A new metallogenical association (Sn-Cd-In-Zn-Ag-Au) in the Deseado auroargentiferous province, Deseado Massif, Patagonia, Argentina

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Abstract. A new metallogenical association (Sn-Cd-In-Zn-Ag-Au) is reported for the low sulphidation epithermal Deseado Auroargentiferous Province, in Patagonia, Argentina. The anomalous presence of Sn, Cd and In, together with anomalies of Zn and Ag, and also high contents of Cu, Mn, Pb, W and Bi in a complex sulphur-rich mineralogy, represent a new metallogenical association. This assemblage could be related to a higher temperature mineralization or a different type into the epithermal range. The presence of this new metallogenical association increases the mining potential of the region, extending exploration targets in this metallogenical province and must be considered during future exploration duties in the region.

Keywords. Sn-Cd-In-Zn-Ag-Au, epithermal deposits, exploration potential, Deseado Auroargentiferous Province, Argentina

1 Introduction

The Deseado Massif is a 60,000 km^2 geological province located in the Santa Cruz region of the southern Argentinean Patagonia. It is mainly characterized by a complex and long-lasted (more than 30 Ma), middle to late Jurassic bimodal volcanic event that is spatially, temporally and genetically related to low sulphidation epithermal deposits.

The Deseado Massif is actually an important Au-Ag producer with two mines (Cerro Vanguardia and Mina Martha) and it is also the subject of intense prospecting activities. The presence of several epithermal occurrences (more than 50) in this region induced Schalamuk et al. (1999) to propose a new metallogenical entity, the *"Deseado Auroargentiferous Province"* (DAP), characterized by typical low sulphidation (LS) type mineralization (Hedenquist, 1987).

This study was based on the Cerro León deposit (Jovic et al., 2004) and communicates a new metallogenical association for the DAP, extending exploration targets for this metal-rich province.

2 Jurassic volcanotectonic setting

The rocks that host, and are genetically linked to, mineralization are bimodal middle to upper Jurassic volcanic rocks (Guido and Schalamuk, 2003).

This important volcanic event was related to extension, possibly linked to opening of the South Atlantic Ocean. The first magmatic evidence of this extension is the lower Jurassic granitoid rocks of La Leona Fm, followed by lower Jurassic tuffs and tuffites of the Roca Blanca Fm, the intrusive basic rocks of the Cerro León Fm, and finally the bimodal volcanic rocks. This volcanism is composed of acid volcanic rocks from the Bahía Laura Group and intermediate to basic volcanics from the Bajo Pobre Formation. Both units represents more than 60% of the surface outcrop of the DAP, but the Bahía Laura Group rocks clearly dominate.

The Bahia Laura Group is composed of volcaniclastics (ignimbrites, tuffs, volcanic breccias, and tuffites) and magmatic (domes, lava flows, subvolcanic bodies and dikes) rocks. They are mainly calc-alkaline and peraluminous rhyolites, with some dacitic members.

The Bajo Pobre Formation is composed mainly of lava flows and minor volcaniclastics (tuffs, agglomerates and tuffites) rocks. They are mainly calc-alkaline andesites to basaltic andesites, with rare basalts.

3 Deseado auroargentiferous province

Mineralization in DAP is typically structurally controlled. It consists of quartz veins and veinlets, vein stockworks and hydrothermal breccias. The dominant direction controlling mineralization is NW, with minor NE and E-W.

Mineralization is commonly hosted in bimodal volcanic rocks, mainly in Bahía Laura Group pyroclastic rocks, but also in Bajo Pobre Formation volcanics (Bajo Pobre, Manantial Espejo, El Dorado-Montserrat, Marianas-Eureka and La Paloma projects). There are also some other epithermal occurrences in older rocks: Tres Hermanas, El Tranquilo projects and minor occurrences in basement rocks and Buena Esperanza project and minor occurrences in Permian sedimentary rocks (Figure 1).

The gangue minerals are silica (mainly quartz with minor chalcedony and some opal), accompanied by scarce pulses of calcite, adularia, barite, fluorite and zeolites.

The quartz textures are commonly massive, brecciate, crustiform and colloform banding with comb, cockade and lattice bladed texture (Dong et al., 1995).

Metalliferous minerals in the quartz veins are scarce, representing commonly less than 1% in volume. They are mainly pyrite, native gold, electrum, argentite, native sil-

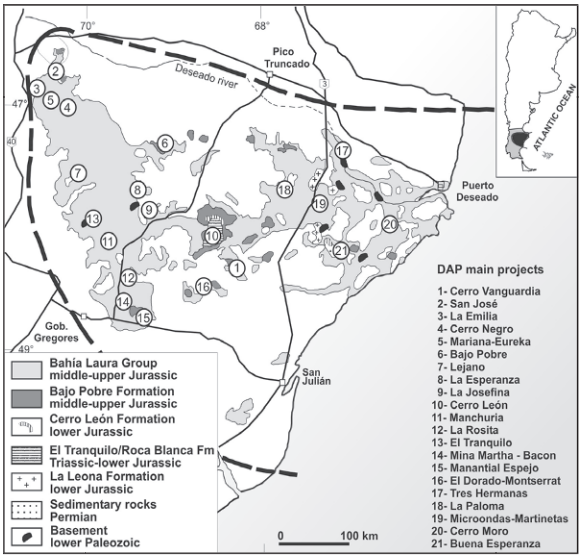

Figure 1: Geology and location of mining projects in the DAP.

ver, Ag-sulfosalts, hematite, sphalerite, galena and chalcopyrite. There are also some Pb, Fe, Mn and Ag secondary minerals.

Hydrothermal alteration is only restricted to the proximity of the veins and is represented by silicification, argillization (illite, smectite, kaolinite), sericitization and propylitization; the latter one only in the intermediate to basic lava flows.

The geochemical signature from quartz veins agree with LS epithermal deposits, with anomalies in precious metals (Au-Ag) and occasional anomalous contents of As, Sb, Hg, Mo, Pb, Zn, Mn and minor Cu.

Mineralization was determined to be upper Jurassic in age (Arribas et al., 1996; Schalamuk et al., 1997), are related to the late stages of bimodal volcanism.

Hydrothermal fluids were characterized as neutral to slightly alkaline H_2O-NaCl solutions, with salinities of 0.18 to 8 wt% eq. NaCl. The homogenization temperatures for quartz and adularia range between <100° to 320° C and $\delta^{18}O_{FLUIDS}$ values of -6.4 to 5‰ suggest an important participation of meteoric waters in the hydrothermal solution.

4 New metallogenical association

In recent years some atypical epithermal occurrences have been found in the DAP. Mina Martha is the best known example, being a Ag-rich deposit with a Ag:Au ratio of 1000:1 and high contents of base metals. These characteristics induced Gonzalez Guillot et al. (2004) to include it in the intermediate sulphidation (IS) type of Hedenquist et al. (2000). Other examples are Buena Esperanza, La Emilia and La Rosita projects. Nevertheless, these new varieties have the same metallogenic signature.

This new metallogenical association is characterized by the anomalous presence of Sn, Cd and In together with anomalies of Zn and Ag, and also high contents of Cu, Mn, Pb, W and Bi, in a complex sulphur-rich mineralogy.

The best example of this new assemblage is the Cerro León project (Jovic et al., 2004), located in the central part of the Deseado Massif, 40 km northwest from Cerro Vanguardia (Figure 1). This project is composed of more than nine quartz veins, which can be grouped in 4 major structures (Marta, Ivonne, Sara and Sonia).

The veins are hosted in an atypical lithology; some in El Tranquilo Formation (Triassic continental sedimentary rocks) and the rest in Roca Blanca Formation (lower Jurassic volcaniclastic rocks). They have a NW strike and are composed of quartz and Fe-Mn oxide and hydroxide veins and veinlets, with occasional hydrothermal breccias. Quartz textures are massive, crustiform banding with important comb and cockade textures and minor colloform and lattice bladed textures.

Metalliferous minerals are pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, tetrahedrite, bournonite, native gold and silver, stannite, kesterite, greenockite, wolframite, Ag-sulphosalts and enargite (determined by preliminary SEM and microprobe studies). Ag, Cu, Pb and Zn secondary minerals and cassiterite are also present and it is important to state the extraordinary concentration of sulphides, which reach up to 90% in volume in some veins.

Hydrothermal alteration is confined to the proximity of the veins and it is represented by silicification, argillization (illite and kaolinite) and pyritization.

The geochemical signature of the Cerro León (CL) veins is summarized and compared with mineralized veins that represent different types of LS mineralization of the DAP (Table 1). These average values (DAP) correspond to 221 samples of mineralized quartz veins, which resulted from the analysis of more than 1000 samples from the whole DAP. The contents of Sn and In are less representative, because these elements are not included in the majority of the analysis. Nevertheless, they were analyzed in 20 samples, 4 of them mineralized and included into DAP for the comparison.

Table 1 shows the anomalous concentrations of Sn (111:1), Cd (93:1), In (60:1), Zn (30:1) and Ag (12:1) compared with LS DAP mineralization. Also, the rest of base metals (Cu=7:1 and Pb=4:1), Mn (6:1), W (4:1), As (3:1) and Bi (1.5:1) are in higher concentrations.

5 Discussion

Table 2 summarizes the characteristics from the DAP epithermal deposits and the new metallogenical association (CL).

This table shows that DAP mineralization characteristics are in good agreement with the LS epithermal type of Hedenquist et al. (2000) or the LS and IS type of Sillitoe and Hedenquist (2003).

Table 1: Geochemical average values from Cerro León (CL) and Deseado Auroargentiferous Province (DAP).

	N	Au	Ag	Cu	Pb	Zn	As	Sb	Hg	Mn	Sn	W	Bi	In	Cd
		ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm
CL	20	872.65	185.80	750.8	3145.8	2372.2	1605.9	14.8	660.	4197.4	65.7	18.2	10.6	9.02	38.14
DAP	221	1601.00	14.91	100.74	720.11	77.98	494.5	29.07	1460	703.7		4.9	8.2		0.41
DAP	4										0.59			0.15	

Table 2: DAP LS epithermal deposits and new metallogenical as-semblage characteristics (CL).

	DAP	CL
Deposit style	Mainly NW strike structurally controlled quartz chalcedony veins	NW strike structurally controlled quartz veins
Quartz textures	massive, brecciated, crustiform and colloform banding with comb, cockade and lattice bladed texture	massive, brecciate, crustiform banding with important comb and cockade textures and minor colloform and lattice bladed.
Possible source rocks	Jurassic bimodal volcanism	Jurassic basic to intermediate volcanic rocks
Host rocks	Jurassic bimodal volcanism and minor older units (Pz, Pm)	Triassic sedimentary rocks and lower Jurassic volcaniclastic rocks
Hydrothermal alteration	Silicification, argillization, sericitization (propylitization)	Silicification, argillization and pyritization
% sulphide in veins	<1% in volume	20 to 90 % in volume
Metalliferous minerals	pyrite, native gold and silver, electrum, argentite, Ag-sulphosalts, hematite, sphalerite, galena, chalcopyrite and secondary minerals	pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, cassiterite, tetrahedrite, bournonite, native gold and silver, stannite, kesterite, greenockite, wolframite, Ag-sulphosalts, enargite and secondary minerals
Main metals	Au, Ag, As, Sb, Hg, Mo, Pb, Zn, Mn and Cu	Au, Ag, As, Sb, Hg, Cu, Zn, Pb, Sn, W, Bi, In and Cd
Ag:Au ratio	9:1	213:1

In contrast, the CL metallogenic mineralization is characterized by deeper quartz textures, differential and unique host rocks, a possibly basic to intermediate magmatic source and important pyritization in the alteration halo. The percentage of sulphides (up to 90% in volume), the complex sulphide mineralogy and the geochemical signature (the presence of Sn-Cd-In and the higher contents of Zn-Ag-Cu-Pb-Mn-As-W-Bi) of CL mineralization clearly differ from LS DAP mineralization.

The abundance of a thick comb quartz texture, the presence of higher temperature metals and the higher Ag:Au ratio could be related to a higher temperature mineralization, which is in agreement with the lower relative contents of shallow epithermal elements such as Au, Sb and Hg (DAP:CL=2:1, Table 1).

Nevertheless, if we consider the similarities in the structural trends, quartz textures in general and hydrothermal alterations, it is possible that CL could be assigned to the epithermal range, as the LS Sn-Ag-base metals deposit from White and Poizat (1995), which also is considered to have Sn-W-Bi association at greater depth and lateral zoning to base metal mineralization.

6 Conclusion

The presence of Sn, Cd and In in high concentrations, together with Ag, base metals and W, Bi, As and Mn indicate the presence of a new metallogenical association for the DAP.

This assemblage increases the mining potential of this metallogenical province and must be considered during future exploration duties in the region.

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