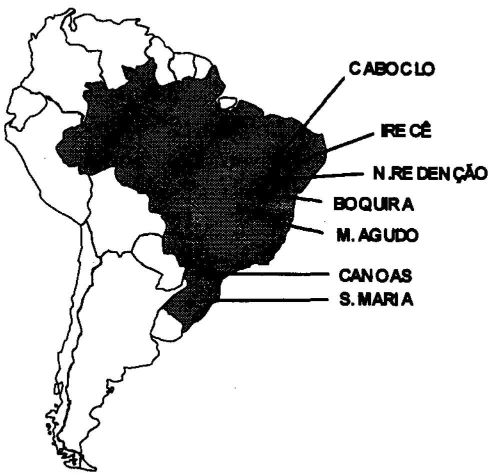

Figure 1: Location of the Proterozoic sediment-hosted sulfide deposits studied.

GENERAL CHARACTERISTICS OF THE DEPOSITS

All the deposits have massive and/or disseminated stratiform+stratabound and vein type mineralization, with remarkable stratigraphic control. Sphalerite, galena and pyrite, associated with barite, calcite and quartz are present, except in Boquira and

NAME	MORPH	ORE MINER.	GANGUE	HOST ROCKS	STRUCT. ASSOC.	AGE OF HOST(Ga)	AGE OF MIN.(Ga)
STA. MARIA (RS)	Dissem. Amas Stratab. Veins	pyr, sph, gal, (Ag)	qz, microcl, albite, moscov, apatite, biotite, tourmal.	Arkosic sandst., siltstones and conglom.	Faults NE-SW	0.57	0.57
IRECÊ (BA)	Dissem. Amas Stratab. Veins	sph+Ag, pyr, gal, jordanite	calcite, dolomite, quartz, chert, barite, gypsum, barr.dol.	Dolaren. (silicified)	?	0.60-0.65	0.60-0.65 (?)
NOVA REDEN-ÇÃO (BA)	Amas Veins Stratab.	gal, sph, pyr, (Ag)	qz, chert, calcite, dolomite, barite	Silicified dolaren.	Faults NW-SE	0.60-0.65	0.60-0.65 (?)
MORRO AGUDO (MG)	Stratifor. Veins	gal, sph, pyr, (Ag)	calcite, dolomite	Dolaren. Dolosilt.	Faults N-S	0.60-0.65	0.65
CABO-CLO (BA)	Stratab. Veins	gal, (Ag), pyr	calcite, dolomite, barr.dol., qz., microcl., albite, moscovite tourmal.	Dolaren.	Growth Faults N-S	1.2	1.2 (?)
CANOAS (SP)	Stratifor. Veins	gal., sph. pyr, pyrr. (Ag)	barite, qz., chert, amphib.	Amphibo-lite, Calc-silicate	Growth Faults NE-SW	1.5 - 1.7	1.5 - 1.7
BOQUIRA (BA)	Stratifor. Dissem. Veins	gal, sph, pyr, pyrr, (Ag)	amphib., magnet., qz,	Amphibo-lite, Car-bonate	?	2.7	2.5 - 2.7

Figure 2: General characteristics of the deposits studied

in Caboclo, where barite has not been found. Silver content is generally high. Mineralization is clearly associated with faults in Canoas, Caboclo, Morro Agudo, Nova Redenção and Santa Maria. Except for Boquira and Santa Maria, hosted by siliciclastic rocks, all the deposits are carbonate-hosted, mainly in dolomites (Fig. 2). Of the deposits listed, Morro Agudo is the only mine in operation , producing 500,000 tons/year (run-of-mine). Reserves in Morro Agudo are calculated in 9 millions tonnes with 6.2% Zn and 2.0% Pb. Boquira was the most important lead mine in Brazil for about 40 years, until 1991, when the mine operation ceased due to the lack of proven reserves. The Boquira mine produced six million tonnes of ore with 9% Pb and 2% Zn.

LEAD AND SULFUR ISOTOPIC DATA

The lead isotope data of five deposits, when plotted in the evolution curve of Zartman and Doe (1981) fall near or above the upper crustal evolution curve (Fig. 3), with calculated model ages close to the respective geological ages of the host rocks. The lead appears to have been derived from upper crustal sources, probably basement rocks or the sediments themselves, thus conforming to the general trend for sediment-hosted sulfide deposits (Large 1983). The data for the Brazilian deposits do show linear trends, similar to that of Sullivan in Canada and other Sedex deposits (Beaudoin 1997).

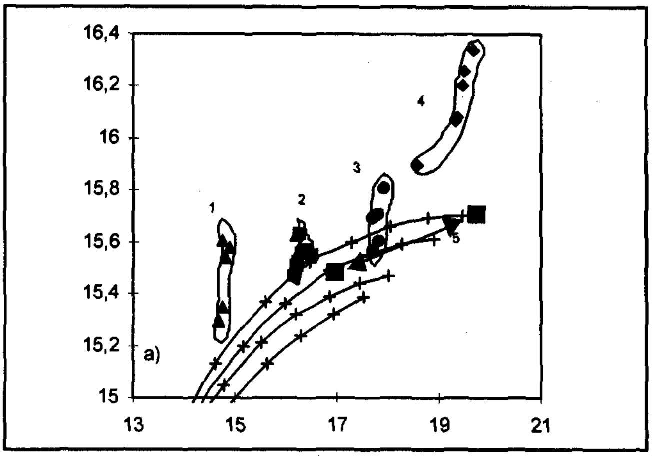

Figure 3: Lead isotope composition of the deposits studied. Evolution curves according to the plumbotectonic model of Zartman and Doe (1981). Upper curve=Upper Crust, followed by mantle, orogen and lower crust evolution curves. 1 – Boquira 2 – Canoas 3 – Morro Agudo 4 – Nova Redenção 5 – Santa Maria.

Lead isotope signatures and the extent of local and regional isotopic heterogeneity for each deposit and area need to be defined. Such signatures will help discover new economic deposits. In this connection it is interesting to note that there is an isotopic contouring in the Morro Agudo – Vazante region with least radiogenic lead being found in the major deposit (Iyer 1984; Iyer *et al.* 1992). Here, isotopic homogeneity and least radiogenic lead appear to be the characteristic of the major deposit. Such characteristics have been found for many massive lead-rich massive sulfide deposits (Gulson 1986).

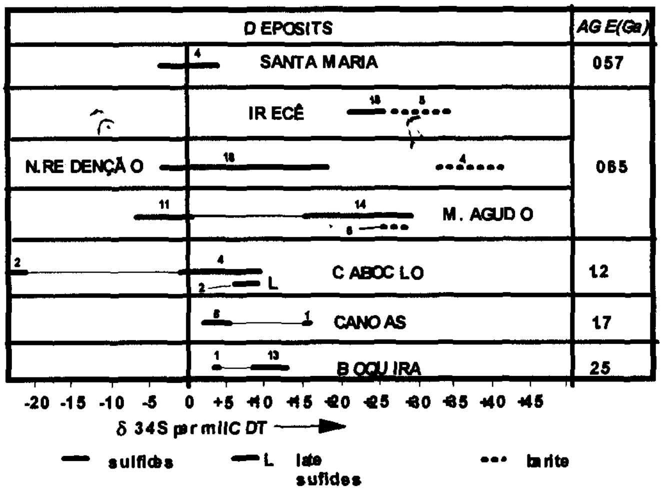

Figure 4: Sulfur isotope variation of sulfides and sulfates. Figures above the lines indicate the number of determinations for the respective range obtained.

The sulfur isotopic composition of the sulfides and sulfates from the deposits, except Santa Maria, indicate a predominant sea water source for the sulfur (Fig. 4). In the Santa Maria deposit the sulfur appears to be of magmatic origin, with little contribution from the sediments. Where ever possible, sulfur isotope data of coexisting sulfide pair was used to estimate the temperature of equilibration. The calculated temperatures obtained are concordant with the geothemometric data measured from fluid inclusion studies, at least for Nova Redenção and Morro Agudo: 150 to 220°C. These temperatures imply the formation of sulfides by thermochemical reduction of sulfates.

CONCLUSIONS

The geological, petrographic and isotopic data for the sediment hosted sulfide deposits of Brazil suggest that they were formed during periods of extensional tectonics. The circulation of fluids within the sedimentary sequence occurred through growth faults or reactivated basement structures, extracting the metals from the basement rocks and/or sediments and depositing sulfides by thermochmical reduction of sulfates. The association of the mineralization with linear structures (normal faults and/or fractures), as observed in most deposits, reflects the possible main pathways available for mineralizing fluids. For the Neoproterozoic deposits, subsequent replacement of evaporative sulfur rich carbonates occurred during early diagenetic stages. This is a tentative model and may have to be revised when detailed data are available.

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