Mineral exploration guidelines for the Ba-Sr ore deposits of the Neuquén Basin, West Argentina

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Abstract. Numerous Ba-Sr deposits are found along the 70°W longitude in the Neuquén Basin, west Argentina. They show a close relationship with the Jurassic-Cretaceous sequence revealing a strong stratabound character. They are mainly composed by barite and celestite with, in some cases, very minor amounts of Pb-Zn sulfides. The deposits appear in three ways: stratiform ("mantos"), veins and irregular bodies. Most of the mineralizations are due to the epigenetic replacement of favorable lithologies as boundstones and gypsum-rich beds. Based on the recognized general geological features, most of these mineralizations can be permissively classified as Mississippi Valley-type (MVT) deposits. Geologic and metallogenic investigations allowed to establish some mineral exploration guidelines for the Ba-Sr deposits of the Neuquén Basin.

1 introduction

The Neuquén Basin is located on the western side of Argentina, between 32° and 40°S latitude (Fig. 1). It represents a large morphostructural unit characterized by a stratigraphic sequence, more than 6,000 m thick, deposited between the Late Triassic and the Lower Tertiary (Legarreta and Gulisano 1989, Howell et al. 2005). It hosts numerous stratabound carbonate-hosted hydrothermal deposits mainly of celestite and barite as ore minerals. They are mainly distributed along the 70°W longitude between Chos Malal and Zapala localities (Brodtkorb et al. 1982, 1989) and appear in three ways: stratiform ("mantos"), veins and irregular bodies in cavities by karstic dissolution (de Barrio et al. 2014). Their origin is mostly related to epigenetic processes of replacement of Mesozoic carbonate or evaporitic rocks. Only Arroyo Nuevo Ba mineralization is syngenetic, formed by sedimentary-exhalative deposition onto the seafloor. Barite and celestite ore minerals also are accompanied, in some cases, by very minor proportions of galena, sphalerite, chalcopyrite, dolomite, calcite, and quartz. In the last years, several metallogenic studies allowed to establish some mineral exploration guidelines for the Ba-Sr ore deposits of the Neuquén Basin.

2 Geological setting

The sedimentary sequence of the Neuquén Basin is constituted by clastic, carbonate, evaporitic, pyroclastic and magmatic rocks (Legarreta and Gulisano 1989). It was developed from the Upper Triassic to the Lower Tertiary, near the western edge of the South American Plate, between a volcanic arc to the west and the eastern flank of the foreland (Howell et al. 2005). The tectonostratigraphic history of the Neuquén Basin involves the development of several alternating marine and continental cycles mainly during the Jurassic-Cretaceous. Moreover, the andesitic magmatism represented by the Naunauco Group (Colipilli and Cayanta Formations, Llambías and Aragón 2011) is an important tectonomagmatic event developed in the Late Cretaceous-Eocene. This magmatism is represented by outcrops of intrusive bodies (sills, dikes and stocks) and extrusive lava series.

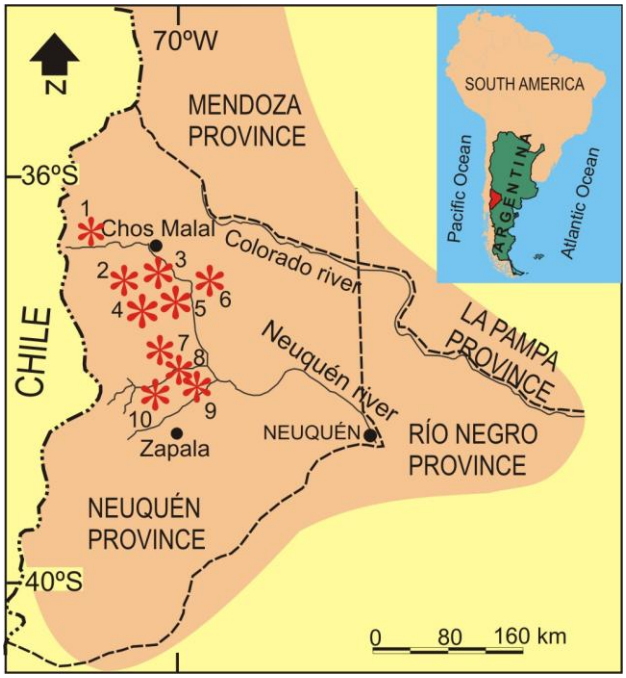

Figure 1. Location map of the Neuquén Basin and distribution of the main Ba-Sr ore deposits. 1. Arroyo Nuevo mine, 2. Colipilli district, 3. Naunauco-Taquimilán district, 4. Loncopué district, 5. Continental Group, 6. Barda Klein mine, 7. Bajada del Agrio district, 8. Llao Llao mine, 9. Achalay mine, 10. San Charbel mine.

3 Mineral exploration guidelines

The mineralizations present conspicuous geological features which may help to mineral exploration programs. Table 1 shows a summary of the main characteristics of representative Ba-Sr ore deposits in the Neuquén province. The mineralizations are catalogued in three groups: a) sedimentary exhalative deposits (SEDEX-Ba), b) epigenetic hydrothermal deposits spatially linked with

igneous rock outcrops, and c) epigenetic hydrothermal deposits no spatially linked with igneous rock outcrops. Most of the celestite deposits are distributed in areas without magmatic activity while the barite deposits are grouped in sectors with igneous rock outcrops. However, both groups show stable isotope data compatible with a non magmatic origin.

The Ba-Sr deposits show a marked stratabound character. They are closely spatially related to the Jurassic-Cretaceous sequence where the carbonate-evaporite and siliciclastic stratigraphical units played a significant role for the genetic processes. These deposits mainly occur in different sedimentary formations: Tábanos Fm. (Middle Jurassic, Fig. 2), Auquilco Fm. (Upper Jurassic) and Huitrín Fm. (Lower Cretaceous), all of them constituted by platform carbonate-evaporitic sequences. Laminated microbial limestones (boundstones) are conspicuous layers in numerous deposits. They constituted favourable beds for the circulation of mineralizing fluids and subsequent selected replacement and infilling processes.

Figure 2. Celestite layer showing carbonate relict at San Charbel mine (Tábanos Formation, Middle Jurassic).

The celestite and barite beds have a length of hundreds of meters and tabular- to lensoid-shapes. Their color varies from light blue to light brown and yellowish white. They are of a few centimetres up to 1.8-2 m thickness lying conformable with the general bedding. Zebra or rhythmite textures (Fig. 3) are very common in the stratiform deposits. They are composed by a laminae alternation of a few millimeters to some centimeters thickness. The texture shows dark and light bands of carbonate and celestite or barite, respectively.

The areal distribution of the deposits is controlled by several regional lineaments and folded structures of N-S general strike. At the present, their attitude depends on local fold structures. Thus, in some places the celestite-barite beds are horizontal while in others, they are near vertical. This variation complicates the mining works.

4 Conclusions

The Ba-Sr deposits of the Neuquén Basin represent a large group of widely distributed mineralizations mostly linked to Middle Jurassic-Lower Cretaceous carbonate-evaporitic sequences showing strong regional stratabound behaviour. The mineralizations form several clusters of deposits showing similar metallogenic features.

The mineralogical, petrographic and textural data support an epigenetic style for the bedded Ba-Sr deposits and point out a replacement of carbonate and gypsum layers by hydrothermal fluids likely formed from basinal brines that were mobilized possibly during the Lower Tertiary. Later, remobilization processes generated infilling of fractures and holes resulting in veins and breccia deposits. Finally, lining of paleokarstic cavities in carbonate rocks occurred (Fig. 4).

Figure 3. Zebra texture at Ba-Sr Santa Elena mine (Lower Cretaceous, Continental Group) in underground works.

The general geological characteristics of the Ba-Sr deposits of the Neuquén Basin are similar to those of the Ba-Sr mineralizations of the Coahuila State, NE México which were considered as MVT deposits (Tritlla et al. 2006, González Sánchez et al. 2009). The indicated features represent useful tools of mineral exploration for the Ba-Sr deposits in a very large region with up to the present scarce exploration programs.

Figure 4. Karstic cavities with remobilized barite at La Luisiata mine (Huitrín Formation, Lower Cretaceous).

TIPOLOGY	AREA/ DISTRICT	ORE DEPOSIT/ MINE	SHAPE OF ORE BODY	MINERAL ASSOCIATION	ORE TEXTURE	HOST ROCK/ FORMATION	ALTERATION STYLE	MAIN GENETIC PROCESSES
SEDIMENTARY EXHALATIVE DEPOSIT (SEDEX Ba)	Cura Mallín	Arroyo Nuevo	stratiform ("manto")	Brt >>> Py ± Gn ± Sp ± Ccp ± Qz	coarse grains	black shales/Los Molles Fm	oxid, sil	sea-floor deposition
			vein	Brt >>> Gn	tabular grains	sandstones/Los Molles Fm	oxid	remobilization/infilling
EPIGENETIC HYDROTHERMAL DEPOSITS SPATIALLY LINKED WITH IGNEOUS ROCK OUTCROPS	Loncopué	La Rosita	stratiform ("manto")	Brt	fine tabular grains	limestones/Tábanos Fm	sil	replacement
			vein	Brt	tabular grains	sandstones/Lotena Fm	minor sil	infilling
		La Florcita	vein	Brt >>> Sp	tabular grains	sandstones/Lotena Fm	minor sil	infilling
	Mallín Quemado Hill/ Cuchillo Cura range	Achalay	stratiform ("manto")	Brt >>> Gn ± Py	comb, tabular grains	limestones/Auquilco Fm	oxid, chlor	infilling/replacement
			breccia	Brt >> Gn ± Ccp	coarse grains	limestones, sandstones, gypsum, and barite blocks	sil, chlor, oxid	hydraulic fracturation/infilling
			vein	Brt >> Gn ± Sp ± Ccp ± Py ± Qz ± Adl	coarse grains	sandstones/Tordillo Fm	ser, sil, arg	infilling
			dissemination	Clt	fine grains	sandstones/Tordillo Fm	arg	infilling
		Río Agrio	vein	Brt >> Ccp ± Gn ± Cal ± Qz ± Adl	coarse grains	sandstones/Tordillo Fm	ser, sil	infilling
		La Porfía	vein	Brt	coarse grains	sandstones/Tordillo Fm	ser, sil	infilling
		Llao Llao	stratiform ("manto")	Clt	massive, fine tabular grains, rhythmites	limestones/Auquilco Fm	pyr, sil, oxid	replacement
			stratiform ("manto")	Brt >> Py	massive		pyr	replacement/infilling
	Colipilli	San Eduardo	vein/stratiform ("manto")	Brt >> Gn ± Ccp	rhythmites, breccia	limestones/Troncoso superior Member, Huitrín Fm	oxid	replacement/infilling
		La Bienvenida	stratiform ("manto")	Brt > Gn	rhythmites	sandstones/ Troncoso inferior Member	oxid	replacement/infilling
		Julio César and others	vein	Brt >> Gn ± Hem	tabular grains, breccia	limestones/Chorreado Member, Agrio Fm	oxid, prop	infilling
	Naunauco	Don Candelario, Clementina	stratiform ("manto")	Clt >>> Py	equant grains	limestones, gypsum/ Troncoso superior Member, Huitrín Fm	weak dol	replacement
	Tralalhue stream	Diablo Hill	vein	Brt >> Gn ± Sp ± Au ±Hem	Tabular grains	Diorite-andesites Naunauco Group/ black shales of Vaca Muerta Fm/ sandstones of Mulichinco Fm	prop	infilling
EPIGENETIC HYDROTHERMAL DEPOSITS NO SPATIALLY LINKED WITH IGNEOUS ROCK OUTCROPS	Cuchillo Cura	San Charbel	stratiform ("manto")	Clt	tabular-prismatic grains, rhymithes	limestones/Tábanos Fm	weak dol	replacement
	Bajada del Agrio	3, 4 and 5 de noviembre, Santa Bárbara, Santa Ana	stratiform ("manto")	Clt > Bar	rhythmites	limestones, gypsum/ Troncoso superior Member and La Tosca Member, Huitrín Fm	weak dol	replacement/infilling
	Salado Range	Dios Alado	stratiform ("manto")	Clt > Brt	rhythmites		weak dol	replacement
		Continental Group (Cecilia mine and others)	stratiform ("manto")	Clt > Brt	rhythmites		calc	replacement
			stalactitic	Brt	crustiform-banded		weak dol	infilling of cavity
			cavity infilling	Brt	druse/geoda		calc	remobilization/ infilling
		Santa Elena	stratiform ("manto")	Clt > Brt	rhythmites		weak dol	replacement/infilling
	Picún Leufú Stream	Puesto Gregor	stratiform ("manto")	Sp > Gn ± Dol ± Cal	disseminated	sandstones/ Las Lajas Fm	dol	replacement

Table 1: Summary of the main characteristics of representative Ba-Sr ore deposits in the Neuquén province, Argentina. References: chlor: chloritization; oxid: oxidation; sil: silicification; ser: sericitization; arg: argilization; pyr: pyritization; prop: propilitization; dol: dolomitization; calc: calcitization. Mineral abbreviations after Whitney and Evans (2010).

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