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Genesis of Ag-rich mineralisation in the Buenaventura and Galera veins, Yacumina zone, SW part of the Morococha district, central Peru

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Abstract

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The Morococha mining district is part of the Miocene polymetallic belt of central Peru and hosts various types of ore bodies – porphyries, skarns, replacement bodies (mantos) and polymetallic epithermal veins. The central, northern and eastern parts of the district are the most intensively mineralised. In the SW part of the district, known as the Yacumina zone, two polymetallic veins – Buenaventura and Galera, host the main part of the economic mineralisation. The two structures are hosted by Aptian-Albian sedimentary rocks, consisting essentially of bituminous limestone-dolostones of the Machay series and Goyllarisquiza Group. The carbonate sedimentary formations are partially covered by rhyolitic tuffs, possibly Late Cretaceous in age. The tuffs are intensively silicified and hydrothermally altered (silica and carbonates). The Miocene Anticona diorite (14.11 Ma) crops out in the northern and eastern parts of the studied area. The intrusion shows volcanic arc signature (Ta, Nb and Ti depletion) with a subducted slab component (high LREE).

The Buenaventura vein is oriented northeast-southwest and dips to the northwest 60°. The mineralisation consists of disseminated euhedral pyrite, Fe-poor sphalerite, chalcopyrite, galena, fahlore group minerals, Ag-rich sulphosalts, surrounded by native silver, rhodochrosite and calcite. Drilling in the NE part of the study area, in the deeper part of the Buenaventura vein, has intersected a calcic skarn similar to that described in the Codiciada area.

The Galera vein is a vertical structure, oriented north-south and surrounded by a halo of intensive silicification. During the early mineralisation stage recorded in the Galera vein arsenopyrite, pyrrhotite, pyrite, and Fe-rich sphalerite were formed. The Fe-rich sphalerite shows oscillatory compositional zoning (10 to 2 wt% Fe). The later base metal stage is composed of euhedral pyrite, Fe-poor sphalerite, galena, fahlore group minerals, Pb-sulphosalts, euhedral arsenopyrite, marcasite, and electrum. Gangue minerals consist of quartz, calcite and rhodochrosite. A south-north zoning is recognised at level 4 (4663m), with an early stage Fe-rich sphalerite-pyrrhotite-arsenopyrite assemblage in the southern part and a base metal Fe-poor sphalerite-galena-pyrite bearing assemblages in the northern one.

To constrain the origin of the mineralising fluids responsible for the economic mineralisation in the studied veins, fluid inclusion microthermometry has been performed in addition to a stable isotope study. Fluid inclusions have been measured in quartz from the Buenaventura vein, and in sphalerite from the Galera vein and from a breccia dyke cutting the rhyolitic tuffs and containing limestone clasts in a silica-rich matrix. Fluid inclusions are usually two-phase liquid-vapour and homogenise to a liquid phase. Homogenisation temperatures measured in quartz-hosted inclusions range from 221 to 294°C (n=116) with a mean at 261°C and salinity ranges from 1.2 to 4.8 wt% NaCl eq. with a mean at 2.9 wt% NaCl eq. Microthermometric results for the different sphalerite-hosted inclusions from the Galera vein are as follows: for early mineralisation stage Th ranges from 173 to 250°C (n=19) with a mean of 207°C and salinity is in the range 4.2-8.3 wt% NaCl eq., with a mean of 5.3 wt% NaCl eq.; for the later base metal mineralisation Th is 167-245°C (n=12) with a mean of 213°C and salinity ranges from 4.2 to 15.3 with a mean of 9.5 wt% NaCl eq.; for the breccia dyke Th is 166-207°C (n=7) with a mean of 190°C and the salinity ranges from 10.1 to 11.3 wt% NaCl eq. with a mean of 10.7 wt% NaCl eq. According to this data, an increase of fluid salinity with time can be noted without significant correlation with Th, and could result from boiling. Boiling is also indicated by the presence of platy calcite textures. In general, the early mineralising fluid exhibits a moderate salinity and quiet moderate temperature, which can be explained by a mixing between a hotter and saline magmatic fluid and a neutral “cold” meteoric fluid. The magmatic component in the fluids is also inferred based on the presence of sericite as accidentally trapped solids in some fluid inclusions.

Abstract

Sulphur isotopic study has been performed on pyrite, sphalerite and galena from the Galera and the Buenaventura veins. Both veins exhibit a range of $\delta^{34}\text{S}$ values from -3 to +5 ‰, typical for polymetallic vein deposits in central Peru and Mexico, and indicate mainly magmatic origin of the sulphur. Sulphur isotopic composition of sulphides in Buenaventura and Galera veins compared to sulphides from others polymetallic veins, show a typical evolution of $\delta^{34}\text{S}$ for pyrite, sphalerite and galena due to isotope fractionation. Bitumen has been found, as dissemination in sedimentary host rocks and has a typical sulphur isotopic signature around -40‰. According to the sulphur isotopic data for sulphides from both veins, H_2S necessary for sulphide formation is not coming from the bitumen but have a magmatic origin. However, the influence of bitumen as redox buffer for the ore-formation can not be excluded.

Carbon and oxygen isotopic study has been performed on quartz from the early stage of the Buenaventura vein and on carbonates (calcite, rhodochrosite) from the late carbonate stage of both veins. Both veins exhibit carbon isotopic value for the mineralising fluid in equilibrium at 180°C with the late carbonates between -10 and -2‰. Whereas both veins exhibit oxygen isotopic value for the mineralising fluid in equilibrium at 180°C with the late carbonates between -8 and -2‰. Given that magmatic fluid has typical oxygen isotopic value between 5 and 10‰ and the local Miocene meteoric water around -18‰, the mineralising fluid in equilibrium with the late carbonate stage is most probably the result of mixing between magmatic and meteoric fluids. Additionally, the mineralising fluid in equilibrium at 260°C with quartz from the early stage of the Buenaventura vein range between -8 to -3‰. This early fluid exhibits same isotopic characteristics as the one from the late carbonate stage. Consequently, we can assume that the mineralising system as a whole results from a mixing between magmatic and external meteoric fluids.

A comparison between both veins can be done to determine potential relationships between them. Even if both veins exhibit the base metal and late carbonate stage, have the same sulphur and oxygen-carbon isotopic signatures, some particularities such as orientation, ore textures, metal grade, metal correlation, accessory sulphides, and sulphide zonation indicate that they are probably not directly related. We assume that the Buenaventura vein could be an external part of the Morococho mineralising system where the magmatic fluid component could derive from one of the Miocene intrusions in the central part of the district, while the Galera vein could be a part of a system developed more to the south.