Geochemical analysis of the Pingüino vein system, Patagonia, Argentina – implications in exploration

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Abstract. Geochemical data from 19 of the 70 veins of the Pingüino project were analysed. Pingüino vein system is characterized by two vein types: early polymetallic rich veins, and late quartz rich veins. Determinations of average vein metal values and spatial distribution of In, Au, Ag; Pb, Zn, Cu; As, Cd and Mn were performed in order to conform groups with similar geochemical behaviour. Individual elements distribution shows a main metals source point on top of the interpreted Kasia dioritic intrusion, with other secondary metal sources at KAL, TR, LUN, FAN, MN, KAR and ISL veins areas/intrusives. According to Ag/Au ratio and indium content three trends were identified; T1 (high In and low Ag/Au) is related to Lower Jurassic diorites and sulphide-rich veins. T2 (low to highest Au/Ag and low In values) is related to Middle Jurassic andesitic porphyries and Ag-rich quartz-rich veins. T3 gather veins with intermediate In and Ag/Au values, reflecting the mixing between the two main type of veins. These trends have a clear geographic association with Kasia intrusion and show a zonation pattern. The geochemical distribution and relationship of metal sources with intrusions should be considered in future Deseado Massif exploration.

Keywords: Metal zoning, Ag/Au ratio, polymetallic veins.

1 Introduction

The Pingüino deposit is located in the central portion of the Deseado Massif (Fig. 1). The area is characterized by a sedimentary sequence of Middle to Upper Triassic age (El Tranquilo Group) composed by sandstones with volcanic clasts, mudstones and black shales with coal. Intrusion of dioritic bodies, intermediate sills and dikes of the La Leona Formation was assigned to Lower Jurassic age (Jovic 2010). The Lower Jurassic Roca Blanca Formation is composed of epiclastic and pyroclastic fine sandstones with conglomerate and tuffitic rocks, volcanic sandstones and some tuffaceous levels and minor ignimbrite deposits. In the northwestern sector, the sequence is intruded by andesitic subvolcanic bodies, assigned to the Middle Jurassic Cerro León Formation.

Pingüino vein district contains more than 70 veins (Fig 1). This deposit is characterized by two vein types related to different magmatic events; (a) polymetallic sulphide-rich veins related to Lower Jurassic (194 Ma) diorites of the La Leona Formation, and (b) Ag-Au quartz veins related to Cerro León Formation Middle Jurassic (168 Ma) andesitic porphyries. The quartz veins cross-cut the polymetallic veins, providing further evidence of overlapping of the two different mineralization events (Jovic et al. 2011).

The polymetallic mineralization presents banded and massive textures in sulphide veins and vein breccias up to 13 m width, and with important Zn, Ag, Pb, Au, In, Cu, Sn, W and Bi anomalies (Jovic et al. 2011). Veins are poorly exposed and develop Fe-rich gossans. Jovic et al. (2011) defined two main mesoscopic pulses of polymetallic mineralization: First pulse (PS_1) composed of mainly pyrite, arsenopyrite and chalcopyrite, with late cassiterite cross-cutting these minerals, ferrokësterite replacing cassiterite and replaced by stannite. Complex Sb-rich sulphosalts of Ag-Pb-Cu-Fe are present in this pulse (Jovic et al. 2005, Crespi 2006), and Ivonne vein is the best example of this pulse. Second pulse (PS_2) is characterized by a Zn, Pb, Ag, In, Cd and Sb paragenesis that represents the infill of a breccia with PS_1 clasts. Galena and black sphalerite are the main minerals of the pulse, with minor sulphosalts of Ag-Pb. This pulse is best characterized in Marta Centro vein (Jovic et al. 2010).

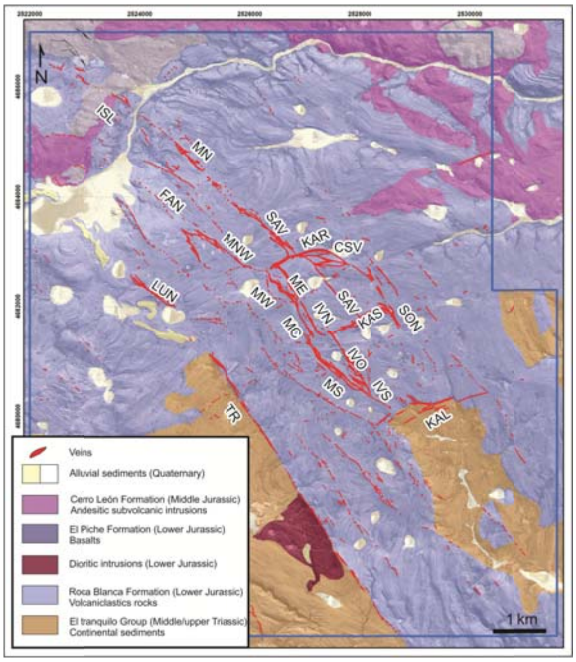

Figure 1. Geological and mineralization map of the Pingüino claim.

Quartz-rich structures are veins and vein-breccias with up to 20 m width, composed by quartz, carbonates and clays with colloform/crustiform banding, comb, cockade and lattice bladed textures. These veins have higher Ag-Au values in comparison with rich-sulphide veins (Jovic et al. 2011). Three quartz pulses were identified in these veins (Jovic 2010; Jovic et al. 2010): First pulse (Q_1) is composed by grey sacharoid-masive quartz with pyrite, chalcopyrite, sphalerite, galena, Ag-

Pb sulphosalts and native silver. The second pulse (Q_2) is characterized by colloform/crustiform banded quartz-carbonate with minor fluorite. Third pulse (Q_3) is represented by white coarse comb textured quartz in veins, veinlets and minor breccias.

The majority of the veins present complex relationships involving the sulphide-rich and quartz rich pulses. The late quartz-rich veins used the same fractures occupied by the previous sulphide-rich veins, therefore most of Pingüino veins exhibit a superimposed paragenesis; "pure" sulphide veins (e.g. Ivonne) and pure Quartz-rich vein (e.g. Marta Sur and Marta Norte) are less frequent. Dominant sulphide-veins considered in this contribution are Marta Centro (MC), Ivonne (IVO), Ivonne Sur (IVS), Ivonne Norte (IVN), Savary (SAV), Kasia (KAS), Karina (KAR) and Sonia (SON), tending to be hosted in NNW direction (N330° azimut) faults, while dominant quartz-veins rich are Marta Noroeste (MNW), Marta Norte (MN), Marta Este (ME), Tranquilo (TR) and Marta Sur (MS), that are mainly hosted in NW direction (N300° azimut) faults.

The aim of this study is to define the geochemical characteristics of each vein, in order to group them according to similar geochemical behavior. Also, it is pretended to make some interpretation about the characteristics of the hydrothermal fluids and to elaborate a hypothesis of the fluid paths. This information could be important for the metallurgy of the several Pingüino veins.

2 Methodology

Statistical analyses of the geochemistry data of veins were performed. Samples from 422 DDH, 225 RC drill holes and 551 trenches were considered and more than 50,000 ICP analyses were used. Only the samples corresponding to veins were selected for further analysis. To perform this selection, each sample was identified with VM (vein mineralization), DM (disseminated mineralization or stockwork halo) and HR (host rock) according to geological logs and cross section interpretation. The studied elements were Au, Ag, In, Cu, Pb, Zn, As, Cd and Mn. Several ratios were analysed, but two (Ag/Au and As/In) were defined as the best for this study. The interception lengths of the VM and VM + DM were calculated from every drill hole or trench.

Analyzed veins were MC, ME, TR, MN, KAS, MNW, IVO, MS, SON, IVS, SAV, IVN, KAR, Colita de Savary (CSV), Kalia (KAL), Isla (ISL), Marta Oeste (MW), Luna (LUN), and Fantasma (FAN). Some of them are conformed by one single vein, but others present several splays (in the hanging or the footwall), but to perform this study, only the main vein was used.

From each vein, media, standard deviation and maximum values were calculated. For further analysis, VM+DM (i.e. vein and halo mineralization) data was used to have a higher number of samples for statistical purpose. This is even more important in those veins with few drills and/or trenches.

3 Geochemical Analysis

3.1 In–Au–Ag

Indium values are very variable in Pingüino project veins. The vein with the maximum media values is MC. Other veins with high In values are, in order of In content: IVN, SAV, IVO, IVS and KAS Distribution of In content in plan view shows a restricted area with high concentrations near MC vein, that elongates to the SSE in the 330° direction to KAL vein.

Gold shows the maximum average value in MNW vein; veins with high Au values are: IVN, SAV, IVO, ME and ISL. In plan view Au values are concentrated in the IVN-SAV veins area, and extend to the NW (N300°) direction to FAN vein. An isolated increase of Au mean value was registered in ISL vein.

Silver exhibits the maximum average value in MNW and ME. Veins with high Ag values are MN, TR, SAV, LUN, CVS FAN and KAL. In plan view, Ag values elongate to NNW and NW directions, and also extends to the WSW to TR vein.

3.2 Cu-Pb-Zn:

Highest Cu average values are located at IVN, TR and IVO veins. In plan view copper shows a wide distribution with a WSW elongated shape related to TR and LUN veins.

The highest Pb average values are in SAV vein, and also is concentrated in MC, ME, KAL, KAS and CSV. Plan view shows a wide distribution of Pb values with a center in SAV, MC and ME and a general extend NW to MN, LUN and KAL.

The vein with the maximum media Zn values is MC, but other veins with high Zn values are IVS, SAV and KAS. Distribution in plan view is reduced in area concentrated in MC and with a trend to SSE to KAL vein and to the WSW to TR vein.

3.3 As-Cd-Mn:

Arsenic has the highest average value in IVN vein, and elevated values were registered in IVS, IVO, SAV and ME. High arsenic values are centered in IVO with a NW-SE trend, and also extends to the WSW to LUN vein.

MC is the vein with the highest average Cd value, followed by SAV, ME, KAS and IVS. In a plan view Cd distribution is similar to Zn.

The highest Mn average values are in ISL, KAL, TR, and MC veins. The Mn distribution is opposite to previous showing the lower values in the central sector of the project.

3.4 Ag/Au ratio

The Pingüino project Ag/Au ratio, considering the 19 veins studied, has an average value of 883. This ratio is elevated compared with others epithermal deposits of the Deseado Massif (Fernández et al. 2008). But, this ratio is highly variable when considering the different vein types. While the dominant sulphide-rich veins (MC, IVO, IVS, IVN, SAV, KAS, KAR and SON) shows an average Ag/Au ratio of 307; the dominant quartz-rich veins (MNW, MN, ME, TR, MS), presents a higher average ratio of 1334. The last value can be only compared in the Deseado Massif with the high Ag/Au ratio of the silver-rich Martha mine (Fernández et al. 2008).

The spatial distribution of the Ag/Ag ratios exhibits a zonation at Pingüino, with relative low Ag/Au ratios in the central area (IVO vein has Ag/Au=48), that rises up to 200 involving IVS, MC, SAV, MW, ME, KAR, CSV and ISL veins, and increases outwards to the rest of the veins, up to 3,889 in the TR vein (Fig. 2).

The Ag/Au ratio is a very effective indicator of geochemical environment and spatial position of gold and silver in hydrothermal ores (e.g. epithermal, porphyries) (Cole 1986; Einaudi 1994). This ratio was even used to distinguish a gold zone from a silver zone in the epithermal deposits Tuscorara (Nevada, Castor et al. 2003). However metal zoning and distribution of Au/Ag exhibits different patterns from core to outside in different deposits (e.g. low sulphidation epithermal deposits and porphyries).

A similar zonation pattern of Ag/Au of Pingüino veins was described in Tayoltita mine silver-gold epithermal vein deposit, Mexico. It shows a zonal pattern characterized by a central core of low Ag/Au ratios and higher salinities about which develop increasingly higher ratios and diluted salinities (Clarke and Tiltley, 1988).

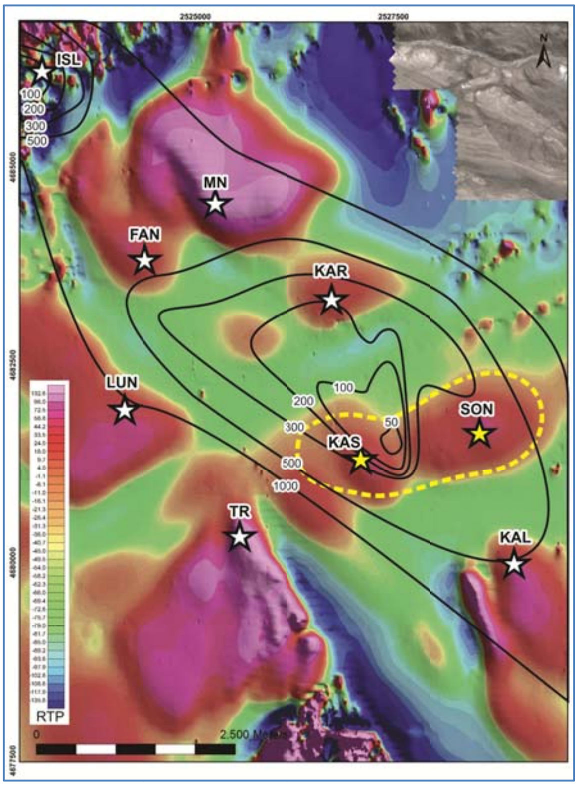

Figure 2. Ag/Au ratio distribution in the Pingüino vein system. Lower ratios are close to Kasia intrusive and extends to NW-SE. Base map is showing ground magnetics RTP evidencing the mafic intrusions (violet anomalies) of La Leona or Cerro León Formations at Pingüino project. White stars represent possible intrusion-related sources for metals (KAL, TR, LUN, FAN, MN, KAR and ISL), dashed yellow polygon is the interpreted location of the Kasia intrusion at depth, with two yellow stars at the possible source points (SON and IVO).

When average Ag/Au ratios are plotted versus In, three clear trends can be recognized (Fig 3) for the Pingüino project veins. Trend 1 (violet arrow), exhibits high In contents (18 to 36 ppm) but a low Ag/Au ratio (~50 to 200), and comprises IVO, SAV, IVN and MC veins. Trend 2 (pink arrow), shows a wide dispersion in the Au/Ag ratio, but In values are low, usually below 1 ppm. This trend is constituted by the following veins ordered with increasing Ag/Au ratio (from ~100 to 4,000): ISL, KAR, CSV, FAN, MS, MNW, MS, KAL, LUN, MN and TR. Trend 3 (orange arrow) gather veins with intermediate In (2 to 15 ppm) and Ag/Au (200 to 1,000) values, involving ME, MN, SON, KAS and IVS. The cluster conformed by ME, KAR and CSV since they are very close to Trend 2 and Trend 3, are difficult to associate to any of these trends.

The three trends have a clear geographic association in plan view (Fig. 4), where the center is occupied with Trend 1, surrounded by Trend 3, and then by Trend 2 group of veins.

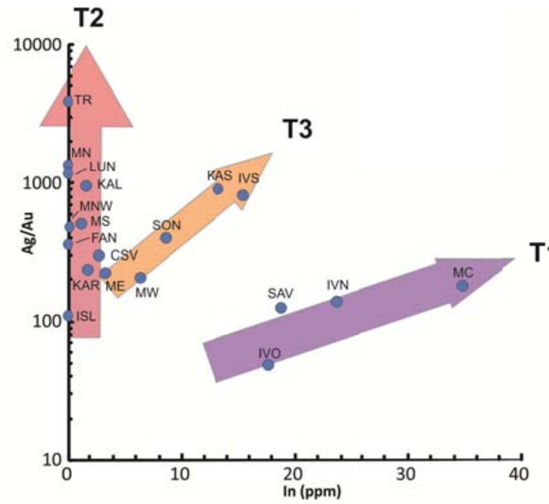

Figure 3. Binary diagram of averaged Ag/Au ratio vs. In values for the Pingüino project veins. Colored arrows represent three Trends, T1, T2 and T3.

Concluding remarks

Plan view of individual elements distribution show a main metals source point centered in the IVO and SON veins, and above the interpreted dioritic Kasia intrusion (Peñalva et al. 2008), with other secondary metal sources at KAL, TR, LUN, FAN, MN, KAR and ISL veins (see stars plotted at Fig. 2). The Au/Ag ratio also shows minimum values concentrated at the Kasia intrusion area.

Metals distribution at the Pigüino vein system show an important zonation and a good spatial correlation with geophysically (ground magnetics) interpreted intrusions at depth.

Kasia mafic intrusion is the most important metal source for the vein district, but also the related to or below the KAL, TR, LUN, FAN, MN, KAR and ISL veins represent a secondary or local metal source for the system.

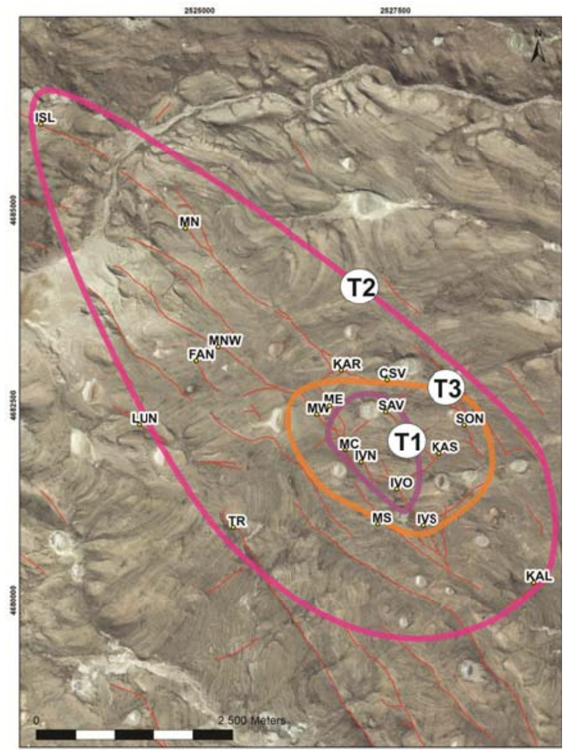

Figure 4. Veins grouped according to Ag/Au vs In. The center occupied with Trend 1, is surrounded by Trend 3, and then by Trend 2.

The three trends defined at Pingüino (Fig. 3 and 4) represent the different veins types. Trend 1 is represented by the dominant sulphide-rich veins (related to Lower Jurassic diorites), surrounded by Trend 2 dominant quartz-rich veins (related to Middle Jurassic andesitic porphyries), with Trend 3 being an intermediate zone that could reflect the mixing between the two main type of veins.

The quartz-rich veins shows very high Ag/Au ratio, compared with other deposits in the Deseado Massif, only comparable with the Ag-rich Martha mine.

The metals distribution and the relationship of possible metal sources with outcropping and/or not-outcropping intrusions should be considered as an important tool for further exploration programs at Pingüino, and other projects in the Deseado Massif.

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