Geology and Cu Isotope Geochemistry of the Las Cruces Deposit (SW Spain)

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INTRODUCTION.

The Las Cruces ore deposit is one of the richest copper deposits in the world. Located in the Iberian Pyrite Belt (IPB), the mine currently works the supergene cementation zone of a volcanogenic massive sulphide (VMS) deposit. It includes a primary VMS and the associated stockwork (30 Mt @ 3.2% Cu, 1.1% Zn), and the supergene cementation zone (17 Mt @ 7% Cu) and overlying gossan (1.7 Mt @ 5.9 g/t Au, 93 g/t Ag) (Fig. 1).

The deposit is located 20 km north of Seville, buried by the Guadalquivir sedimentary basin. The mineralization was discovered during a geophysical survey developed by Rio Tinto plc. in 1994; nowadays the project is run by Cobre Las Cruces, S.A. a subsidiary of INMET Mining. Open pit production started on 2009.

In this study we describe the lithologies present at Las Cruces ore deposit, and their geochemical and Cu-isotope composition. Our preliminary results indicate that the formation of the system is polyphase and it has been active well after the Tertiary sedimentation.

GEOLOGICAL SETTING.

The IPB, located in the SW of the Iberian Peninsula, is on the largest VMS provinces in the world. The stratigraphy, of late Devonian to Carboniferous age, is simple and made up by the PQ basal unit, a thick unit of alternating shale and quartzite. It is overlain by the Volcano-Sedimentary Complex, which hosts the VMS, and is made up of alternating volcanic and sedimentary rocks. The sequence finishes with the Culm Group, a flysch unit (Schermerhorn, 1971). The structure is controlled by folds and faults produced during the Variscan Orogeny.

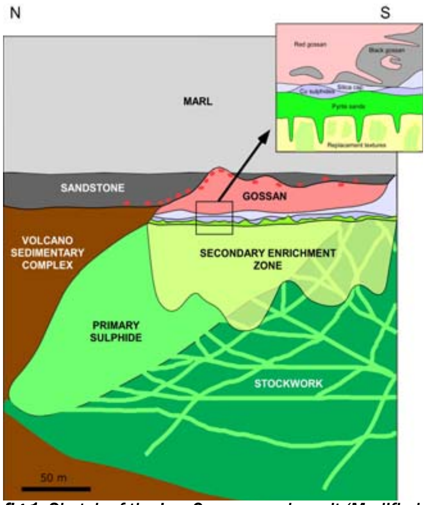

fig 1. Sketch of the Las Cruces ore deposit (Modified from Knight, 2000).

Later erosion exposed some of the VMS of the IPB, with subsequent formation of the gossans and, usually small underlying cementation zones.

The later oceanic transgression covered the Las Cruces ore deposit and host rocks. The stratigraphic sequence of the Guadalquivir Basin includes a few meters thick calcarenite unit overlain by at least 150 m thick of homogeneous marl. The calcarenite basal unit hosts an aquifer which has interacted with the ore deposit.

The structure of the ore deposit is simple: the primary VMS has an E-W direction and dips 45° N; it is delimited by first grade E-W Variscan faults. The supergene alteration zone and the Tertiary sedimentary cover lie horizontally. There are large N-S Alpine faults that crosscut the deposit but do not change the architecture significantly.

MINERALIZATION.

The primary VMS mineralization has been described in previous studies; they are broadly similar to other equivalent deposits of the southern IPB, except for the larger Cu content (Knight, 2000).

Current mine works allow the access to the supergene alteration zone and the sedimentary cover. The cementation zone replaces the primary VMS and stockwork, and includes different minerals of the chalcocite group and, in a lesser extent, neoformed pyrite; there is local covellite and remnants of earlier, probably also supergene, chalcopyrite and bornite. Enargite and tennantite are fairly abundant. A similar assemblage is also present in late calcite-quartz-anglesite veins and breccias. The hanging wall of this unit is horizontal, but the footwall is irregular, with the major thickness related to the Alpine faults.

The boundary between the cementation zone and the overlying gossan is marked by the presence of a 0.5-1 m thick layer of barren coarse grained pyrite. The upper part shows a significant enrichment in galena that coats and replaces pyrite and marks the transition to the "Black Rock". It underlies the gossan and here is interpreted as a product of its alteration. This lithology is composed by galena, siderite, quartz and minor amounts of Fe-sulphides as greigite and pyrrhotite. Galena shows skeletal growths and mat-like textures; the carbon isotope composition of siderite is typical of biologic derivation suggesting that these rocks are product of the biogenic reduction of the gossan. The Yellow Rock, associated to the Black Rock, seems to have been formed by its later supergene oxidation. It is composed by goethite, siderite, anglesite and quartz. Finally, the gossan, is composed mainly by haematites, siderite, quartz and minor goethite and calcite. Here, euhedral siderite and skeletal goethite grow in cavities.

palabras clave: Las Cruces, Alteración supergénica, Isótopos de Cu.	*key words:* Las Cruces ore deposit, Supergene alteration, Cu isotope.

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macla nº 15. septiembre 2011
revista de la sociedad española de mineralogía

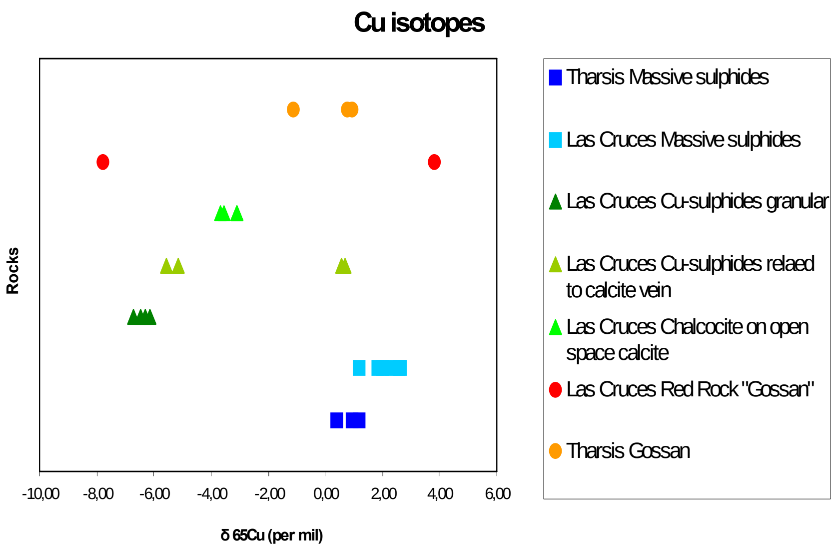

fig 2. *Cu-isotopes distribution for Las Cruces and Tharsis ore deposits.*

Finally, there is a pervasive silica alteration, which occurs associated to the Alpine faults. This alteration irregularly replaces all the described lithologies as well as the base of the sedimentary sequence. It occurs mainly as massive silica along the fault plane, and as stratabound irregular replacements along the contact between the gossan and the cementation zone. This rock is locally rich in pyrite.

GEOCHEMISTRY.

A total of 48 samples from Las Cruces and the Tharsis and San Miguel gossan rocks were analyzed in order to compare the geochemistry of the supergene alteration zone and that of other nearby deposits.

The gossan in Las Cruces and in the other deposits of the IPB have similar geochemical patterns. Anyhow, that at Las Cruces shows a marked enrichment in Ag, Pb and Sb and is depleted in As and Zn. Also, it is depleted in Al_2O_3, Ba and Ce.

The Black Rock shows a marked enrichment in Ag and Zn and a large depletion in Fe, Cu and As if compared to the overlying gossan. The barren pyrite layer is enriched in Co and Cu.

COPPER ISOTOPES.

The behaviour of copper in the Las Cruces ore deposit has been studied through Cu-isotope geochemistry. We selected representative duplicate samples of Las Cruces primary VMS (massive and brecciated ore), the supergene cementation zone (stratabound mineralization, and sulphides on veins), gossan and Black Rock; some other samples come from the Tharsis primary VMS and the gossan.

The Tharsis results are consistent with previous studies done in similar deposits (Larson *et al.* 2003); however, the Las Cruces Cu-isotope pattern (Fig. 2) is significantly different. The Cu isotope geochemistry of the primary VMS is enriched in ^{65}Cu respect to primary Cu-sulphides elsewhere while the supergene sulphides have depleted $\delta^{65}Cu$ values instead of showing enrichment respect to primary sulphides, as it is reported in previous studies (Larson *et al.,* 2003). A linear enrichment of the $\delta^{65}Cu$ values occurs in the three samples from the cementation zone. The Red Rock $\delta^{65}Cu$ values show very large variation from positive to negative. The Black Rock has insufficient copper to analyse the $\delta^{65}Cu$.

CONCLUSIONS.

The Las Cruces ore deposit has some key features, both in the hypogene and supergene mineralization, that make it unique at regional and global scale. This is due to the combination of the existence of a Cu-rich primary mineralization and an unusual maturation below a sedimentary cover – probably with major biogenic activity – after its exhumation and partial oxidation to a gossan. The Cu isotope pattern is also unique and the behaviour of Cu isotopes follows a pattern not observed in any other deposit.

ACKNOWLEDGEMENTS.

This ongoing study is part of a PhD project at the IGME, partly fund by the ProMine of the VII Framework Program of the EU. We want to thank Cobre Las Cruces, S.A. for their support and access to information and grounds.

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