GEOTHERMOMETRY, ORE GEOCHEMISTRY AND FLUID FLOW IN THE ESPERANZA VEIN, HUACHOCOLPA DISTRICT (HUANCAVELICA, PERU)

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Introduction

The Esperanza Zn-Pb-Ag vein, owned by Compañía de Minas Buenaventura S.A.A., lies over 4000 to 4650 masl in the Western Cordillera of the Peruvian Central Andes.

The Esperanza low sulphidation epithermal vein trends ~E-W along 1500 m; it dips to the South and can be followed to 350 m depth. As other veins of the district, like Teresita and Bienaventurada, it is hosted by intermediate to felsic volcanics (andesitic to dacitic compositions) of the Huachocolpa Group (Middle Miocene to Upper Pliocene).

The mineralisation occurs mostly as open space filling related to fracture development during the Quechua III deformational event. Main ore minerals are sphalerite, galena, tetrahedrite, pyrite, chalcopyrite and Ag and Pb sulfosalts; quartz, barite and calcite are the main gangue minerals. Current production grades are ~5% Zn, ~8Oz/t Ag, ~3% Pb; usually very low Cu (mean ~0.04%).

Ore deposition

Three hypogene events of ore deposition can be distinguished:

i) A precursor event, with deposition of chalcedony, barite and pyrite, followed by brecciation and deposition of “black quartz” (chalcedony and fine grained pyrite), fine grained quartz, sphalerite, galena, pyrite and, less commonly, calcite.
ii) The main depositional event follows another brecciation episode, is characterized by coarse quartz, barite, coarse sphalerite (rich in FI), galena (often Ag-rich), pyrite, chalcopyrite, tetrahedrite, polybasite, marcasite, jamesonite, antimonite, realgar, bournonite, and is closed by a late brecciation episode.
iii) A last hypogene event, with calcite and disseminated pyrite in small cavities between sphalerite crystals.

A later episode of supergene alteration is evidenced by iron oxides and changoite.

Fluid Inclusion (FI) study

FI petrography identified primary (**P**), pseudo-primary (or modified), secondary (**S**) and pseudo-secondary (**PS**) FI. Careful petrographic work showed that the most reliable FIAs (FI assemblages, as defined by Goldstein & Reynolds, 1994) are hosted by Stage ii sphalerite. Some FI´s have been measured in quartz and barite of the same event, but unfortunately FI in barite suffered stretching or decrepitation during heating, while the quartz FI are usually too small or, in other cases, they seem to be pseudo-primary FI (Pérez-Puig, 2008).

Fluids are aqueous and moderately saline (5 to 7 w% NaCl eq.), showing total homogenisation temperatures (**Th**) in the range from 250ºC to 300ºC. Boiling was common, as shown by: (i) the coexistence of small consistent liquid-rich and bigger vapour-rich FI, the former being more saline than in other parts of the vein, and (ii) bladed calcite replaced by quartz. The Th can therefore be considered as the trapping temperature.

The (palaeo)isotherms deduced from the FI study (Fig. 1) show two thermal maxima, suggesting two heat sources, the larger in the west (300ºC) and the smaller in the east (~250ºC).

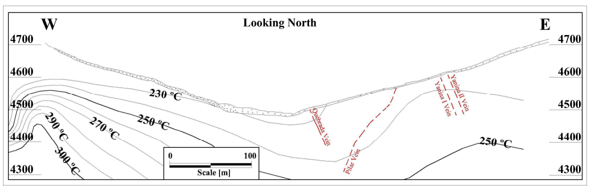

Figure 1. Palaeoisotherm geometry deduced from the FI microthermometry study.

Geochemical zoning

The Esperanza Vein has been the subject of a lithogeochemical study. Its metal contents have been systematically analysed (over 3000 samples), compared, and related to their spatial distribution along the structure, to depict the evolution (Pérez-Puig, 2008). Metal ratios (as ln) have been used to show fluid chemistry variations of the evolving hydrothermal system. These variations can be related to the directions of fluid flow. The resulting picture (e.g. Figs. 2 to 4 for lnPb/lnZn, lnAg/lnCu, and lnAg/lnPb metal ratios) suggests an upward flow of the hydrothermal fluids, progressing from both sides (west and east) of the structure –arrows– and selectively precipitating Zn and Pb at lower levels. A relative Cu enrichment at higher levels is depicted by the low Ag/Cu ratio in the east side (Fig. 3), while in the west Cu was later removed by supergene alteration above 4500 m. This distribution could be explained by the relatively poor Cu concentration of the original solutions (both Zn/Cu and Pb/Cu metal ratios are >15), which would prevent the precipitation of this metal until its saturation threshold is reached, at shallower levels. The meaning of the relatively low Pb/Zn ratio at the center (Fig. 2) is not straightforward, since it corresponds to low grade values in both metals, approaching the detection limits; it could also be produced by a second hydrothermal event, since it is located at the intersection with another vein.

Comparison of the metal ratio distribution with the (palaeo)isotherms (Figs. 1 & 2) shows the importance of boiling in the precipitation of the ores, particularly sphalerite.

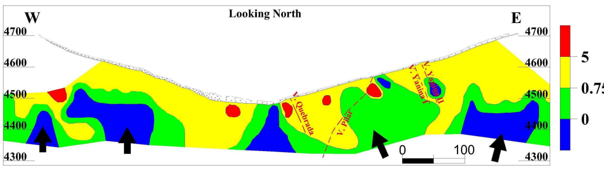

Figure 2. Metal ratio ln(%Pb)/ln(%Zn). Zn (blue) dominates at depth.

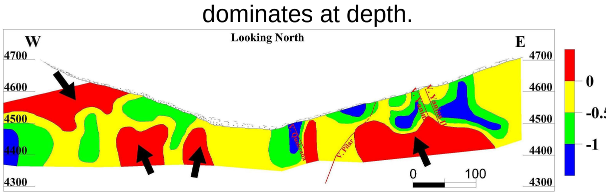

Figure 3. Metal ratio ln(Oz/t Ag)/ln(%Cu). Ag (red) dominates at depth and in the upper west corner.

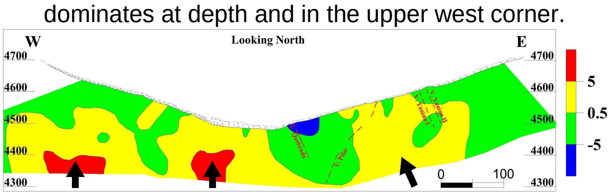

Figure 4. Metal ratio ln(Oz/t Ag)/ln(%Pb). Ag (red) dominates slightly at depth in the west zone.

Mineralogical information

The presence of the rare Zn sulphate changoite ($Na_2Zn(SO_4)_2{\cdot}4H_2O$), detected in the west at shallow levels points to fresh, oxidizing groundwater, which also leached Cu.

The spatial distribution of ore minerals, with sphalerite predominating at depth and galena near the surface, and the presence at the surface of such ores as stibnite, goethite, and realgar in the east corner, accompanying gypsum and other supergene minerals, is consistent with our results.

Conclusions

A combined FI and lithogeochemical study of the ores gives a consistent picture of the hydrothermal evolution of the ore fluids. Two source areas were identified at depth by the (palaeo)isotherm geometry deduced from FI geothermometry and by the geometry of selected metal ratios.

These criteria can be applied to exploration, as in the Julcani district (Goodell and Petersen, 1974; Petersen et al., 1977). Nevertheless, the peculiarity of each district must be taken into account: the variation trends of Cu ratios are at the Esperanza Vein opposite to those found in Julcani by these authors, but similar to the Rublo Vein (Castroviejo et al., 2008). This is explained by the different relative metal contents of the ore solutions in Huachocolpa and Julcani districts.

Supergene alteration, consistent with oxide mineralogy, has also been detected in this case by metal ratios.

Acknowledgement

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References

Castroviejo, R.; Yparraguirre, J.A.; Chacón, E. 23rd International Applied Geochemistry Symposium. Oviedo, Spain. pp 159 – 160 (2007).

Goldstein, R.H.; Reynolds, T.J. Systematics of fluid inclusions in diagenetic minerals. Short Course 31, Society of Economic Palaeontologists and Mineralogists. Tulsa, Oklahoma (1994).

Goodell, P.C.; Petersen, U. Econ. Geol, vol. 69, pp. 347 – 361 (1974).

Pérez-Puig, C.R. Investigación de los controles geológicos de la mineralización en Veta Esperanza (Huachocolpa, Perú). ETSI Minas, Universidad Politécnica de Madrid. Madrid, Spain (2008).

Petersen, U.; Noble, D.C.; Arenas, M.J.; Goodell, P.C. Econ. Geol.., vol. 72, pp. 931 – 949 (1977).