European Mineralogical Conference
Vol. 1, EMC2012-251, 2012
European Mineralogical Conference 2012

The secondary high-grade Cu deposit of Las Cruces (S Spain): A VMS deposit with superimposed epithermal-like present-day mineralization

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The Las Cruces mine, currently worked by Cobre Las Cruces SA (INMET Mining) is the most recent operation in the Iberian Pyrite Belt (IPB), SW Iberia. The deposit includes a folded felsic volcanic and shale-hosted volcanogenic massive sulfide orebody (30 Mt @ 3.2%Cu and 1.1%Zn) of late Devonian age, similar to those found elsewhere in the IPB but also a large and complex secondary cementation zone (17 Mt @ 7%Cu) and a small overlying gossan (1.7 Mt @ 5.9 g/t Au and 98 g/t Ag). The deposit is covered by ca. 150 m of subhorizontal sandstone and overlying marl (Miocene) that are critical for the formation of the secondary mineralization.
The contact between these sediments and the mineralization is marked by a red gossan similar to those found elsewhere in the Pyrite Belt and probably formed during an early sub-aerial alteration in Pre-Miocene but post-Variscan times. It is underlain by a different style of mineralization, the “black rock”. It is a low fS2 assemblage with galena, greigite-smythite, siderite, gold and diverse Ag-rich sulfosalts. This rock is interpreted as formed by the reduction of the former hematite-siderite-rich gossan by the biogenic reduction of sulfate and concomitant increase of the pCO_2 related with the circulation of groundwater along the basement-cover unconformity.
Thee cementation zone is separated from the previous one only by some metres of barren, coarse grained pyrite. It includes the widespread replacement of pyrite by a complex high sulfidisation assemblage including chalcocite s.s., tennantite, enargite and calcite. The mineralization here is crosscut by abundant veins and breccias with epithermal-like banded textures including the aforementioned sulfides plus quartz, barite and calcite. This mineralization formed at temperatures higher than 100-120ºC, in relationship with the mixing of, locally boiling, deep hydrothermal fluids with the surficial ones between the Miocene and the present day. The stable and radiogenic isotopes suggest that the metals and sulphur are derived from the host massive sulfides.
Our model for the genesis of this unusual high grade secondary mineralization involves the spatial coincidence of an earlier volcanogenic massive sulphide deposit with a more recent, post-Miocene in age, upflowing hydrothermal system and an a aquifer confined to the basement-cover contact. The fluid mixing zone under the sealing marl was the loci of major chemical changes and microbial activity that lead to the Cu enrichment and the formation of the black rock; the changes in the water fluxes and in the temperature are responsible of the variations in the mineral assemblages.

Acknowledgements: Study funded by the ProMine FP7 UE Project, the SEDI CGL2011-23207 project of the Spanish Government and Basque Government (Research Group IT-340-10) grant BFI-2011-254. We acknowledge Cobre Las Cruces for granting access to the deposit and the information provided.