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Roman Copper Archaeometallurgy at Sítio do Cobre, Central Portugal

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The copper mines of Ingadanais, located in Vila Velha de Ródão near Castelo Branco, central Portugal, are a remarkable example of a preserved ancient copper production site in Iberia, where smelting took place at the mine site. The small size of the deposit and the reasonable amount of slags produced, without reaching extensive exploitation, like other places in Iberian Pirite Belt like Rio Tinto or Aljustrel, its perfect for understanding archaeometallurgical processes at a local scale. Preliminary and promissing data are presented here.

Ingadanais comprise seven mines that were mined from 1904 to 1986, but with references to ancient mining, at least, for Sítio do Cobre. The copper mineralization occurs in a NE-SW fault system associated with the Ponsul fault that has an inherited Variscan geometry and an Alpine reactivation. The primary mineralization comprises chalcopyrite (Cpy) $\pm$ pyrite (Py) $\pm$ arsenopyrite $\pm$ marcassite $\pm$ gersdorffite $\pm$ tetrahedrite-tennantite in quartz veins or silicified greywacke brechias. Microscopic and textural interpretation indicates at least three mineralization stages through fault reactivation. The secondary mineralization results from the oxidation of the sulfide minerals (mainly Cpy and Py), and comprises secondary sulfides, copper oxides and sulfates, and iron hydroxides. A slag deposit near Sítio do Cobre, with 8 slag heaps identified, has a Roman chronology (II-IV century), based on archaeological finds and preliminary Carbon dating on separated charcoal from the slags.. These slags can be relatively heterogeneous, from dense, compact, and devitrified to more vacuolar and vitreous smelting products. Furnace walls with metallic adherences, furnace clay fillings are common. Slags often contain a considerable amount of sulphide iss (intermediate solid solution), copper, and/or cuprite droplets implying a reduction chain and low-efficiency smelting. The copper droplets are commonly surrounded by a cuprite coating. Cuprite and brochantite also fulfill vacuoles.

Primary mineralization and slags were chemically analysed for both elemental and copper isotopes in order to evaluate heterogeneities within the deposit, Cu sources, fractionation along the reduction chain, and the efficiency of the metallurgic processes. Si and Fe are the main components of the slags reflecting the mineral assemblage, containing almost pure fayalite (Fa $\sim$98 %) and some scattered magnetite associated with quartz relics. Their high S and Cu contents are due to the presence of Cu-sulphide, Cu-oxide and metallic copper prills. Based on mineralogy and chemistry three reduction steps were recognized.

Preliminary copper isotopic data show that Cpy from Ingadanais mines varies widely, with Cpy from Sítio de Cobre being isotopically lighter, -0.21‰ to -1.35‰ 65Cu/63Cu, than those from other Ingadanais mines (0.00‰ to 0.18‰. This is consistent with a multistage mineralization as revealed by the textural interpretation. The copper isotopic data for the native Cu (-1.89‰ to 0.28‰ and cuprite (-2.51‰ to 0.02‰ from the Roman(?) slags is somewhat compatible with Sítio do Cobre Cpy values. However, the extreme negative values and the noticeable fractionation between cuprite and native Cu suggest fractionation controlled by incomplete oxidation reactions during the metallurgic process. This also corroborates the low-efficiency smelting.