Juan Aurelio Pérez Macías

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Umschlagfoto: The mine of Mocissos (Portugal) with pioneer plants, 25 April 2005. In the background the river Guadiana, the border between Portugal (left) and Spain (right), photograph: Michael Kunst.
Die Mine von Mocissos (Portugal) mit Pionierpflanzen, 25.4.2005. Im Hintergrund der Guadiana, die Grenze zwischen Portugal (links) und Spanien (rechts), Foto: Michael Kunst.

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Widmung

Mit herzlichem Glückwunsch
Herrn Prof. Dr. Dres. h. c. Hermanfrid Schubart
zu seinem 90. Geburtstag am 1. Dezember 2020

Hermanfrid Schubart, im Hintergrund der Puig Llorença – Cumbre del Sol, Benitachell, Comunidad Valenciana, Spanien
(Foto: Annie Schubart, April 2004).
Hermanfrid Schubart, no background Puig Llorença – Cumbre del Sol, Benitachell, Comunidad Valenciana, Espanha
(Foto: Annie Schubart, Abril 2004).

Die archäometallurgischen Untersuchungen, die im Zentrum dieses Bandes stehen, gingen von den Ausgrabungsergebnissen in Zambujal aus. Zambujal gehört zu den besonders intensiv erforschten kupferzeitlichen befestigten Siedlungen der Iberischen Halbinsel. Das verdanken wir Hermanfrid Schubart, der 1963 von Seiten der Madrider Abteilung des Deutschen Archäologischen Instituts die Untersuchungen in Zambujal begann und zusammen mit Edward Sangmeister und Leonel Trindade sowie einem großen, internationalen Team von 1964 bis 1973 sechs umfangreiche Ausgrabungen in dieser prähistorischen Siedlungsanlage durchführte. Ohne seine Initiative wären die interdisziplinären und internationalen Forschungen, die inzwischen schon sechs Monographien gefüllt haben, nicht möglich gewesen. Auch dieser Band wäre gar nicht zustande gekommen. Die Grabungskampagnen von 1964-1973 in Zambujal und ihre Veröffentlichung in Band 5, 1 der Madrider Beiträge markieren einen Wendepunkt in der Erforschung der Kupferzeit der Iberischen Halbinsel! Vor allem hat Hermanfrid Schubart aber einen wichtigen Grundstein zu gegenseitigem Vertrauen und zu intensiven wissenschaftlichen wie freundschaftlichen Kontakten zwischen den deutschen Wissenschaftlern und denen der Iberischen Halbinsel gelegt, Kontakte, die sich schließlich auch in der vorliegenden Veröffentlichung wiederspiegeln.

As pesquisas arqueo-metalúrgicas, que constituem o tema central deste volume, partiram dos resultados das escavações de Zambujal. Zambujal apresenta-se como um dos povoados calcolíticos fortificados da Península Ibérica com investigação mais intensa. Tal devemos a Hermanfrid Schubart, que iniciou em 1963, com o Instituto Arqueológico Alemão, as investigações em Zambujal, e realizou, em conjunto com Edward Sangmeister e Leonel Trindade com uma equipa grande e internacional, seis campanhas de escavação entre 1964 e 1973 nesse povoado pré-histórico. Sem a sua iniciativa, as investigações interdisciplinares e internacionais, que, entretanto, produziram seis monografias, não teriam sido possíveis. Também este volume não se teria realizado. As campanhas de escavação de 1964 a 1973 em Zambujal e a sua publicação em volume 5,1 da série Madrider Beiträge marcam um ponto decisivo na investigação da Idade do Cobre na Península Ibérica! Sobretudo, Hermanfrid Schubart preparou um fundamento importante para a confiança mútua e para contatos intensivos científicos e amigáveis entre os científicos alemães e da Península Ibérica, contatos que, finalmente, são também refletidos nesta publicação.

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Copper Ore Resources and Prehistoric Exploitation in Southwestern Spain

Juan Aurelio Pérez Macías

1. Introduction

The southwestern Iberian Peninsula has so many mineral deposits that it is impossible to plot every single mining concession with copper minerals onto a small map (fig. 1)[1]. From an archaeological point of view, the prehistoric and Roman exploitation of these massive polymetallic sulphides within this density of deposits has always been emphasized. The extent of these mineralizations – some of which still have large reserves due to a lack of a technology that can separate the distinct minerals – are useful for explaining particular historical processes, such as the Megalithic Culture colonization, that would have brought the first mining prospectors. Sometimes such conclusions do not stop with the geological description of the minerals and the weathering processes that they have undergone. The general aspects of weathering are marked by such geological principals as leaching and cementation of its metallic substances. This also needs to be studied in detail, because such general principals do not always behave in the same way on every occasion. Additionally, in order to approach prehistoric mining, it is essential to know the arrangement and form of the minerals in each orebody or vein. The mere existence of copper minerals, even when abundant and of high quality, does not mean that they were exploitable using the technology available in that epoch. For example, it seems clear that the massive polymetallic deposits in Andévalo and Alentejo were not exploited during prehistory for the production of copper. The As (arsenic) will be explained below together with the processes of oxidation and weathering of the primary sulphides. Copper minerals are not present in the superficial zones there, which would have been the most accessible to prehistoric mining, but rather in the secondary enrichment zone, which was not exploited until the Roman Imperial period. Prehistoric, as well as Roman, mining exploited the minerals in the oxidation zone, i.e. copper oxides and carbonates.

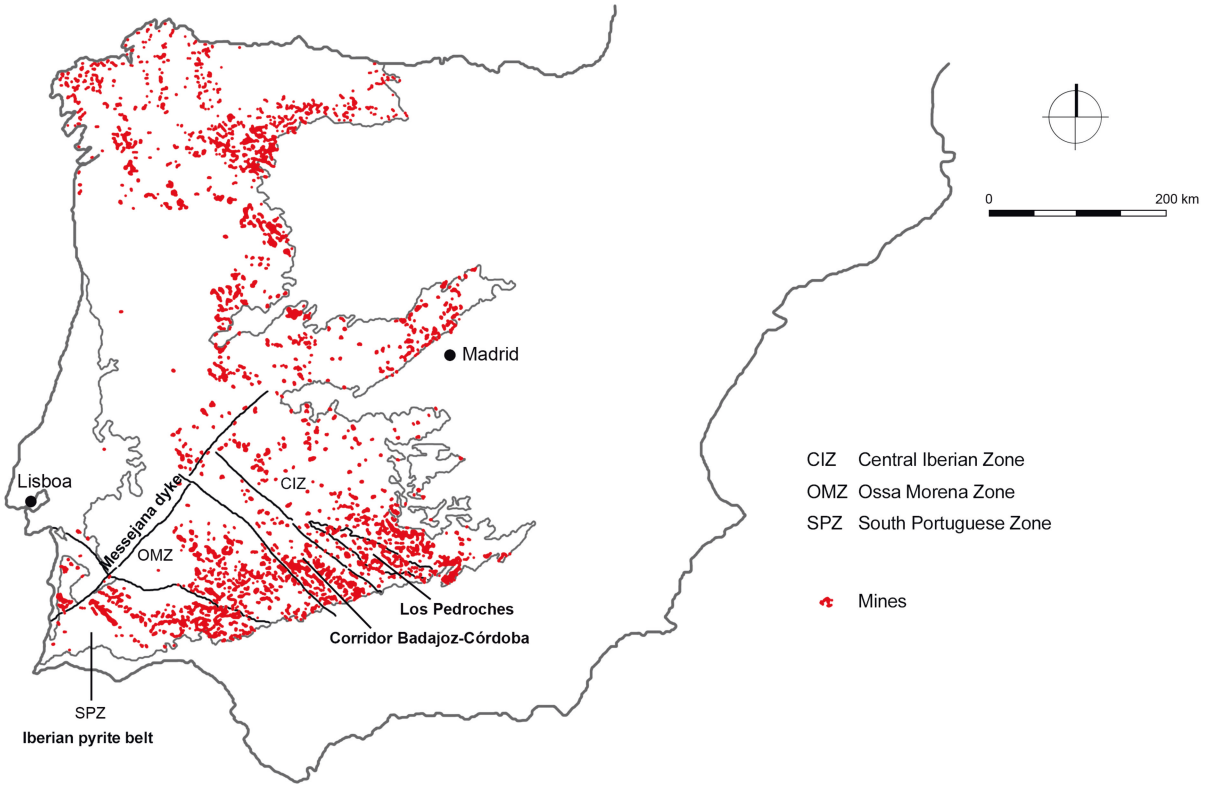
A second question which needs to be discussed is the composition of the ore minerals. Geologists from the last century have already explained that the seams are mainly formed from diverse minerals, although some minerals may dominate over others. When catalogued in this way, a mining site is converted into an important problem, where, for example, a mineralization with antimony sulphides (stibnite) can also contain copper sulphide and carbonates as accessory minerals, like at Nerón (Cerro de Andévalo, Huelva)[2]. Such sites would never be inventoried as a copper deposit in a description of mines in the southwest of the Peninsula, even though these minor minerals could have been beneficial ores for prehistoric and Roman mining activities.

What has contributed to a large amount of confusion about the knowledge of all of these mineral deposits is that they are seen through the eyes of a geologist or mining engineer, who logically has other interests than an archaeologist. Their view tends to gauge and estimate the quality of the minerals (in bulk), which includes the ore and gangue material of the mineralization. This analysis does not stop with the composition of the non-major minerals, i. e. those that are not economically feasible for exploitation. In this way he slants very important information for those who want to study pre-industrial mining; where the mineral was extracted in a selective manner and if it is precise, whether it did not touch the host rock, a technique known in mining as ›method of theft‹.

This information that comes to us from the geological and mining institutes and from the geological services is also not always complete or systematic. Exploration and sondages are meant for mineralizations that can be exploited and not for small structures that are not economically viable. It is possible to find mineralizations that were intensely worked in prehistory and during the

1 In the province of Huelva, it is possible to count the concessions on one hand, from the solicitations found in the Catálogo de Cartografía Histórica de Huelva, Junta de Andalucía, Consejería de Obras Públicas y Transportes, Seville (1995).

2 For this information, I would like to thank Prof. Sáez Ramos of the Departamento de Geología de la Facultad de Ciencias Experimentales de la Universidad de Huelva.



1 The Iberian Massif as geological core of the Iberian Peninsula during the Precambrian era and Palaeozoic period, from Pérez – Schattner 2013, 242, fig. 2.

Roman period, but are not even listed on current metallogenic maps. Case in point is the small lode near the Bronze Age settlement of El Trastejón (Zufre, Huelva) that has an oxidation zone composed of iron and copper carbonates. Metallurgical remains found in the excavation of this settlement have been associated with copper ore occurrences from Minas de Cala (Dolores), situated more than 15 km away, even though the lode that is less than 1 km distant would also be a good area for the procurement of such copper minerals. This apparent contradiction is not the fault of the archaeologists who were investigating the settlement, since it is not possible to find any reference to these copper lodes in the area, and it was discovered unintentionally during a field survey. Another case is the mine Rizón (Zalamea la Real, Huelva), for which no geological information exists, but was probably worked at least during the Roman period, based on the moderately sized slag heaps found in its environs.

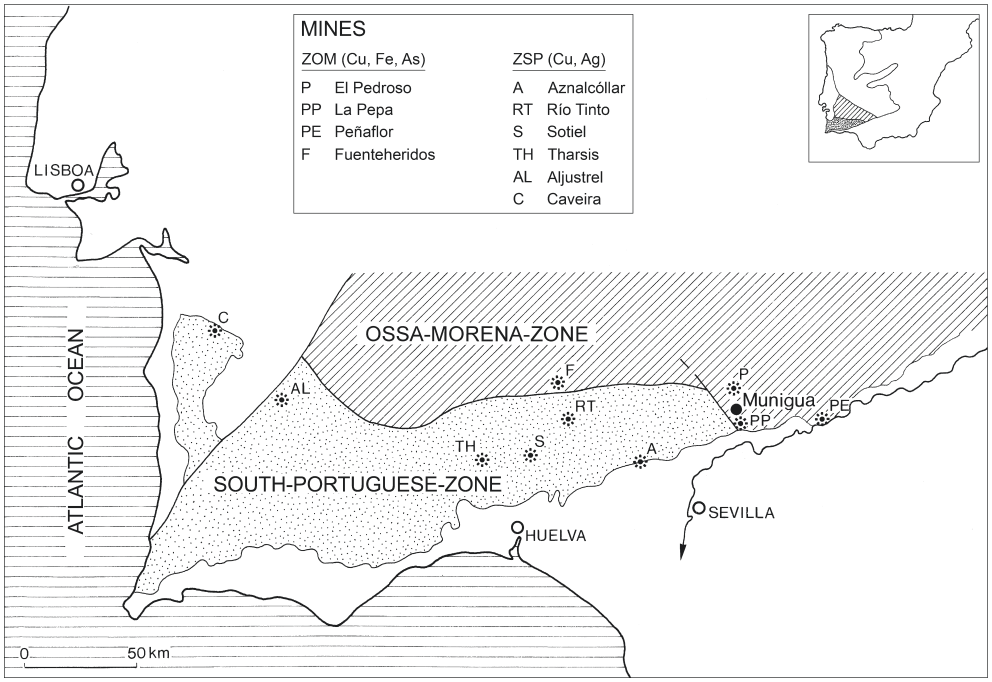
Thus, it should not come as a surprise that the descriptions of copper mineralizations in the southwestern part of the Peninsula also include lead sulphide, complex sulphides, and iron oxide mines. In these mines, there are also copper minerals that could have been exploited in antiquity. In the inventory of copper deposits listed below, we have followed a classification that follows the geological zones in which they are found, such as massive mineralizations, those of volcano-sedimentary origin, and small lenses or veins that are exhalative (stockwork) or hydrothermal in origin. As previously explained, this inventory is not exhaustive, but constitutes a starting point for a mining archaeological investigation, which for the most part still needs to be developed[3].

The mineralizations in southwest Iberia are distributed into two zones: The South Portuguese Zone and the Ossa Morena Zone (fig. 2). Below the South Portuguese Zone are the Tertiary and Quaternary formations of the Baetic Depression, which consist of bands of limestone, sandstone and conglomerates in transgressive formations, Miocene blue marls, and yellowish silts and Pleistocene sands.

The Iberian Pyrite Belt is located within the South Portuguese Zone and is a group of mineralizations of a common origin with large polymetallic sulphide deposits and lenticular bodies of manganese that extend from the mine of Aznalcóllar in the province of Seville to the mine Serra de Caveira in Portugal[4]. The deposits Aznalcóllar,

3 Much of the collected information originates from Gonzalo 1888.

4 García 2004.



2 The Hispanic Southwest with the designation of the two ore-bearing zones, from Pérez – Schattner 2013, 241, fig. 1.

Riotinto, Tharsis, Castillo de Buitrón, Sotiel Coronada, São Domingos, and Aljustrel stand out due to their size[5].

The South Portuguese Zone is delimited to the north by the oldest materials of the Ossa Morena Zone, which occupies in this sector the south of the province of Badajoz and the north of the province of Huelva. Within its deposits are abundant vein-type deposits of iron, copper and lead, as well as skarn-type contact metamorphism deposits.

2. Iberian Pyrite Belt

2.1 Polymetallic pyrite ore bodies

The large amount of activity which has taken place in these polymetallic sulphide deposits in southwestern Iberia has led to a very detailed description of the origin of these mineralizations, weathering phenomenon, and the composition of each orebody; an indispensable knowledge for those who wish to understand the evolution of its mining from prehistory onwards.

The geological origin of the pyrite deposits in southwest Iberia has been contemplated since the reactivation of mining activities in the 19th century, and can be used as a preamble in the explanation of the genesis of most of the mineralizations in southwest Iberia, i. e. those of hydrothermal and volcano-sedimentary origins.

When looking at the studies which theorize about the formation of these mineral bodies, the works of Joaquín Gonzalo y Tarín, David Williams, Gordon Williams, John C. Allan, and Jorge Doetsch[6], among others, come to mind. These authors explain that genesis of the pyrite orebodies and lenticular bodies of manganese as a result of hydrothermal activity. During the Hercynian orogeny, Lower Carboniferous slates were folded and produced intrusions of porphyritic rocks that have partially surfaced, aligned roughly E-W, following the di-

5 The deposit in Las Cruces, hidden underneath Tertiary deposits, was discovered in 1994, and extends the oriental extremity of the known Pyrite Belt by roughly 12 km to the east of the deposits of de Aznalcóllar, cf. Ovejero 2004a.

6 An ample commentary on all of these theories and bibliography of the references can be found in Pinedo 1963, 95–113.

rection of the folds. The appearance of brittle hypogenic rocks was preceded by fractures, bringing into existence at the same time an exit for liquids and vapours which were the main cause of metamorphism in the sedimentary strata and the true vehicle of the metalliferous substances that created these deposits. Torsion broke the porphyritic masses and produced cracks along the contact zone with the slates. The highly pressurized and hot waters dissolved the minerals and ascended through the cracks in the earth's crust where the metals were precipitated at lower pressure and temperatures. These diluted mineral solutions ascended through a network of small channels in the porphyries until they reached zones with favourable lower pressures along the contact zone. There they deposited their metallic content in favourable physio-chemical conditions, which generally occur where the porphyries cut the cleavage of the folds of the adjacent sedimentary rocks and in the salients and entrants of the porphyritic rocks.

Nonetheless, during the 20th century, it was taken into consideration that these pyrite masses were concurrent, stratigraphically and in age, with the rocks that enveloped them[7]. In this way, the genesis of the pyrite orebodies took place during Prehercynian times, and they are volcano-sedimentary in origin. According to this theory, the pyrite masses should have been produced by volcanic emissions through fractures in a marine environment with favourable conditions for the precipitation of the sulphides. The Hercynian orogeny only provoked the metamorphic process, the rifting, remobilizations and consequent transformation of the pyrite deposits, especially in regards to their initial disposition.

The magmatic gasses in a marine environment can be highly soluble and are diluted and spread in the water, or they can be highly insoluble. In the first case, when they do finally precipitate, they create sedimentary formations. When they are insoluble, the sedimentation occurs near the centres of volcanic activity. The components of these sediments can precipitate in various forms; in waters with a high Ph, the minerals tend to form oxides, or carbonates in waters with less oxygen; sulphides tend to form in stagnant and reductive waters. This phenomenon can also be affected by organic influences, fumarolic action, pressure, and temperature. For example, in regards to pyrite and pyrrhotite, the dominance of one or the other depends on the temperature, hydraulic pressure of the hydrogen and the presence of hydrogen sulphide. The mineralogical composition of the deposits is thus variable as a function of these factors.

The majority of researchers agree that the formation of the iron sulphides occurred at a great depth in still waters, where the lack of a current impeded the renewal of oxygen. The action of anaerobic elements, such as bacteria, could have produced the reduction of the sulphides into sulphates. This organic activity could be related to the organic elements which were found in the bulk analyses of some of these minerals. Thus the precipitation of sulphides should also have occurred in an organic medium near or underneath it.

Volcanic activity should have started with the emission of volcanic rocks. Inside these volcanic rocks, one can differentiate between an acidic upper phase and a lower less acidic phase, in which basic lavas with andesitic composition and tuffs dominated. The acidic rocks are mostly lavas and breccias with variable compositions, from rhyolite to dacite. The mineralizations are situated inside a group of volcanic rocks. All of the sulphide masses are associated with a pyroclastic horizon (Transition Series), at the roof of the acidic rocks and below a deposition of Culm-shales (Lower Carboniferous). However, it is also possible that other mineralization horizons could exist between the volcanic rocks.

The sulphide orebodies known in Riotinto are directly connected to a zone of stockworks, which give access to the hydrothermal solutions laden with accessions that precipitated on the marine floor in the form of sulphides. Through these stockworks, the metals and sulphur came from the same basaltic magma as the volcanic rocks, which is indicated by the presence of stannite in the mineralogical formations. The concentration of sulphur and metals occurred thanks to hydrothermal solutions connected to the volcanic centres. In this way the water should have been in continuous recirculation, acting as a source of transport from the volcanic centre to the bottom of the sea. Although no connection has been found between the volcanic centres and the stockworks in the area of Riotinto in which the hydrothermal solutions could have flowed, Félix García Palomero believes that this lack of a connection is because the stockworks disappear at greater depths and its formation was dependent on factors such as the pressure and temperature that affected the hydrothermal solutions on their journey to the bottom of the sea[8]. The massive sulphides were deposited on top of the stockwork and are connected with these pyrite chimneys.

Banding occurred during the sedimentation, due to the varying content of sulphides in the sediments. During compaction, an almost complete recrystallization of the sulphides took place, especially sphalerite,

7 García 1980.

8 García 1980.

chalcopyrite, galena, arsenopyrite, tetrahedrite, baryte and carbonates.

After the volcano-sedimentary activity, the deposits were buried under hundreds of meters of Carboniferous sediments and finally folded during the Hercynian orogeny in the Upper Carboniferous. During this time, the pyrite masses displayed three different stages related with this deformation: in the first stage it behaved like a brittle mass; in the second, the fissures that were produced were filled, mostly with chalcopyrite, sphalerite and galena; and in the third stage cemented breccias were formed by finely crushed sulphides along the faults and other unstable zones. The Hercynian folding created isoclinal folds with a distinct slatiness, reverse faults and thrusts to the south.

Finally, peneplains were formed during the continentalization of the zone, with the formation of the iron caps (gossan), as well as masses of oxides and hydroxides of iron that formed in a marshy setting (transported gossan) and seem to be associated with the evolution of the rivers within the district.

This type of geological evolution of the pyrite belt can be simplified in the following sections:

- Volcanism that deposited rhyolites on the marine floor.
- Pyroclastic rocks and a large amount of sulphides escaped via fractures into the sea.
- Deposition of muds or ferruginous sediments slates.
- Folding that affected the whole zone during the Hercynian orogeny.
- Erosion that breaks apart the massif and allows the outcropping of part of the sulphide mass and probably the disappearance of others.

The mineralizations are intimately connected with volcanic activity. This volcanic activity produced fumarole-type manifestations that emitted sulfur and metals on the seafloor, where they precipitated in the form of sulphides, and formed the origin of the massive sulphides, the unaltered primary mineralization. Sulphides also precipitated in the access fumarolic fissures, producing stockwork type mineralizations. The fumaroles' emissions (massive sulphides), as well as the precipitation of sulphides in the fumaroles' canals (stockwork sulphides) are contemporaneous, and there is a stratigraphic relationship between the two mineralizations. The massive sulphides are in an overlying position in respect to the stockwork deposits. The stockwork mineralizations underwent alterations related to the fumarole process: chloritization, silification, and sericitic alteration. When the massive sulphide bodies are not found on top of a stockwork mineralization, it is possible that the deposition of the massive sulphides took place on submarine banks with some amount of gradient and was displaced by gravity from the related stockwork formations.

The mineralizations that were formed by the fumarole emissions are as follows:

- Disseminated mineralization: consists of sulphide crystals within the acidic and basic lavas. It is thought that they were formed from the fluids accompanying the lavas, which were then retained by them during consolidation. Sometimes the disseminated mineralization was formed by hydrothermal alteration of pyrites in the host rock, which can contain copper and zinc sulphides along with pyrite from hydrothermal alteration.
- Mineralization in veins (stockwork): consists of a system of sulphide veins related to the centres of fumarole activity. It is very irregular, the mineralization ranges from a disseminated mineralization to a complete lack of host rock and only sulphides.
- Sedimentary mineralization (massive sulphides): formed on the seafloor by the crystallization of the mineral components contained within them. They have a stratiform structure and appear in the form of large lenses or in thin layers. The crystallization is not always produced in a manner parallel to the deposition of the volcanic rocks and can originate afterwards from the elements contained in the waters and sediments. Occasionally this forms a disseminated mineralization.
- Mineralizations in tectonic fractures: produced when a previously formed mineralization is subjected to folding with remobilization towards the fracture zones. This remobilization can establish micro-remobilizations in existing veins and recrystallization, especially of the quartz, galena, chalcopyrite, baryte, calcite, fahlores and arsenopyrites.

Generally, these sulphide deposits in southwestern Iberia are composed of complex ores formed by an association of minerals dominated by pyrite[9]. Within these sulphides, the principle elements are iron and sulphur, which account for 91 % of the mineral body. Silica accounts for up to 4 % of the total mass and the remaining 5 % is made up of minor elements including copper, lead, zinc, arsenic, gold, silver, cobalt, selenium, cadmium, thallium, indium, germanium, nickel, manganese, titanium, bismuth and antimony. The most abundant of

9 For the most complete listing of these mines see Pinedo 1963.

these are copper (ca 0.3–1.5 %), lead (0.2–0.7 %), zinc (0.4–2.0 %) and arsenic (0.2–0.7 %). Except for accumulations in the secondary enrichment zone, the other components are found in such small concentrations, that their percentages are expressed in grams per ton.

Within the pyrite mines, it is also possible to find sulphides with important proportions of galena, sphalerite or chalcopyrite, known as complex sulphides[10]. Some of these complex sulphide mines include the mine of Monte Romero (Almonaster la Real) and the group of mines in Vuelta Falsa – El Toro in the Rivera de Malagón (Puebla de Guzmán – Paymogo, Huelva), which includes Romanera, la Sierrecilla, El Cura, Nuestra Señora del Carmen, and Vuelta Falsa. The content of zinc and lead dominates over copper in these mines; the mine of Romanera, for example, contains, 0.38 % Cu, 3.35 % Pb and 6.21 % Zn.

These complex pyrites can also appear within the normal pyrite masses, and are richer in zinc, lead, and arsenic. Generally, they are located in the roof and walls of the masses, although they have also been detected as lenses or small masses within the deposit. The following primary minerals have been identified: pyrite FeS_2 (which is easily altered by oxygen into ferrous and ferric sulphate, as well as hematite and limonite); marcasite FeS_2 (decomposes more rapidly than pyrite and forms limonite); pyrrhotite Fe(1-x)S, also known as magnetic pyrite (transforms into pyrite, limonite, hematite, and siderite); pentlandite $(Fe,Ni)_9S_8$ (associated with chalcopyrite in the massive sulphides); native copper Cu (usually present as sheets, filaments, or dendrites); chalcopyrite $CuFeS_2$ (frequently auriferous, argentiferous, and/or cobaltiferous, and has the tendency to convert into secondary copper sulphides: chalcocite and covellite, copper carbonates: malachite and azurite, and copper sulphates, i. e. blue vitriol); bornite Cu_5FeS_4; arsenopyrite FeAsS; galena PbS (found in long belts alternating with sphalerite and chalcopyrite. Transforms into cerussite $PbCO_3$ and can be argentiferous); sphalerite ZnS; tetrahedrite $(Cu,Fe)_{12}Sb_4S_{13}$ (also known as fahlore); cuprite Cu_2O; tenorite CuO (frequently found in the upper zones of the sulphide deposits, the black colouring gives it its Spanish common names of ›negrillos‹ or ›cobre negro‹); malachite $Cu_2CO_3(OH)_2$; azurite $Cu_3(CO_3)_2(OH)_2$ (associated with malachite in the superficial zones of some deposits); blue vitriol $CuSO_4$; green vitriol $FeSO_4$; chalcocite Cu_2S; magnetite Fe_3O_4 (abundant as nodules in basic rocks); limonite $FeO(OH)\cdot nH_2O$; goethite FeO(OH); hematite Fe_2O_3; siderite $FeCO_3$; baryte $BaSO_4$[11].

Additionally, Fernando Rambaud lists other minor minerals: melnikovite $FeFe_2S_4$; loellingite $FeAs_2$; berthierite $FeSb_2S_4$; covellite CuS; chalcostibite $CuSbS_2$; bournonite $PbCuSbS_3$; enargite Cu_3AsS_4; famatinite Cu_3SbS_4; witherite $BaCO_3$; umangite Cu_3Se_2; jamesonite $Pb_4FeSb_6S_{14}$; meneghinite $Pb_{13}Sb_7S_{23}$; bismuthinite Bi_2S_3; smaltite $(Co,Fe,Ni)As_2$; safflorite $(Co,Fe)As_2$; cobaltite CoAsS; gersdorffite NiAsS; ullmannite NiSbS; rammelsbergite $NiAs_2$; linnaeite $Co^{+2}Co^{+3}{}_2S_4$; hauchecornite $Ni_9Bi(Sb,Bi)S_8$; native gold; native bismuth; calcite $CaCO_3$[12].

The same author also cites other minerals that are accepted by the Royal School of Mines, London: argentite Ag_2S; stembergite $AgFe_2S_3$; stromeyerite AgCuS; pyrargyrite Ag_3SbS_3; proustite Ag_3AsS_3; native silver; gratonite $Pb_9As_4S_{15}$; tenorite CuO; oligiste Fe_2O_3; ilmenite $FeTiO_3$; cerussite $PbCO_3$; melanterite $FeSO_4\ 7H_2O$; chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4\cdot nH_2O$; zircon $ZrSiO_4$; jarosite $KFe_3(SO_4)_2(OH)_6$; plumbojarosite $Pb_{0.5}Fe_3(SO_4)_2(OH)_6$; argentojarosite $AgFe_3(SO_4)_2(OH)_6$; beudantite $PbFe_3(AsO_4)(SO_4)(OH)_6$; chlorargyrite AgCl; scorodit $FeAsO_4\ 2H_2O$.

From the point of view of its mining, the most interesting phenomenon to comment on is the weathering of these minerals, which originate from transformations and enrichments and result in a vertical zonification of the ore bodies in accordance to a predominance of one or another of the minerals. Three different levels of alteration have been described for these ore bodies. Of these, the most interesting level when studying ancient mining is the most superficial one, the oxidation or infiltration zone, which is situated between the topographical surface and the subterranean phreatic surface. It is directly influenced by the infiltration of groundwater into the sulphide ore bodies. The characteristics of this zone are:

- Formation of oxide minerals
- Vertical movement of groundwater
- Typical phenomena:
  - Disappearance of the sulphur
  - Dispersion of certain mineral elements
  - Formation of oxide minerals

Fundamental in the involved relationships is the superficial water that carries dissolved oxygen and results in an oxidizing reagent. This oxidation zone can be of a large magnitude, and is roughly 80 meters thick in Cerro Colorado (Riotinto). The activity of some of the original metals in the oxidation zone is as follows:

10 For the classification of these mines and the composition of the minerals see Pinedo 1963.

11 Pinedo 1963.

12 Rambaud 1969.

– *Iron*. In oxidizing and humid conditions, pyrite reacts to form iron hydroxides.

$2S_2Fe + 7O_2 + 2H_2O = 2SO_2 + 2SO_2H_2$
$4SO_4Fe + 2SO_4H_2 + O_2 = 2(SO_4)_3Fe_3 + 2H_2O$
$(SO_4)_3 Fe_2 + 6H_2O = 2Fe(OH)_3 + 3SO_4H_2$

These iron hydroxides are not very soluble and separate in the form of a gel that dehydrates and transforms into limonite. The final ferric hydroxide is considered the producer of a series of mineral varieties related by their degree of hydration and their appearance. Most of the limonite in these outcrops is hematite (Fe_2O_3) and goethite (Fe_2O) along with variable quantities of jarosite.

The gossan is formed as a consequence of the almost total insolubility of the hydroxides, which are deposited and appear in the oxidation zone. Most of the other constitutes of the iron sulphides are eliminated, resulting in a considerable augmentation of the iron content.

– *Copper*. Contrary to iron, the copper content is lowered in the oxidation zone. Chalcopyrite is oxidized and transformed into copper sulphate, which is soluble and migrates downwards, and the iron sulphate is transformed into limonite and sulphur, which can then be transformed into sulphuric acid.

$S\ 2CuFe + 4O_2 = SO_4Cu + SO_4Fe$

– *Zinc*. Zinc sulphate also easily dissolves and migrates.

$S\ Zn + 2O_2 = SO_4Zn$

– *Lead*. Lead sulphate only reacts with great difficulty and quite slowly with ground water. It does, however, have a tendency to transform into lead carbonate. Because of this and its only slight capacity to react, it is possible to find some galena in the oxidation zone. The sulphates and carbonates that have already formed, create a film and impede the penetration of oxygen into the rest of the mineral body.

$S\ Pb + 2O_2 = SO_4Pb$

In this infiltration zone, certain lead oxide minerals appear with a certain frequency, like plumbojarosite $Pb_{0.5}Fe_3(SO_4)_2(OH)_6$ or beudantite $PbFe_3(AsO_4)(SO_4)(OH)_6$.

– *Barium*. Its behaviour is similar to those of lead. Barium sulphate (baryte) is not very soluble and certain quantities can accumulate in the oxidation zone.

– *Gold*. Gold resists dissolution and is found in the oxidation zone, leading to a residual concentration via the loss of other more mobile elements. Nevertheless, some of the gold is slowly transported through the oxidation zone, concentrating in the lowest areas.

The movement of gold can be explained by various processes: mechanical immigrations of the particles, or in colloidal aqueous solutions according to sulphuration or halogenation processes. The sulphuration depends on the abundance of the sulphur that is produced by the sulphuric acid and ferric sulphate, when these react, especially the latter, they can partially dissolve the gold and slowly transport it downwards. Gold, which is transported colloidally, can be deposited by the action of the electrolytes and under the influence of certain minerals, such as baryte, kaolinite, and quartz which can precipitate it from solution.

– *Silver*. Silver is more abundant than gold, and is also relatively enriched in the oxidation zone by the elimination of other elements. Part of the silver can react with the ferric sulphide:

$2\ Ag + (SO_4)_3Fe_2 = SO_4Ag_2 + SO_4Fe$

Silver sulphate, and including silver, are very instable in the oxidation zone which permits that it is sometimes precipitated from solution and deposited as Cl Ag or also as native silver. However, it is more common to encounter earthy yellowish accumulations of argentojarosite $AgFe_3(SO_4)_2(OH)_6$. In the case of silver, the immigration conditions are somewhat more favourable than those for gold, and permit better displacements.

By this process of lixiviation and cementation, the oxidation of these polymetallic massive sulphide deposits forms three clearly defined zones: the superficial cap of the gossan, mainly composed of iron oxides and hydroxides that have been lixiviated of almost all of the copper, zinc, and original sulphides; a cementation zone below the phreatic surface; the secondary enrichment zone, where the copper and zinc are mainly precipitated, is rich in high quality copper sulphides (chalcocite, covellite, melaconite and tetrahedrite); below this the original unaltered sulphides (primary sulphides).

Within the oxidation zone, three successively deeper subzones have also been described, although they are not always present[13]. The most common and of the greatest

13 Martín 1981.

interest for the study is the uppermost, most prominent superficial subzone of oxide minerals or gossan (iron cap). It is the most extensive and in certain areas the only one present, and can reach depths of up to 70 meters. It is characterized by the gossan, which is present in certain quantities depending on the quantity of original sulphides. Frequently the rocks near the gossan undergo an intensive limonitization due to transported limonite impregnations, while in some stockworks kaolinization is also frequent and gives the rocks a typical white colour. This alteration is the result of the action of solutions formed during the oxidation of the sulphides.

The gossan subzone is the most intensely weathered and therefore undergoes the greatest amount of modification. Its importance is centred on the gossan, due to the possibilities derived from the concentration of metallic elements, such as gold and silver. In these iron oxide and hydroxide outcrops, it is possible to find small concentrations of gold, silver, arsenic, barium and lead – elements that do not react with the acidic waters as easily as copper and zinc. Larger quantities of gold and silver accumulate in the base of the gossan, where it is in contact with the cementation zone of secondary copper sulphides and where clayey minerals (hydrated iron sulphates, jarosites) have accumulated, sometimes with economically viable amounts of silver. Williams[14] investigated a layer of earth with varied colours and little thickness that was located at the base of the gossan of Cerro Salomón. The analysis of its composition detected, among others, the presence of jarosite, plumbojarosite, pyrargyrite, argentojarosite, argentite, stembergite, stromeyerite, proustite, native silver and native gold. However, the formation of these jarositic levels rich in silver depends on the existence of sufficient levels of silver in the primary sulphides and thus determines the viability of its formation. Not all of the mines in the Iberian Pyrite Belt have jarositic levels worth exploiting. It is also possible that a single mining district can contain some bodies which have such levels while others do not[15]. Metallurgical studies carried out on the Roman slag heaps associated with these mines show that these silver enrichments in the jarosite subzones were present in the orebodies of Filón Norte in Riotinto (Lago, Salomón and Dehesa), the orebodies of Centro, Filón Sur and Almagrera in Tharsis, as well as Cueva de la Mora, Castillo de Buitrón, Sotiel Coronada, Herrerías, Descamisada, Lagunazo, Lapilla, Prado Vicioso, La Zarza, Vulcano, Poderosa, Romanera, San Platón, San Miguel, San Telmo, Umbría de Palomino, and São Domingos. The jarositic levels do not contain economically viable quantities of silver in Filón Norte and Masa Bullones in Tharsis, Filón Sur and Masa Planes in Riotinto, nor in Aguas Teñidas, Cibeles, Concepción, Chaparrita, El Carpio, Lomero-Poyatos, Mimbrera, San Eduardo, Confesionarios de las Herrerías, and Aljustrel[16].

The most interesting relationship for prehistoric copper mining is that the superficial zones of these massive polymetallic pyrite deposits (gossan) did not contain copper minerals, which had migrated to the secondary enrichment zone, and only rarely had outcrops of copper carbonates. This explains why prehistoric copper mining, which was preferably based on the extraction of copper carbonates from the oxidation zone, is sparsely represented, and the mining tools found in this area can be associated with silver mining. A paradigmatic case is the study of the settlement of Monte Romero (Almonaster la Real, Huelva) which is situated above a complex sulphide deposit rich in lead, copper and silver[17]. Its complex minerals are rich in copper in the cementation zone, principally native copper, followed by secondary copper-silver sulphides. This example can be used for other sites with prehistoric stone hammers in pyrite orebodies, such as Riotinto, Aznalcóllar, Almagrera and San Platón, which are associated with metallurgical occurrences with argentiferous production[18]. In these mines, where the primary sulphides are poor in concentrations of silver, there was also no prehistoric silver mining, since there were no viable percentages of lead or silver in the gossan. Only later, with Roman mining activities which developed engineering capable of reaching the secondary enrichment zone, was it possible to start the first mining activities for the production of copper.

2.2 Secondary mineralizations

Secondary copper mineralization can appear near these larges pyrite masses where, in some cases, superficial copper carbonates can occur and which were mined in pre- and protohistoric periods.

One of the best known examples is the mineralization at the mine of Santa Bárbara in the mining complex of Minas de Herrerías (Puebla de Guzmán, Huelva), which is composed of copper carbonates, cuprite and native copper that were produced from the complete

14 Williams 1962.
15 Pérez 1998.
16 For the composition of the slags from these mines see Blanco – Rothenberg 1981; Domergue 1987; Pérez 1998.
17 Kassianidou 1993.
18 Pérez 1996.

weathering and erosion of a pyrite mass. The acidic water produced from the weathering decomposed the neighbouring chalks and freed the copper, which was leached from the carbonates in the spilites[19].

Another interesting case of secondary mineralizations of copper is at the Corta Esperanza in Tharsis, where these copper minerals were precipitated in the chalks by the weathering and erosion of the Filón Sur. During modern exploitation, up to 30,000 tons of these minerals were extracted, in particular chalcocite and malachite. This is the only mineralization in Tharsis that has superficial copper carbonates and the only one that could be associated with the metallurgy of Cabezo Juré. The minerals found in Cabezo Juré, malachite, cuprite and chalcocite[20], cannot originate from the supergene enrichment zone of the masses in Tharsis since no copper carbonates exist there, at least not this type of mineralization, where the copper precipitated in the form of carbonates in contact with the chalks.

Other known examples of prehistoric mining of copper carbonates could appear in the oxidation zone of stockwork mineralizations. Secondary mineralizations comprised of copper carbonates (malachite and azurite) can occur, which impregnate the volcanic rocks and occasionally outcrop on the surface, such is the case at the mine of Cuchillares (Campofrío)[21].

2.3 Vein-type mineralizations

Within the South Portuguese Zone, there is also a large quantity of veins, including copper, lead-zinc, and antimony. These mineralizations contain a hydrothermal fill, of low temperature, and are above fissures or dikes. Some are found in the batholith of Campofrío – Castillo de las Guardas and others in sedimentary or volcano-sedimentary sequences[22].

In the batholith of Campofrío – Castillo de las Guardas, the veins are found in quartz or porphyritic-granitic dikes, and the mineralization is of chalcopyrite or pyrite, with malachite-azurite, hematite, and limonite as accessory minerals. A characteristic deposit is the copper vein of Valdehiguera (Campofrío), which is very rich in copper carbonates[23]. Other mineralizations, with disseminated pyrite and chalcopyrite in quartz veins, are situated in Monte Carmona and Majuelo (Campofrío). Within the municipality of Aracena is the concession of Tres Amigos, which contains pyrite, chalcopyrite and malachite in a small porphyritic dike with a disseminated mineralization. In Castillo de las Guardas, the vein structures of Valquemado and La Llana stand out with their quartz veins containing chalcopyrite, malachite, hematite, and limonite[24].

In the volcano-sedimentary sequence, there are quartz veins, following the direction of the chalks. The mineralization forms pockets, strings and lenses of up two meters thick with chalcopyrite, pyrite, bornite, chalcocite, malachite, cuprite and iron oxides. In these same copper sulphides mines, the following mines stand out:

– Ratera/Sierra de Rite group (Valverde del Camino)

This is a typical example of the deposits and is formed by various copper sulphide veins that extend into four sectors: Cabezo de los Silillos, La Ratera, Diego Díaz, and Masegoso[25]. The veins outcrop in quartz crests with iron oxides, and the mineralization is of chalcopyrite associated with pyrite. However, in the easternmost veins – those of the concessions of Masegoso and Segunderalejo – there are also copper oxides (cuprite), copper carbonates (malachite) and copper sulphides (chalcocite and chalcopyrite). The potency of the veins varies, and the copper minerals appear as pockets within a quartzite gangue. In Masegoso, the vein is between 2 and 6 meters thick, with carbonates and iron oxides on the surface. In the mine of Ratera, the principal vein is 2.50 m thick with quartz, iron oxides and carbonates in the upper levels.

All of these veins were exploited in Roman times, and some of the workings are preserved in the form of galleries at Cabezo de los Silos and Ratera, but the prehistoric exploitation is in evidence in the sector of Masegoso, where grooved stone hammers occur in abundance[26].

– Pozuelo group (Zalamea la Real)

The best known mine in this group is Chinflón (Vencida), although there are other veins nearby that are not well investigated, such as the mine of Cura. In Chinflón, the mineralization is comprised of pyrite and chalcopyrite with malachite in the oxidation zone. According to the data from the exploitation in 1929, at least 14 tons of copper carbonates were extracted. It is the first prehistoric mine that has been excavated on the Iberian Peninsula[27], with ceramic material that points to a chronology in the Late Bronze Age, with no continuation of exploita-

19 Pinedo 1963, 241.
20 Nocete 2004.
21 Blanco – Rothenberg 1981.
22 Sánchez – Florido 1993.
23 Pérez et al. 1990.
24 Sánchez – Florido 1993.
25 Pinedo 1963, 480–486.
26 Blanco – Rothenberg 1981.
27 Rothenberg – Blanco 1980.

tion into the Orientalizing period[28]. Evidence from modern exploitation demonstrates that the abandonment of the mine was not caused by a lack of copper carbonates, since large reserves were still present.

– *Sierra de Tejada (Escacena del Campo) group*

Another important group of mines with copper sulphide veins is located in the Sierra de Tejada. The minerals include iron and copper oxides and copper carbonates, but with copper sulphides in the depths, which are sometimes argentiferous and accompanied by lead and zinc sulphides.

Within these vein structures, those of Mesas de las Minas (Trinidad) stand out: they are located in the chalks and are composed of five parallel veins running east-west, ca. 300 meters long, and with a breadth of up to 65 cm. They are composed to copper sulphides that outcrop in the form of abundant amounts of iron oxides and copper carbonates in the oxidation zone. The concession of Ángeles is composed of small quartz veins that are found within the chalks with mottled areas of iron oxides, copper carbonates, and copper sulphides. All of these veins are found along a fault roughly 6 km wide, and extends in the direction of Cueva del Monje, Barcita, Barranco Abadejo, Tallista, Mancha de los Venados, Cumbres de las Navas and La Caba. The length of these veins is variable, from 250 meters to 2 km: the vein at Barcita reaches up to 1,200 m in length; the Mancha de los Venados is 800 m, and Cumbre de las Navas is 800 m long. All of these veins are composed of copper sulphides, although some also contain lead and zinc arsenides.

Large amounts of grooved stone mining mauls have been found at all of these veins[29].

– *San Cristóbal (Calañas) group*

This is another type of vein formation that is found in the chalks, mainly composed of chalcopyrite, but very rich in copper carbonates in the superficial zones. It was exploited during Roman and prehistoric times. Large quantities of grooved stone hammers can be found in the modern mining tips[30].

– *Conchita (Alonso)* group

This contains a principal vein, ca. 600 m long and 1.5 m wide. The primary mineralization consists of copper sulphides with silicified copper carbonates and iron oxides in the oxidation zone[31].

– *Cabezo de los Silos/Monterrubio (Puebla de Guzmán) group*

The vein is found in the carboniferous chalks and is distinguished by a ferruginous outcrop and rubefaction of the chalks. It is ca. 70 m long and contains predominantly chalcopyrite. Some small copper veins have impregnated the surrounding chalks and created a secondary copper carbonate mineralization[32].

– *Peñuelas (Paymogo) group*

This group consists of two parallel veins that join deeper down and have a breadth that varies between 1.5 and 2 meters. The mineralization contains pyrite and chalcopyrite, as well as secondary copper sulphides (chalcocite) in the supergene enrichment zones[33].

– *Becerra (Paymogo) group*

There is very little geological information available for this group, except that it is rich in chalcopyrite[34].

– *Malagón (Paymogo y Puebla de Guzmán) group*

This group contains quartz veins within the chalks, which can be up to 2 km long and contain predominantly pyrite, copper sulphides, zinc sulphides, argentiferous galena, a mixture of iron sulphides, lead, silver, zinc and copper. Some ferro-cupreous veins also contain argentiferous fahlore. The concessions of Cerrejón del Tamujoso and Barranco de Trimpancho are particularly notable.

These copper vein deposits are composed of carbonates in the upper part of the mineralization and iron and copper sulphides in the lowest levels, sometimes associated with somewhat argentiferous galena. The copper sulphide veins are more often found in small discontinuous quartz veins within the chalks, as well as forming inclusions or impregnations within the chalk itself[35].

– *Corumbel (Manzanilla, La Palma del Condado and Paterna del Campo) group*

This is an ore field known by the name Minas del Río Corumbel[36]. The quartz-bearing veins extend into the chalks and have complex compositions, distinguished by their amounts of lead and zinc. They are related to east-west running fractures and the mineralization consists of cassiterite, sphalerite, arsenopyrite, tourmaline,

28 Pellicer – Hurtado 1980.
29 Gonzalo 1888.
30 Pérez 1996.
31 Pinedo 1963, 478.
32 Pinedo 1963, 543.
33 Pinedo 1963, 468.
34 Pinedo 1963, 471.
35 Pinedo 1963, 360–363.
36 Sáez et al. 1989.

muscovite, argentiferous galena, pyrite, pyrrhotite, marcasite, and chalcopyrite[37].

Notable concessions include Las Completas, Florida, Nuestra Señora del Amparo and Victoria; many of which contained grooved stone mining hammers.

3. Ossa Morena

It is possible that there are more deposits in the Ossa Morena zone than in the South Portuguese Zone, but the magnitude of the deposits of the Iberian Pyrite Belt is lacking. The vast majority are vein-type deposits that form part of long structures, sometimes discontinuous, with different types of sulphides, including iron, copper, lead, zinc, silver, and eventually gold and tin[38]. The mineral deposits of the Ossa Morena are of variable ages and geneses, from submarine exhalative volcanic geneses, hydrothermal deposits, deposits that fill in fractures within a large regional area in which hydrothermal solutions have ascended from the deepest layers of the earth's crust, and deposits formed by replacement phenomenon from contact with calcareous rocks (skarn).

The history of the Ossa Morena finds its roots in pre-Hercynian ages, since it started to form in the Upper Precambrian and extended to the Carboniferous period. The genesis of these structures is varied: volcano-sedimentary, like the polymetallic sulphide deposits of the Iberian Pyrite Belt; exhalative mineralizations related to submarine volcanic activity; replacement phenomenon in the earth's crust (skarn); or the filling in fractures caused by orogeny. Most of the mineral deposits in the Ossa Morena are Hercynian in age and are formed on regional alignments produced during the Hercynian orogeny, which generated fractures, faults, shear zones, and geological shear stress in a predominantly northeast-southeast and west-northwest-east-southeast lineament, through which magmatic and sulphide intrusions outcrop on the earth's crust. This phenomenon affected large areas, sometimes more than 400 km in length, such as: the Messejana – Plasencia faults that mark the transition to the South Portuguese zone to the south; the Badajoz – Córdoba shear zone that separates the Central Iberian Zone – represented by the Los Pedroches batholith – with abundant vein deposits of complex metallic compositions (lead, silver, zinc, barium, tin, antimony, etc.); the fracture zone of Linares – La Carolina with lead-zinc deposits and the cinnabar of Almadén[39]. The fracturing continues into the Late Hercynian, which corresponds to the vertical faults with lack of direction.

Within the mineralization of the Ossa Morena, groups were formed according to their origin: mineralizations that were formed between the Upper Precambrian and Paleozoic in a marine environment connected with exhalative volcanic mineralization (hydrothermal), which formed small lenticular deposits and whose main component is pyrite, but are generally polymetallic with zinc, copper and lead; pockets or impregnations of minerals in the Lower Cambrian calcareous rocks, including the mineralizations of the Sierra de Aracena, with zinc, lead and iron; and the ferruginous belt of Jerez de los Caballeros (Badajoz), with iron and manganese.

The Ossa Morena has been divided into a series of geological domains: the unit of Pulo do Lobo, Macizo de Aracena – Almadén de la Plata, Terena unit, Zafra – Monesterio domain, Arroyomolinos domain, Unit of Cumbres and Cubito Unit. The unit of Pulo do Lobo has recently been considered as an independent unit situated between the South Portuguese Zone and the Ossa Morena Zone, and the Terena Unit is an extensive shear zone in which materials with distinct natures and metamorphism outcrop, with layers that date from the Cambrian to Lower Carboniferous periods[40].

3.1 Stratiform mineralizations

Among the Precambrian mineralizations of submarine volcanic origin are the lenses at: Puebla de la Reina (Badajoz), which spread out in a 7 km strip and contain zinc, copper and lead; Peñaflor (Seville) with pyrite that contains moderate amounts of copper; María Luisa (La Nava, Huelva), Gibla (Constantina, Seville), Alanís (Seville) and Vicaría (Calera de León, Badajoz), with copper sulphides, lead and zinc.

37 Vargas – Prieto 1924.
38 Apalategui 2001.
39 Ovejero 2004b.
40 Apalategui 2001.

– *Zinciferous belt of Aracena*

The metamorphic belt of Aracena developed in the area closest to the South Portuguese Zone, during the Cambrian period, and extends to the other side of the border, up to Portel[41]. Here one finds a collection of mineralizations in which zinc dominates, and a minor proportion of copper, which corresponds to the acidic volcano-sedimentary sequence of Jabugo, in the Carbonaceous sequence of Aracena, and within the later basic volcano-sedimentary material of La Corte. Within these mineralizations, the deposits of Fuenteheridos (Huelva) are of particular interest. These mineralizations are found in the limestones and are iron sulphides rich in zinc and lead, lead sulphides and zinc sulphides[42].

– *María Luisa (La Nava) group*

The María Luisa mine was exploited between 1969 and 1981 for copper and zinc. Its paragenesis is comprised of one primary mineral where magnetite, pyrrhotite, arsenopyrite, pyrite, sphalerite, galena, bornite, calcocite, and tetrahedrite predominate. Secondary minerals include predominantly hematite, limonite, and cuprite. The origin of the mineralization could have had a ferriferous phase with the appearance of magnetite that substituted for the silicates, and another of sulphides of hydrothermal origin[43].

– *Repilado (Jabugo – Galaroza) group*

This group is situated in an area of stratiform sulphide mineralizations and forms a collection of copper sulphide and pyrite veins with gangue of quartz and calcite with pyrite, tetrahedrite, galena, chalcopyrite, sphalerite, and boulangerite. The mines of Reprise (Galoroza) and Santa Ana (El Repilado, Jabugo, Huelva) belong to this group[44]. They are located in the volcanic rocks, both acidic and basic, and are found in massive bodies, 10 to 15 meters thick.

The mine Reprise contains a mineralization represented by the dissemination of sulphides in a mineralized band, 1 km long and up to 250 m thick, in quartziferous veins. It has been investigated in three sections: Chinas I, Chinas II and Chinas III. Chinas I is a mineralization formed by iron oxides (magnetite), iron sulphides (pyrite), arseno-iron sulphides (arsenopyrite), copper-iron sulphides (chalcopyrite), and lead sulphides (sphalerite and galena). The sector Chinas II (San Manuel) is rich in arsenopyrite, pyrrhotite, chalcopyrite and limonite. The minerals from Chinas III (Casa de la Mina) include iron sulphides, copper-iron sulphides, and arseno-iron sulphides[45].

In the mines of El Repilado (Jabugo), those of Santa Ana, Mª Victoria de Fátima, and Sierra El Monte particularly stand out. Santa Ana is a vein, some 150 m long with a mineralization of magnetite, pyrite, chalcopyrite, baryte, and sphalerite as major components and copper carbonates in the oxidation zone. In Mª Victoria de Fátima, the primary mineralization is magnetite, pyrite, arsenopyrite and chalcopyrite, with covellite in the secondaries. In the Sierra El Monte magnetite, pyrite, chalcopyrite and sphalerite predominate[46].

In all of these mines, the oxidation zone contains an abundance of copper carbonates and although they have not been sufficiently prospected, the evidence of copper production using crucible smelting in nearby prehistoric settlements, such as the copper crucible from the Cueva de la Mora (Jabugo)[47], and copper slag from the cist necropolis Valdegalaroza (La Nava)[48], are elements demonstrating that these minerals were known in later prehistory and should be taken into consideration.

– *Conchita (Aracena) group*

Other evidence in this zone is the Conchita group, formed by the concessions of Conchita, Hullera and Fátima, near Aracena. The mineralization is pyrrhotite, pyrite, sphalerite, and chalcopyrite with a minor proportion of magnetite, galena, marcasite, and limonite as secondary mineralizations[49].

– *Gibla group (Constantina, Seville)*

The concession of San Enrique exploited a quartz and calcite vein some 400 m long and 2 to 5 m thick. The primary mineralization was much disseminated chalcopyrite distributed along the length of vein, with some amount of gold and silver. Copper carbonates predominated in the oxidation zone.

Grooved stone hammers were found in abundance in this mine, which points to an intense exploitation during the Bronze Age[50].

– *Peñaflor (Seville) group*

The mineralization is composed of two veins, 170 m and 60 m long, in which iron oxides, iron sulphides, copper-iron sulphides, and copper oxides predominate.

41 Fernández 2004.
42 Fernández et al. 1989.
43 Vázquez 1972.
44 Vázquez 1974.
45 Vázquez 1974.
46 Vázquez 1974.
47 Blance 1971, 80.
48 Romero 2002, 473–480.
49 Pinedo 1963, 571.
50 Hunt 1991.

There is a lack of iron oxides outcrops, but it is given away by green stains from the copper sulphides reacting with the surface water.

Some prehistoric tools were recovered during contemporary exploitation of the Preciosa mine, including grooved stone hammers together with the bodies of miners who died during a mine collapse[51].

The amphibolites of Los Acebuches are associated with these Cambrian volcano-sedimentary formations (formation of Almonaster la Real) that contain traces of mineralization in the municipalities of Almonaster la Real, Cortegana y Aroche: Alto de la Tabaca, Santa Rita, Tabacas, Río Chanza, and La Mezquita[52].

3.2 Vein-type deposits

In addition to the evidence of copper in polymetallic sulphide stratiform mineralizations, there are also many vein-type structures situated in distinct geological domains. Some of the most important ones are found in the groups of Rivera de Cala, Nava, Linares – Alájar, and the ore field of Rivera de Múrtigas.

– Rivera de Cala (Sultana – San Rafael) group

One important group of mines within the Ossa Morena is formed by the vein-type mineralizations of Sultana – San Rafael, in the municipality of Cala (Huelva). These mineralizations correspond to a typical scheme of small vein deposits of copper sulphides which are very abundant in the Sierra Morena. The geology of these deposits has not been studied in depth, but the mineralization from each concession is well known, thanks to the work of the mining engineers[53]. The vein formation extends over a series of concessions, whose most important starting points are located at Zarina, Sultana, San Rafael, Nuevo Cometa, and Extremeña, with the workings at Sultana and San Rafael being some of the most important. The vein is known to be some 3,000 meters long, running in a N 20° W direction, adjusting to the contact zone of the granitic rocks. The minerals are found in quartzite bands between the granites of the Santa Olalla del Cala batholith and the Cambrian chalks and greywackes.

In the Rivera de Cala group, the paragenesis is composed of quartz, siderite, chalcopyrite with pyrite, sphalerite, arsenopyrite, and some gold that has been found in the form of native gold in the concessions of Extremeña and Sultana. The minerals, principally iron sulphides (pyrite) and copper-iron sulphides (chalcopyrite), filled fractures produced by igneous activity which produced an outcrop of granitic rock, and vein fissures that were completely filled by the fumaroles, slowly precipitating the minerals as the temperature and pressure dropped. These copper mineralizations can be related to a later sulphurous phase, in the metasomatic stage of the granites in the zone and with the existence of longitudinal fractures.

The mineralization of the concession Sultana consists of copper-iron sulphides, with ca. 27.51 % Cu, 32.38 % Fe and 36.40 % S. The vein appears as small branches of quartz veins in the granite, no more than 0.05 m wide, with patches of iron oxides, copper carbonates, and copper sulphides, though at greater depths they join to form a vein half a meter wide. Although the predominant mineral is chalcopyrite, there are also zones with other copper minerals, like bornite and fahlores, also occasionally bismuth and native gold. Nevertheless, the richness of the mineralization in the vein is not very constant. Sometimes it is sterile and in other points it can reach a thickness of 1.60 m of chalcopyrite. Within the vein the thickness of mineralization is also variable, sometimes hugging the roof, other times the wall, and less often in the centre or just peters out. In the concession of San Rafael, the mineralization also consists of a quartzite band hosted in the porphyries and granites.

Prehistoric exploitation is evidenced by grooved stone hammers found in the concession of Sultana[54] and by copper smelting crucibles in some Bronze Age settlements, such as el Cerro de los Rehoyos[55] and Santa Marta[56].

– Almadén de la Plata group

There is evidence of stress fracture veins caused by shearing. The mineralizations are hosted in different lithologies (chalks, marbles, and amphibolites) and structures (Units of Terena, Macizo de Aracena, Unidad Pulo do Lobo). Generally, they are quartz veins with disseminated pyrite and chalcopyrite, although other sulphides appear in minor quantities, such as covellite, arsenopyrite and pyrrhotite. The veins extend into the municipalities of Real de la Jara, Monesterio and Almadén de la Plata[57].

Near the city centre of Almadén de la Plata (El Torbiscal), the principal minerals include chalcopyrite, pyrite, malachite, azurite, and goethite, with accessory

51 Mata 1975, 583.
52 Ovejero 2004b.
53 Palacios – Prieto 1921.
54 Quiring 1935.
55 Pérez – Rivera 2004a.
56 Pérez et al. 2002.
57 Ovejero 2004b.

minerals of chalcocite, covellite, bornite, and less often sphalerite, galena, tetrahedrite and arsenopyrite.

The veins at Real de la Jara also contain copper minerals, with pyrite and chalcopyrite (Isabel). In some of them, iron sulphides predominate, with hematite and magnetite, but there are also copper minerals, like malachite and covellite (Herrerías de San Carlos).

– *La Nava group*

In the zinciferous belt of Aracena, there are also small mineralizations, hydrothermal in origin, associated with quartz and calcite veins. These mineralizations are composed of copper-iron sulphides (chalcopyrite), with superficial zones rich in copper carbonates (malachite) and secondary enrichment zones with predominantly copper, lead and antimony sulfosalts (tetrahedrite, boulangerite, bournonite, and jamesonite). Noteworthy are the mines in the municipalites of La Nava, Las Lanchuelas, Eureka, Horcajo, Retamar, Valle del Perro, and Cadena[58].

The mine of Las Lanchuelas contains a mineralization comprised of tetrahedrite, jamesonite and chalcopyrite, while in Eureka, lead and antimony sulphides (boulangerite) and lead-copper-antimony (bournonite) with a general percentage of 1.98 % Cu, 2.32 % Pb and 2.10 Sb predominate. In Horcajo, the mineralization is mainly composed of iron sulphides, iron-arsenic sulphides, copper-iron sulphides and lead sulphides. In Retamar, the paragenesis is pyrite, chalcopyrite, sphalerite, galena, and tetrahedrite, with secondary minerals including covellite, cuprite and limonite. In the Valle del Perro, the minerals are pyrite, chalcopyrite, and bornite.

– *Linares – Alájar group*

The veins are of quartz with pyrite, chalcopyrite, azurite and malachite in shear zones. Some of them can reach up to 300 m in length, and the concession of Pizarro stands out in particular.

– *Ore field of Rivera de Múrtigas and La Contienda*

One of the largest ore fields is found in the municipality of Cumbres de San Bartolomé and Encinasola, in the vicinity of Rivera de Múrtigas and La Contienda and continues into the territories around Barrancos and Moura (Portugal). The deposits are generally scantily investigated in terms of their geology, except for the work of Jubes and Carbonell, but the exploitation of the deposits in antiquity is evidenced by numerous grooved stone hammers and roman slag heaps[59]. The lodes fill in large transversal crevices in the stratification of the rocks and its paragenesis could be of two different types: those formed by pyrite and chalcopyrite and those that contain larger amounts of copper sulphides. Generally, the veins are of quartz and calcite-siderite with pyrite, chalcopyrite, galena, sphalerite, and tetrahedrite, and are hosted in Devonian chalks and greywackes. Only in the Portuguese zone have there been large scale exploitations at the concessions of Minancos and Aparis[60].

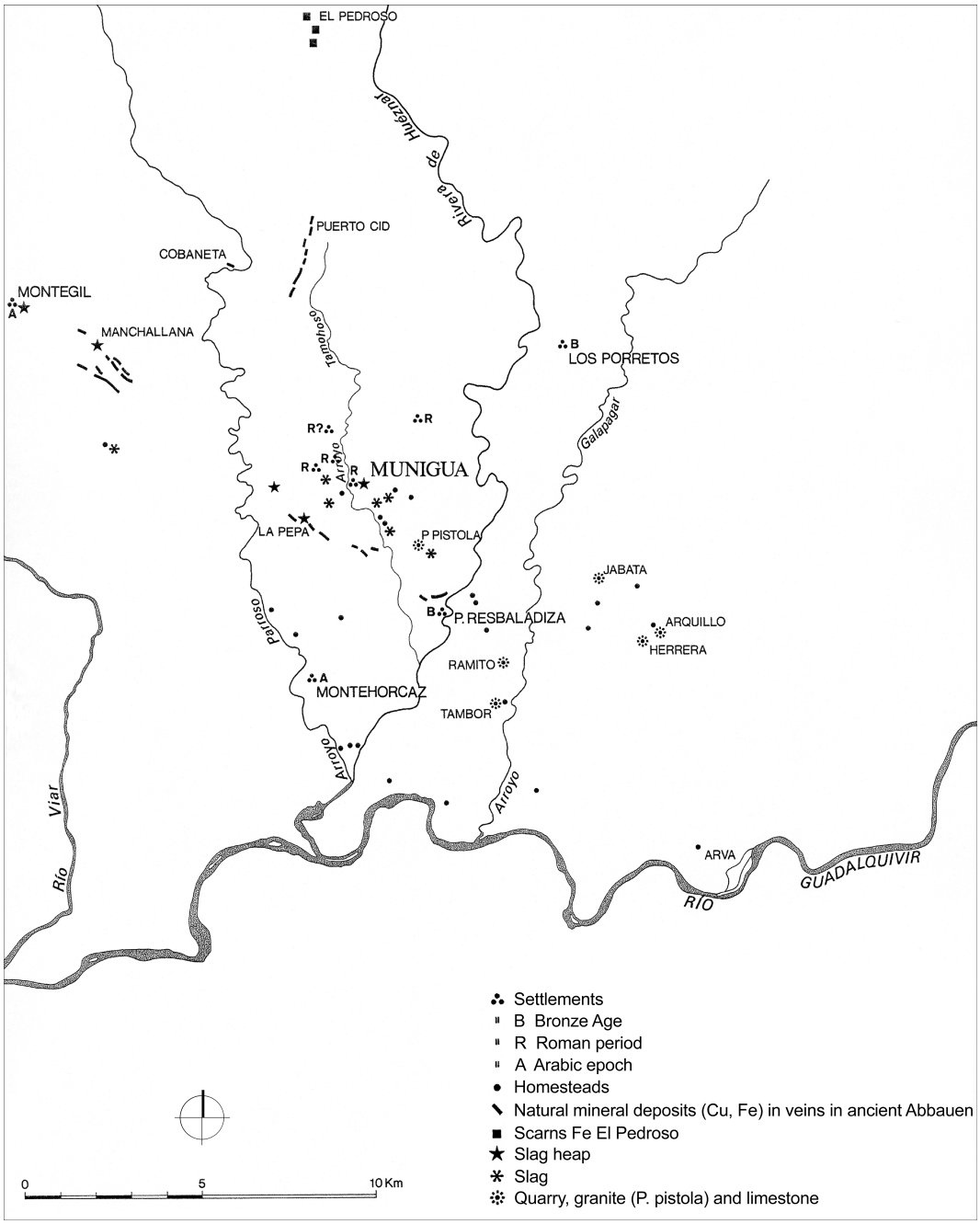
Some structures worth mentioning are those of Múrtigas, where the copper minerals dominate and a ferruginous crest marks the outcropping of the vein, with patches of malachite in the chalks, as well as patches of fahlore in the quartz-filled veins. It is a discontinuous vein which has been identified in various sectors: Juncal (Victoria), Puente del Múrtigas, Valdelosajos, Fraga del Tío Jesús, Estremozal, la Capitana, la Lapa, and Fraga de Pero Gil.

The principal ore field is interstratified with the chalks and extends towards the Portuguese border, via Cerro de la Cebada, Pico Centeno, Fraga de la Loba, and Los Guijarros (Diamante). The sector of Guijarros is 75 cm wide and is composed of a quartz gangue with baryte, malachite, hematite, and nodules of fahlore, and in other parts of a quartz vein with baryte, nests of chalcopyrite and fahlore.

In Pico Centeno, the copper sulphides are associated with variscite[61]. Although it has been said that it was exploited in the Chalcolithic[62], this doesn't seem very plausible due to the form of the mineralization – 1 to 2 mm nodules in siliceous veins that are only 1 to 2 cm thick[63]. The mined areas that were linked to the extraction of variscite in the Chalcolithic also do not correspond to this time, but to exploitations at the end of the 19th century[64]. The settlement (Sierra de la Concha) and mining tools from these lodes are from the end of the Bronze Age.

The last vein structure (Contienda) developed in the regions of Cuevareja, Dehesilla, Cuesta de la Morena, Huerta Barbas, Macareno, Caseta del Hoyo, Curtidero, Barranco de las Ánimas, Arroyo del Tortillo, Sierra de Santa María, Sierra del Águila, Culeritos, Mohosa, and Amoladera, where there have been diverse prospections of small quartz veins of baryte with chalcopyrite, fahlore and malachite. Up to three small discontinuous parallel veins have been detected. In all of these veins, the superficial copper minerals disappear with increasing depth. In the superficial zones, the copper minerals are distrib-

58 Vázquez 1974.
59 Jubes – Carbonell 1920.
60 Martins da Silva 1949.
61 Moro et al. 1991.
62 Nocete 2001, 107 figs. 9–11.
63 Moro et al. 1992.
64 Jubes – Carbonell 1920, 13.



3 Munigua and surroundings, from Pérez – Schattner 2013, 244, fig. 4.

uted in seams and pockets, and many of the cupriferous traces in the chalks come from pyrite impregnations that have deteriorated due to weathering[65].

– *Rivera de Huéznar group*

Another one of these large vein structures is found in the vicinity of Villanueva del Río y Minas, in the Sierra Norte, province of Seville, and is formed by two principal structures – Piedra Resbaladiza – Manchallana and Puerto Cid – and other minor ones, especially the lode at Cerro de la Mina. These are vein-type deposits of copper sulphides and iron sulphides, within veins that do not exceed 10 m in thickness (fig. 3)[66].

These veins contain mineralized seams less than 1.5 m thick and are formed by a mottled occurrence of quartz and siderite (iron carbonate), with patches of iron

65 Jubes – Carbonell 1920.

66 Schattner et al. 2005.

sulphides (pyrite) and copper-iron sulphides (chalcopyrite). In the superficial zones, which can reach a depth of up to 10 meters, the weathering has formed an outcrop where minerals from the oxidation zone predominate, such as copper carbonates and iron oxides, although there are also relicts of the primary minerals (pyrite and chalcopyrite) preserved from alteration within the oxidized minerals. The interesting thing about this formation, which can be extended to other structures in the Ossa Morena, is that there is no cementation zone with secondary sulphides: the oxidation zone shifts gradually to the primary sulphides. The vein of Piedra Resbaladiza – Manchallana is associated with the Arenillas fault, and is formed by three discontinuous vein sectors: Manchallana, Miraflores, Pilar de la Pepa, and Piedra Resbadaliza. Iron is present as siderite, which has been altered in the superficial zones to iron oxides and hydroxides (gossan), while copper is present as carbonates (malachite) on the sides of the vein. Copper dominates over iron only in the sectors of Piedra Resbaladiza and Pilar de la Pepa.

The lode at Puerto Cid is a major entity, some 2.5 km long and copper dominates over iron.

In addition to these principal structures, the whole zone is dotted with small vein structures – Cobaneta, Casa Alcántara, Cerro de la Mina, Cueva de la Bruja, etc., where outcrop of iron oxides and hydroxides and copper carbonates appear on the surface.

– *Blanquilla (Cazalla de la Sierra, Seville) group*

This is formed almost exclusively by copper carbonates and oxides with some chalcopyrite which was exploited in the 19th century in the mine of La Unión.

– *Puebla de los Infantes (Seville) group*

This is another ore field with diverse mineralizations, some veins are cupriferous, and others are predominantly iron; almost all have lead. These veins have extensions and can reach 1 km in length and around 1m in thickness.

3.3 Copper deposits in the skarns

The intrusive massifs associated with the Hercynian orogeny caused skarn-type contact and replacement mineralizations. The most well-known are those of Sierra de la Lima and Navalázaro (El Pedroso, Seville), Minas de Cala (Cala, Huelva), Mina Teuler (Santa Olalla del Cala, Huelva), San Guillermo (Jerez de los Caballeros, Badajoz), and Monchi (Burguillos del Cerro, Badajoz)[67]. The contact minerals are basically composed of iron oxides, magnetite and oligists, but can also be accompanied by some copper sulphide veins.

In the iron skarn mineralizations of El Pedroso are abundant massive pockets of iron oxides (magnetites and oligists), oxidized on the surface to hematite (Sierra de la Lima). Occasionally, these iron minerals are accompanied by iron sulphides and copper-iron sulphides[68], like at the concession of Juan Teniente, where prehistoric mining tools have been found. The mine of Juan Teniente is made up of three parallel veins hosted in the chalks and surface in a small ferruginous outcrops: the first one between 4 and 20 m thick and 500 m long; the second being between 3 and 11 m thick. The mineralization is composed of pyrite, but it is probable that copper carbonates that were exploited during the Roman and prehistoric periods existed on the surface.

One of the best studied mineralizations are those from Minas de Cala, which belongs to a skarn-type deposit. The Minas de Cala is found in Cambrian limestone, between two series of Cambrian chalks. One intrusion of granodiorite hosted in the original chalks is the origin of calcic silicates with characteristic skarn minerals, such as epidote. Through contact with the carbonates, it became desilicified and formed pyroxenes and amphibolites. The iron mineralization, originating from contact metasomatism that replaced the limestone, is found in the pyroxene skarn (diopside) and is rich in iron oxides (magnetite). Related to the iron mineralization are copper sulphides from a hydrothermal origin (Dolores), whose quantity increases with increasing distance from the granites[69]. Within the concession at Dolores, there are veins which extend for about 1 km, some of which are very rich in copper minerals, especially the lodes of Portugués and San Lorenzo, which are circa 150 m wide. These appear in the limestones, where the mineralization of chalcopyrite and iron oxides precipitated in the oxidation zone in the form of copper carbonate crusts, as well as in the granites with pyrite and chalcopyrite and malachite in the outcrops.

Some stone tools and nearby settlements can be associated with the prehistoric exploitation of these copper veins, but the most intensive mining activity took place during the Roman period[70].

In the Teuler mine, mineralizations were created along the contact zone between the Cambrian limestone and the granodiorite batholith of Santa Olalla del Cala, causing a magnetite skarn in which small quantities of iron sulphides (pyrite) and copper iron sulphides (chal-

67 Vázquez 1968.
68 Vázquez – Amado 1969.
69 García et al. 2003.
70 Pérez – Rivera 2004b.

copyrite) appear. In the upper levels, concretions of copper carbonates (malachite) can also form[71].

These iron mineral skarns in the contact zone between the granites and limestones is extended to the southern part of the province of Badajoz. One of these is the mine of San Guillermo (Jerez de los Caballeros) where a skarn is embedded in a carbonated layer between schists and igneous rocks that is formed by magnetite and iron and copper sulphides. Close to this is the Berrona mine, near Jerez de los Caballeros and Fregenal de la Sierra, which are also located in the contact zone between calcareous and igneous rocks, but the mineralization is dominated by iron oxides (magnetite) and pyrite, while chalcopyrite and pyrrhotite are found in minimal quantities. A last mine in this group of skarns is Monchi (Burguillos del Cerro), which is sandwiched between the batholith of Burguillos and limestones, and has important reserves of magnetite, although chalcopyrite is also present[72].

3.4 Copper mineralizations in ultramafic rocks

Another new type of deposit that originated during the Hercynian was recently discovered at Monesterio (Badajoz) at the mine of Aguablanca, which is associated with ultramafic rocks[73]. The mineralization is composed of massive sulphides or disseminated sulphides in magmatic rocks and gabbros that have economically viable amounts of nickel and copper. Copper carbonate crusts have been found in the most superficial zones of these ultramafic rocks.

4. Conclusions

Finally, the information that has been laid out in these pages needs a brief conclusion that establishes future criteria for an investigation that is still in its beginning stages. It has been shown in the descriptions of the mineralizations and the remains of the mines found within them that the base information is mainly from studies done by geologists and mining engineers, who have investigated the minerals and noted the remains of mining activities they encountered on the way. There is still no empirical knowledge of the distinct mining techniques, and still less about archaeological remains associated with them. Generally, the interpretation of these traces of ancient mining have been catalogued as Roman, although in many cases – this is something that we have made progress in – they are pre-Roman. But at this point we stumble upon an important problem: it is impossible to easily distinguish between Bronze Age activities and those from protohistory. The only criteria which is considered valid – besides the characteristics of the extraction techniques – is to find ceramic material that can help improve the chronology. As an example, one can look at some of the conclusions from the Archaeometallurgical Project of the Province of Huelva, a meritorious work of exploration and excavation of mining and metallurgical traces that later, unfortunately, was not continued. In this work, it was decided to catalogue all superficial manifestations that had the form of an open trench or cut as prehistoric, and all underground mining containing galleries and wide adits as Roman. Afterwards it was proved that these two mining techniques – surface and underground mining – do not have anything to do with the chronology, but are more dependent on the disposition of the mineralization: a veiny structure, especially if the orebody is narrow, was worked in a narrow cut where the extraction was adapted to the structure of the vein. Lenses and masses, on the other hand, needed to be extracted using deep mining. There are still many clarifications to be made, but generally superficial mining and underground mining coexisted in prehistory since the Neolithic, in the form of non-metallic mining, such as at the mines of Gavà, and also in the Roman period, although there was a better planning of the engineering which attributed to the possibility of reaching greater depths and with this, a better level of profit.

Thanks to these preliminary works carried out by the Institute for Archaeometallurgy and the University of Seville, experience has been gained, which allows us to distinguish between Roman and pre-Roman mining, but this investigation also showed that it is necessary to know quite well the geological setting, as well as to carry out excavations at the mines. This was demonstrated in

71 Casquet – Velasco 1978.
72 Vázquez 1968.
73 Tornos et al. 2002.

the case of Chinflón, considered a priori as a Chalcolithic mine. Only after its excavation, could it be properly dated to the Late Bronze Age.

These problems that are raised in the investigation of mining are incremented by the most primitive metal mining, which developed during the Chalcolithic and whose characteristics and examples continue to be unknown. In the inventory of the mineralizations in the area of the South Portuguese Zone, I have put forward, as much as I could, in geological terms why there is an absence of settlement and mining in these mines, that they were not an exploitable resource. This is evident when one studies the settlements up to the Bronze Age and by looking at the mining of silver. It has been shown that only a few of the lodes there have secondary copper mineralizations that would have been available to the Chalcolithic miners, such as Esperanza in Tharsis or Santa Bárbara in Herrerías.

However, in southwest Iberia there are large quantities of sulphide vein deposits with copper minerals. These are present within all areas that pertain to the Hesperic Massif, in the southern most parts of the South Portuguese Zone, as well as in the northern part of the Ossa Morena. These mineralizations have the advantage that they were far less exploited in the 19th and 20th centuries and almost all of the old mining traces were preserved on the intact lode. It is essential that this prehistoric mining research focuses on them, for however small the mines or mining indications, there is greater chance of success. The same could be said for the copper sulphide lenses and veins of the South Portuguese Zone, where much of the work to date has been concentrated (Chinflón, Cueva del Monje, Masegoso, etc.). Nevertheless, in the large polymetallic sulphide masses, the large open pit mines have removed all superficial outcrops, i.e. the oxidation zone, in which the prehistoric mining was concentrated.

During the Late Bronze Age, all of these vein-type mines of copper sulphides went through a period of intense exploitation, which can be seen by the thousands of grooved stone hammers[74]. These exploitations from the Bronze Age are a good lead to start the search for mining traces for the period before, the Chalcolithic, which at the moment is only represented by the mine of Cuchillares at Campofrío, although the chronology is not yet sufficiently assured and the lack of ceramic material does not allow verification. An established fossilized guide, stone hammers without a central groove, should be added to the standard study of the settlements. Although the most primitive metallurgy of copper minerals using crucible smelting does not produce true slag[75], metallurgical residues and metal tools from the habitations, such as what took place at Cabezo Juré and some other settlements on the left hand margins of the Guadiana[76], are the best evidence to demonstrate the working of the mines of these mineralizations.

In summary, there is very little that we know about the beginnings of mining in southwest Iberia. Only with research projects that continue the path taken by the Archaeometallurgical Exploration of Huelva, with multidisciplinary teams, would it be possible to reveal the characteristics of these primitive extractions, which up until now are only confirmed by smelting crucibles and metal tools found in the settlements and graves.

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74 A compilation in Hunt 2003.
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Abstracts

This paper is concerned with the mineral deposits of southwestern Spain, their geological features, and evidence of prehistoric mining.

There are two extremely interesting mining areas in the Southwest of the Iberian Peninsula: the Iberian Pyrite Belt, which is situated in South Portuguese Geological Zone, and Ossa-Morena Zone. The Iberian Pyrite Belt, with its exploitable copper and silver ores, is dominated by large deposits of polymetallic sulphides over copper ore lodes. Ossa Morena has abundant small deposits of copper sulphides and iron ore skarns.

Prehistoric mining was concentrated in Ossa Morena for the production of copper. In this zone, the oxidation of copper sulphides favoured the formation of copper carbonates in the upper levels (malachite and azurite), which was within reach of prehistoric mining technology. In the Iberian Pyrite Belt, the copper ores were concentrated in the supergene enrichment zones, which were sometimes over 100 feet deep, and mostly unexploitable for prehistoric mining, with the exception of some copper sulphide ore lodes such as Chinflón. Moreover, in certain localities of the Iberian Pyrite Belt, there are formations of exogenous copper with carbonates and inclusions of secondary copper sulphides, which were formed from the erosion and sedimentation of the nearby primary ore bodies, which explains some copper metallurgical settlements, like at Cabezo Juré. In prehistoric times, only the silver ores that were exploited

in the Iberian Pyrite Belt were situated in the oxidation zone (jarosite gossan). The industrial production of copper did not begin until Roman imperial times.

Keywords: Mining, Copper, SW Peninsula, Prehistory

In diesem Beitrag werden die Kupfervorkommen in Südwestspanien behandelt, sowohl ihre geologischen Merkmale als auch die Belege für prähistorischen Bergbau.

Im Südwesten der Iberischen Halbinsel befinden sich zwei außerordentlich interessante Bergbaugebiete, der Iberische Pyritgürtel in der südportugiesischen geologischen Zone und die Ossa Morena Zone. In ersterem, mit Kupfer- und Silbererz, überwiegen polymetallische Sulfidmassen das Vorkommen von Kupfererzadern bei weitem. Die Ossa Morena Zone dagegen ist reich an kleinen Erzadern mit Sulfiden sowie an Eisenerz-Skarns.

Der prähistorische Bergbau in der Ossa Morena war auf die Produktion von Kupfer konzentriert. In dieser Zone begünstigte die Oxidation von Kupfersulfiden die Bildung von Kupferkarbonat (Malachit und Azurit), und zwar in den oberen Niveaus in Reichweite des prähistorischen Bergbaus. In den Massen des Iberischen Pyritgürtels dagegen befand sich das Kupfererz in den supergenen Anreicherungszonen, manchmal über 100 Fuß tief. Die tieferen Niveaus entzogen sich damit den Möglichkeiten des prähistorischen Bergbaus, der deshalb nur in einigen Erzgängen von Kupfersulfiden anzutreffen ist, wie in Chinflón.

Außerdem gibt es an bestimmten Stellen des Iberischen Pyritgürtels Formationen von exogenem Kupfer mit Karbonaten und sogar sekundären Kupfersulfiden, hervorgerufen durch Erosion und Sedimentation von primären Sulfiden in der Nähe der originalen Masse. Dies erklärt die Lage einiger Kupferproduktionszentren wie z. B. Cabezo Juré.

In der großen Masse des polymetallischen Iberischen Pyritgürtels aber wurden in prähistorischer Zeit lediglich die Silbererze abgebaut, die in der Oxidationszone vorkamen (Jarosit-Gossan). Die industrielle Kupferproduktion begann nicht vor der Römischen Kaiserzeit.

Schlagwörter: Bergbau, Kupfer, Südwesten der Iberischen Halbinsel, Metallzeiten

En este trabajo recopilan los yacimientos minerales del suroeste de España, se describen sus características geológicas, y se indican las evidencias de minería prehistórica.

Dentro del Suroeste de la Península Ibérica se encuentran dos formaciones geológicas de enorme interés minero, la Faja Pirítica Iberica, que se desarrolla en la Zona Geológica Surportuguesa, y Ossa Morena. En la Faja Pirítica Ibérica, con cobre y plata como menas aprovechables, predominan los grandes depósitos de sulfuros polimetálicos sobre los yacimientos filonianos de cobre. En Ossa Morena son abundantes los pequeños yacimientos filonianos de sulfuros de cobre y skarns de minerales de hierro.

La minería prehistórica se concentró en Ossa Morena para la producción de cobre. En esta zona los fenómenos de oxidación de los sulfuros de cobre favorecieron la formación de carbonatos de cobre en los niveles superficiales (malaquita y azurita), una posición al alcance de ingeniería minera prehistórica. En las masas de la Faja Pirítica Ibérica los minerales de cobre se encontraban en el enriquecimiento supergénico, a veces a más de 100 metros de profundidad, a unas cotas alejadas de las posibilidades de la minería prehistórica, sólo presente en algunos filones de sulfuros de cobre, como Chinflón. Además, en determinados yacimientos de la Faja Pirítica Ibérica se encuentran formaciones de cobre exógenos, con carbonatos e incluso sulfuros secundarios de cobre, procedentes de la erosión y sedimentación de los sulfuros primarios en los alrededores de las masas originales, que explican algunas explotaciones prehistóricas, como Cabezo Juré.

En las grandes masas polimetálicas de la Faja Pirítica Ibérica en época prehistórica sólo se explotaron los minerales de plata que se encontraban en la zona de oxidación (gossan jarosítico). La producción industrial de cobre no comenzaría hasta época romana imperial.

Palabras clave: Minería, Cobre, Suroeste Ibérico, Prehistoria Reciente

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General Index

1 The classifications and terminologies of the Bronze Age phases and their absolute chronology differ from region to region and author to author. Therefore you find here the terminology used by the single authors, and sometimes, if it is not the Iberian Peninsula or general, an indication of region or culture.

2 For casting, smelting and melting in the Spanish and Portuguese texts sometimes is used fundición / fundido / fundição. It will say: Fundición of ore = smelting; fundición of metal = melting; fundición of metal into objects = casting.

3 See also the Geographical Index, letter M following the local name. Most of the indicated mines contain various minerals. Because of this, they are not classified as copper mines.

Geographical Index

The names of countries and places are given in the language of the country or in English. Differences between English, German, Portuguese and Spanish are indicated.

Abbreviations:
AS Archaeological site
A Administrative place name
D. District /Distrito
G Geography, Geology
M Mine, Mining region or Mining group, Mineralization

Personal Name Index

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