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Metallogeny of the Triassic-Jurassic Rift-Related Mineralizations in Argentina

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1 Introduction

The Triassic-Jurassic NNW-SSE extensional phase affected the western margin of Gondwana and marked the beginning of the fragmentation of this supercontinent. Extensional faulting began in the Late Permian in the northern areas, becoming younger to the south, i.e. Jurassic in Patagonia.

During this stage extensive rhyolitic ignimbrite magmatism developed. The rift system, was filled with continental sediments that locally have intercalated bimodal, predominantly mafic, volcanic rocks.

The region affected by the Triassic-Jurassic rifting in the Argentine territory hosts a number of deposits that have no direct link with magmatic activity and whose age has previously been attributed, in general, to the Mesozoic (Zappettini, 1999), or are herein ascribed to this event. These include the Se-rich polymetallic deposits, five elements deposits, Pb-Zn-Ag simple veins, epithermal Mn, fluorite and barite veins.

The various types of deposits analyzed have a wide regional distribution reflecting the extent of the processes of rifting that started during the Triassic and reached the Cenozoic, generating thermal and fluid flow anomalies leading to hydrothermal mineralizing processes. Where there was a favorable source, fluids collected selected elements resulting in a mineralogical specialization and inhomogeneities in the distribution of the mineralization types along the belt affected by rifting. Characteristically, where the rifting affected Paleozoic or older sedimentary sequences, polymetallic and barite type deposits were generated. Where rifting affected acidic Triassic-Jurassic volcanic and volcaniclastic sequences the fluids originated fluorite mineralization. In the cases where there was an associated restricted basic magmatism or by leaching or volcanic sequences Mn ore bodies were formed.

In all cases, this rift environment has been favorable for the emplacement of alkaline to subalkaline acid magmatic rocks. In these cases, besides the presence of fluorine and fluorine-rich fluids, evidenced by the presence of fluorite and / or topaz, there are associated REE mineralizations (Rodeo de los Molles, Sierras Pampeanas of San Luis and Rangel district, Puna of Salta), Mo-rich stockworks (Elsiren and German) and epithermal gold deposits (Pantanito, and, in general, the Au-Ag epithermal deposits of the Deseado Province). In this context the Pb-Ag polymetallic mineralization of the Navidad deposit formed in relation to a rift-related magmatism represented by volcanic and pyroclastic deposits associated with biochemical and epiclastic sediments deposited within the Cañadón Asfalto hemigraben (e.g. Fernandez et al., 2008). From a global point of view, the fluorine, manganese and polymetallic deposits related to extensional environments may be associated with precious metal mineralization (Au-Ag) and Mo-rich porphyries, so that their presence can be used regionally as an exploration guide (e.g. Wallace, 2010).

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2 A Regional Metallogenic Model

The analysis of the deposits located in relation to extensional processes in Argentina along with background information on the various deposit models associated with this type of environment worldwide, allows proposing to:

(1) Complete the type of mineral deposits in extensional environments in general.

(2) Expand the model of detachment fault-related deposits as described by Long (1992).

(3) Propose a conceptual metallogenic model of regional extent as a basis for analyzing the mining potential of areas affected by rifting and help the exploration programs in terms of the defined metalotects.

The detachment zones consist of extensional faults with displacements that can reach several tens of kilometers. They have been explained as a product of the evolution of low-angle shear zones that controlled extensional

Table 1 Detachement-fault environments and related deposit types

Environment			Deposit types
In the vicinity of detachment faults			Cu-Fe veins, stockworks and replacement-type Pb-Ag-Zn veins, stockworks and replacement-type
High angle faults	Related to hemigrabens	Upper block with acid magmatism	Fluorine veins Mn veins
		Upper block with basic magmatism	Se-rich polymetallic veins Ag-Pb-Zn simple polymetallic veins
	Normal faults without evidence of hemigrabens with sedimentary filling	Metasedimentary basement	Five element deposits without U intrusions Ag-Pb-Zn simple polymetallic veins Barite beins
Sedimentary sequences in hemigrabens			Mn lacustrine deposits Stratabound barite deposits

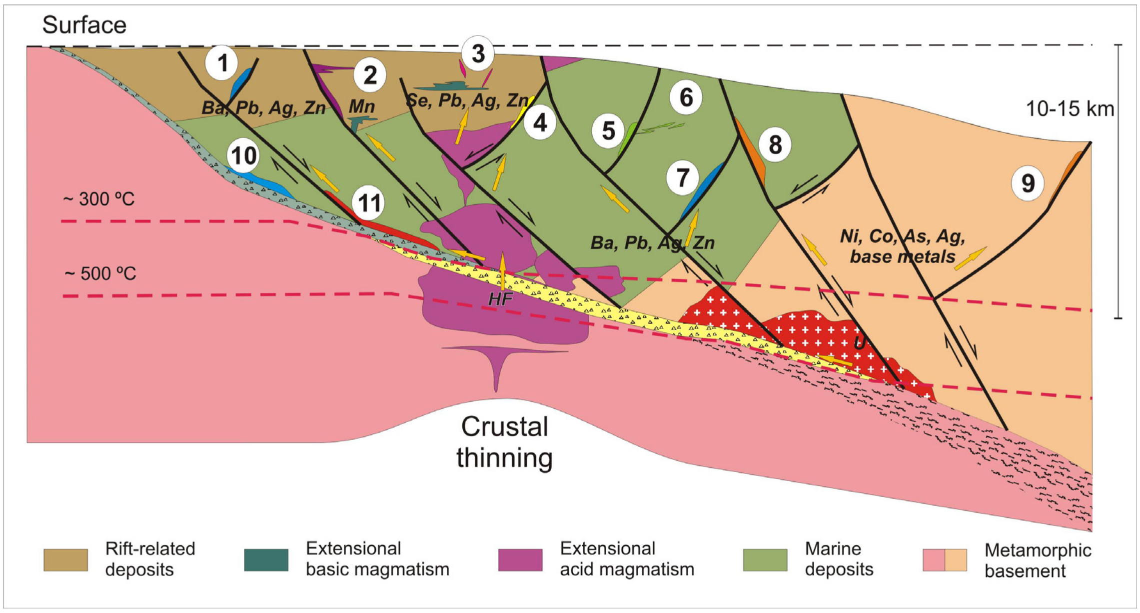

Fig. 1. Conceptual model of deposit models associated with detachment faults. 1. Pb-Zn-Ag simple polymetallics. 2. Epithermal Mn and lacustrine Mn. 3. Se-rich polymetallics. 4. Epithermal fluorite. 5. Epithermal barite. 6. Stratabound barite. 7. Pb-Zn-Ag simple polymetallics. 8. U-rich five-elements deposits 9. Five-element deposits. 10. $CaCO_3$. 11. Cu-Au-Fe deposits.

lithospheric processes at high crustal levels. They are usually associated with pull-apart complexes at surface levels and with closely spaced normal faults. In these areas associated brecciation and retrograde metamorphism processes are common in the lower block as well as their juxtaposition with unmetamorphosed supracrustal rocks of the upper block.

Two different geotectonic environments of metallogenetic interest can be identified, where detachment zones and normal faulting are developed:

(1) Continental extension in back-arc environment.

(2) Extension with rift development and generation of oceanic crust on a passive continental margin.

From the analysis of mineral deposits and their geological context herein summarized, these deposits are characterized by the absence of any direct relationship between hydrothermal fluids and magmatic processes. They can be grouped into three environments as synthesized in Fig. 1 and Table 1.

Regarding the extent of the favorable areas for locating the different deposit models, four main domains have been identified (Fig. 2):

(1) Neoproterozoic to Paleozoic basin: it is the source of Pb, Ag, Zn, Ba, Co, As, Ni, Bi, among other elements, which remobilized along extensional structures leading to the formation of Pb-Zn-Ag simple polymetallic veins (e.g. Pumahuasi and Paramillos de Uspallata) epithermal barite veins (e.g. Santa Victoria district) and five elements deposits (e.g. Purisima-Rumicruz).

(2) Triassic Basin: A set of depocenters associated with continental sedimentation and associated basic magmatism, which are the source of Se and other metals, with Se-rich polymetallic veins emplaced in extensional faults (e.g. Llantenes and Cacho districts).

(3) Triassic-Jurassic acid volcanics domain: It comprises the Choiyoi Magmatic Cycle volcanics and subsequent syn -rift volcanism and, in Patagonia, the volcanic rocks of the Los Menucos, Chon Aike and Marifil units. A deep asthenospheric source, possibly an alkaline magma, is postulated as the source of F in epithermal fluorite veins

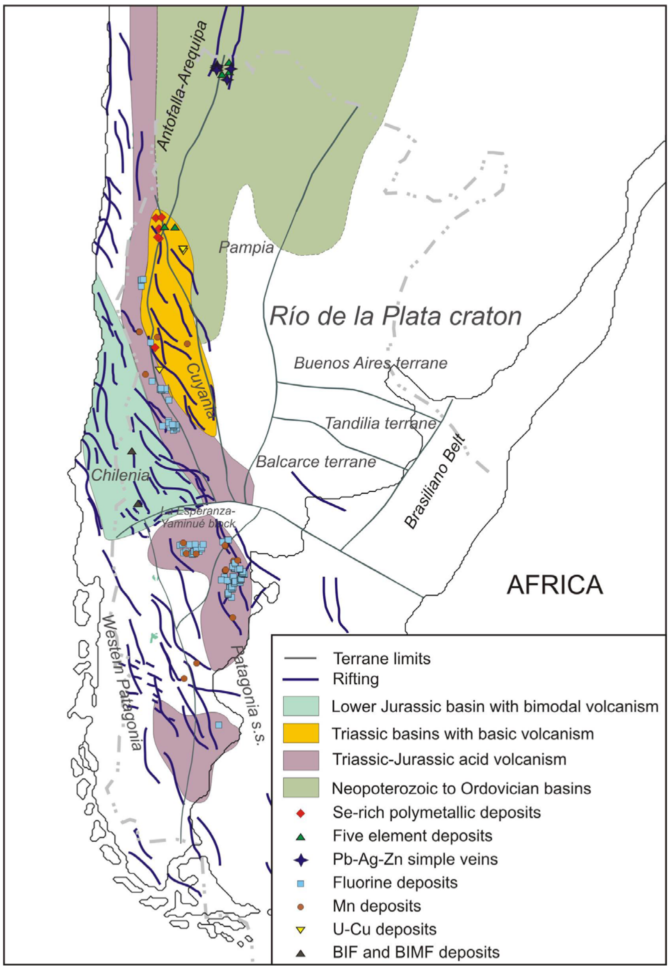

Fig. 2. Regional metallogenic model metallogenic belts and structural metalotectos indicating types of deposits associated

(e.g. Sierra Grande district); alkaline basic volcanics would provide the Mn of Mn epithermal veins (e.g. Arroyo Lagañoso), although in both cases the mineralizing fluids are not genetically linked with magmatism.

(4) Upper Triassic-Lower Jurassic bimodal volcanics domain: It comprises isolated depocenters with bimodal volcanics and sedimentary infilling. Where marine ingression is present, concomitant volcanic activity leads to the deposition of volcanogenic banded iron and manganese mineralization (Algoma type BIF and BIMF, e.g. La Casualidad and Colomichicó).

In all environments, identification and exhumated deep levels exposing detachment faults constitute a favorable environment for locating Cu-Au-Fe (-Pb-Zn-Ag) veins and replacement mineralization.

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