The production of silver in Monte Romero, a 7th century B.C. workshop in Huelva, Spain

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Introduction.

At the beginning of the I millennium B.C. a new culture developed in southwestern Iberia, as a direct continuation from the southwestern Bronze Age. This was the so-called Tartessian culture whose sphere of influence was spread over the western part of Andalusia, namely the modern day provinces of Huelva, Sevilla and Cadiz (Fig.1).

The culture takes its name from the historical town of Tartessos. Although some scholars still believe that the location of Tartessos remains unknown and that it was probably situated somewhere in the Guadalquivir region (e.g. Harrison 1988: 54), many are now convinced that Tartessos was, in fact, situated in the hills of the modern town of Huelva (Fernández Jurado 1988-89a: 294).

The Tartessian period spans roughly from the beginning of the first millennium B.C. to the end of the sixth century B.C. It is divided into three major stages, of which the Middle Tartessian is relevant to this paper. The chronological boundaries of this period are the end of the eighth century B.C. to the last quarter of the seventh century B.C.

During the earlier period sporadic trading between the Tartessians and the Phoenicians began. These trading links were intensified in the Middle Tartessian with the establishment of Phoenician colonies on the south coast of Iberia, and as a result a whole new stage in the development of the Tartessian culture is defined. The effect of the oriental culture of the Phoenicians on the indigenous material culture, the pottery, architecture, technology and even religious and burial customs was so strong so as to name this period the Orientalizing period (Ruiz Mata 1990: 406).

The motive behind the Phoenician colonisation of the West is clearly described by Diodorus Siculus (Book V. 35)[1]:

> "The country has the most numerous and excellent silver mines.... The natives do not know how to use the metal. But the Phoenicians, experts in commerce would buy this silver in exchange for other small goods. Consequently, taking the silver to Greece, Asia and all other peoples the Phoenicians made great earnings. Thus practising this trade for a long time, they became rich and founded many colonies, some in Sicily and on the neighbouring islands, others in Libya, Sardinia and Iberia."

Silver was the commodity at the centre of the trade with the Phoenicians. The booming metal trade is witnessed in the mining areas of the Huelva Province, where there is a marked increase in mining activities and the smelting of ores.

Metallurgical workshops have been found at a number of excavated sites such as San Bartolomé de Almonte (Ruiz Mata and Fernández Jurado 1986) and Huelva-San Pedro and La Esperanza (Fernández Jurado 1988-89b), but more often than not these are dedicated to the refining of silver rather than to primary smelting (Fig.1). On the other hand, evidence of extractive metallurgy dating to this period discovered in sites such as Rio Tinto are often found under metres of metallurgical debris accumulated over centuries of exploitation.

The site of Monte Romero, a metallurgical workshop dedicated to the extractive metallurgy of silver, is the subject of this paper. It differs from sites such as Rio Tinto in that it was occupied for a short period only, which, based on the pottery, dates from the second half of the 7th century B.C. to the beginning of the 6th century B.C. The archaeometallurgical finds from the site, therefore, offer a unique opportunity to study the technology of this period and to understand how silver was produced.

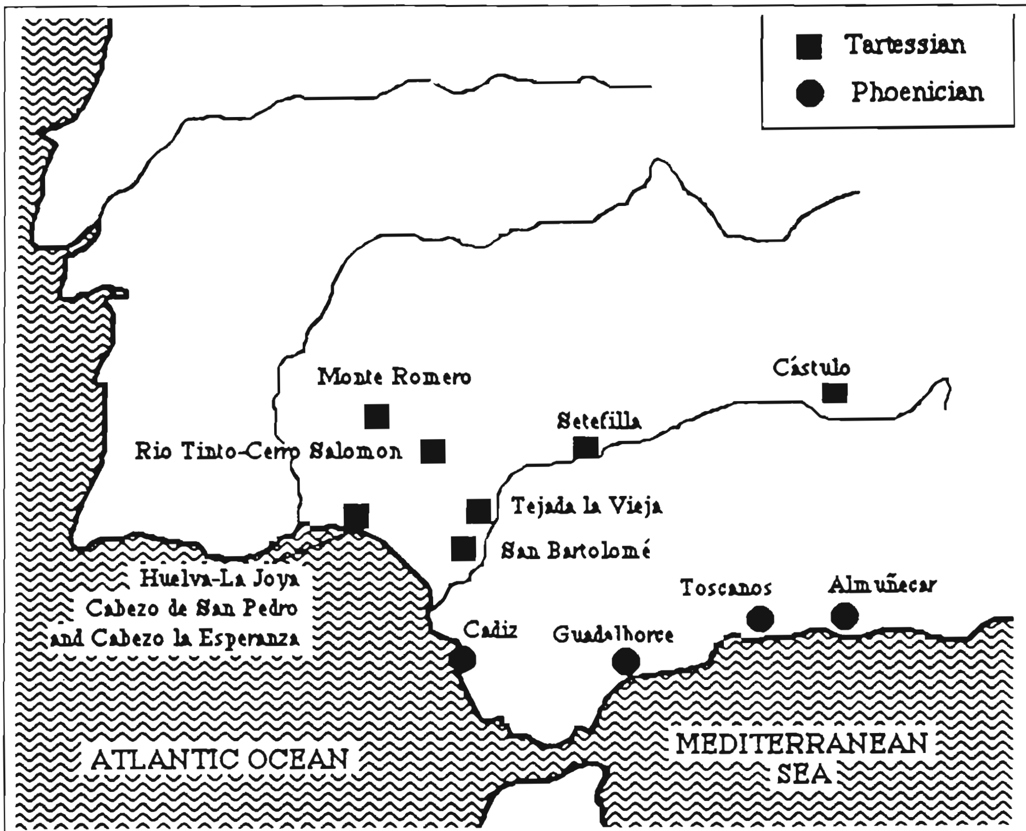

Fig. 1 Location of major Tartessian and Phoenician sites

Monte Romero

The ancient workshop was first discovered in 1975 during the Institute of Archaeometallurgical Studies (IAMS) survey of South West Spain, directed by Prof. B. Rothenberg. It is situated in the precinct of the modern mine of Monte Romero, located in the Sierra Aracena. It is close to Almonaster la Real, about 100 km from Huelva and about 1 km south-east of the modern mine of Cueva de la Mora (Fig. 2).

The lode of Monte Romero is part of the Iberian Pyrite Belt and as such it is composed of lenses of pyrite and chalcopyrite whose extremities are composed of sphalerite and galena (Fernández Alvarez 1975: 80). It has to be emphasised that the deposit is extremely complex and ore types tend to overlap in characteristics. However, six principal types of ore have been defined (Fernández Alvarez 1975: 81). The one that is believed to have been processed in the ancient workshop is what is called the 'massive complex mineralization' and is composed of coarse crystals of galena and sphalerite with a small quantity of pyrite and quartz. Copper is also present in the form of freibergite [$(Ag,Cu)_{12}(Sb,As)_4S_{13}$] which may be present at 0.2 - 0.6 %. It is due to the presence of this mineral that both silver and arsenic levels in this type of ore are higher (Fernández Alvarez 1974: 252). Although this type of mineralization is usually found in deep deposits, at Monte Romero it outcrops to the surface, and would have been readily accessible to ancient prospectors and miners.

During the survey of this area, a scatter of archaeometallurgical debris such as slag, *tuyères*, fragments of cupellation dishes and so forth were found in association with pottery which was initially dated to the 8th-7th centuries B.C. (Blanco and Rothenberg 1981: 84-87). This wide variety of metallurgical finds, the early date of the site and the complexity of the typical ores from Monte Romero, which would require a considerable degree of sophistication in exploitation, convinced the IAMS research group that the site should be properly excavated. Excavation took place in 1986 (Rothenberg *et al.* 1986).

The excavation of the ancient workshop

Two squares of a total area of ca. 50 square metres were excavated (Fig. 3). Square A2 was covered by small slag heaps (e.g. Locus 4) as well as concentrations of discarded furnace wall fragments and other refractories, shown as Loci 5 and 13. None of the furnaces have been found complete or in situ. However, based on the location of these two loci, it is believed that the smelting area was situated directly to the south of the excavation. Thus area of Square A2 is believed to have been connected with the smelting of the ores.

Square A3 on the other hand, contained the remains of a structure - a partly preserved wall. Along this wall a stack of complete, used cupels was discovered. It is, therefore, believed that this area was connected with cupellation. Once again it is suggested that what has been excavated is more likely to be a storage area, while the actual cupellation took place just north of the excavation.

The archaeology of the site

The excavation has not revealed any archaeological evidence of a domestic nature. The site appears to consist only of a small metallurgical workshop situated directly adjacent to the source of the ore and dedicated to the production of silver. As a result the archaeological finds from the excavation are very limited and restricted to pottery only. However, although the quantity of pottery found was very small, it was quite diagnostic.

Most of the pottery is of the coarse handmade ware, typical of prehistoric levels in western Andalusia. Most fragments belong to globular bodied vases with a narrow neck, projecting rim and a border of impressed decoration on the shoulder. In other cases, the decoration is incised, with triangular motives or parallel lines at the base of the vase, or also impressed lines on the lip of the mouth (see Pérez Macias 1991: 106).

This type of ware first appears and its use becomes widespread in the Middle Tartessian II period. In fact, its appearance marks the transition from Middle Tartessian I to Middle Tartessian II and it is used to characterise the latter phase (Fernández Jurado 1988-89a: 220). This is the period when trading connections with the Phoenicians are beginning to intensify and metallurgical activities increased in a number of sites. The use of this pottery continues through the Orientalizing Period, when trading relations with the Phoenicians reach their peak (Fernández Jurado 1988-89a: 224), and into the end of the Middle Tartessian Period and the beginning of the Late Tartessian period. In absolute terms this type of ware was in use from the end of the 8th century B.C. to the middle of the 6th century B.C. Thus one may date the site within this time frame.

A complete, also handmade, vessel of conical form was among the finds. It was fired in a reducing atmosphere and had a burnished surface. According to Pérez Macias (1991: 107), the closest parallels to this come from the excavation of Cerro Salomón and a level of Cerro Macareno dated to the second half of the 7th century B.C. This helps to narrow down the period of occupation of Monte Romero from the second half of the 7th century to the middle of the 6th century B.C.

Besides the handmade ware, wheel-made pottery was found during the excavation. This group consisted mainly of Paleo-punic amphorae with flat rims of triangular section and carinated shoulders. Based on the chronology established at Cerro Macareno this pottery was in use during the 7th and the

6th centuries B.C. (Pérez Macias 1991: 107).

On the basis of the above discussion of the pottery, Monte Romero should be dated from the second half of the 7th century B.C. to the first half of the 6th century B.C. It is a site occupied during a single period after which it seems to have been abandoned.

However, the pottery type is not only significant from a chronological point of view. The coarse handmade ware appears in the Orientalizing levels of a number of Tartessian sites such as Cerro Salomón, San Bartolomé de Almonte, and Tejada la Vieja. Furthermore, the coarse ware is also present in the contemporary levels of the Phoenician emporia. The common factor between these sites is their connection with silver production and/or trade. This type of pottery has not been found in sites which are of an agricultural economy such as Setefilla. It has been suggested that on the basis of their distribution, this type of ware can be directly related to indigenous Tartessian people, connected with metallurgical activities (Fernández Jurado 1988-89a: 221).

The fact that most of the pottery from Monte Romero, a metallurgical workshop, was of this type, further supports this hypothesis. Moreover, it sets Monte Romero within the same economic network of silver production and trade as the rest of the sites.

Although it is not possible to suggest a more exact date for the establishment of the workshop, the chronological framework defined by the pottery indicates that the site may have been first occupied at a time when metallurgical activities in all the Tartessian sites are believed to have intensified due to a marked increase in the silver trade with the Phoenicians. Furthermore, although it is not possible to state when exactly the site was abandoned, the lower chronological limit generally falls within the period when a general decay of smaller Tartessian sites connected with silver production is observed (Ruiz Mata 1990: 426). This phenomenon has been attributed to the breakdown of the trading relations between the Tartessians and the Phoenicians and the decrease in the demand for silver.

The archaeometallurgy of the site.

The archaeometallurgical material recovered during the excavation has been the subject of detailed scientific research undertaken at the Institute of Archaeology, University College London. In this paper, some of the results of this investigation and some of the conclusions drawn from these results will be presented and discussed.

The excavation of the site has produced two types of slag: tapped slag and 'free silica' slags. The tapped slag, which had clearly been fluid, is dense and homogeneous. It does not contain any metallic prills visible to the naked eye. In contrast, the second type is extremely inhomogeneous and contains metallic lead visible on a freshly cut surface, as well as large rock inclusions. These slags are usually called either 'free-silica' slags or slag balls. The first name is derived from the fact that they contain a large amount of unreacted siliceous rock fragments, the other because they have the shape of a ball or a bun.

'Slag balls' are found at other sites located in southwestern Iberia which are connected with the extraction of silver (Blanco and Rothenberg 1981: 99; Fernández Jurado 1988-1989b: 192). They have often been interpreted as having been accidentally produced by a mistake in the smelt (Ruiz Mata and Fernández Jurado 1986: 260) and they are frequently considered a problematic find whose exact identity is not understood. This interpretation can be dismissed by the mere fact that they are found at many different sites over a wide span of time: the same mistake could not have been repeated at all these sites. Any suggested process model has to offer an explanation of how and why these slags were produced.

Also included among the archaeometallurgical finds from the site was speiss, a waste product formed as a separate phase in the presence of an excess of arsenic and/or antimony in the charge. Used cupels are clear evidence of the cupellation process. Finally, the excavation revealed a quantity of metallic lead whose presence is very significant, as it could either be an intermediate product, the product of primary smelting and, therefore, silver rich, or a by-product of the cupellation process and, therefore, de-silvered.

A series of analytical methods were employed for the thorough investigation of all these finds. X-Ray Fluorescence (XRF) was used for the bulk chemical analysis of samples of each of these groups of finds.

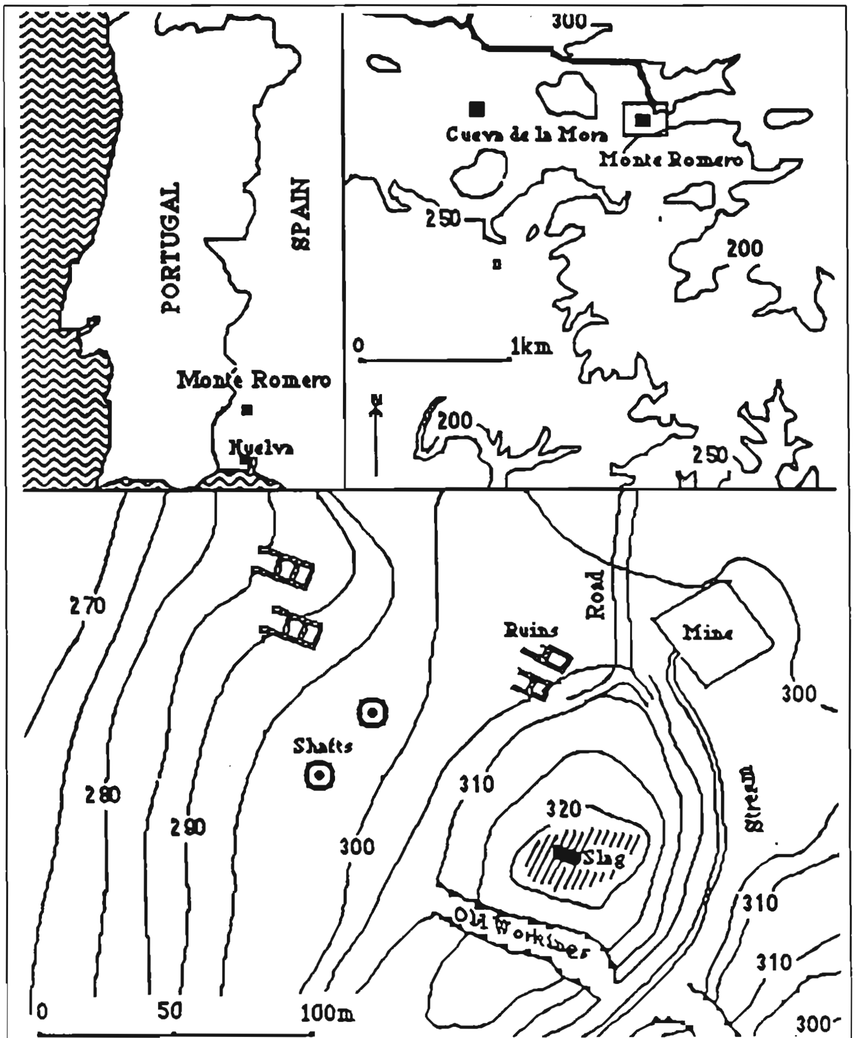

Fig. 2 Location of Monte Romero (*after Rothenberg 1986*)

As, however, a great number of the finds were quite inhomogeneous in nature, microanalysis was deemed to be necessary. A microprobe was used to analyse not only the metallic prills trapped in the slag matrix of both the tapped slag and the slag balls but also the different minerals of which the slag is composed. The mineralogical investigation of the slags was supplemented by X-Ray Diffraction (XRD) analysis. Finally, Atomic Absorption Spectrometry (AAS) was employed for the analysis of the metallic lead in order to ascertain silver concentrations.

In the initial publication of Monte Romero, all tap slags were identified as copper-smelting tap slags (Blanco and Rothenberg 1981: 86-87). This was based on the analysis of two samples collected during the survey of the area. The new analytical results, however, show that the lead content of the excavated tap slags is consistently higher than that of the copper content (Pb ranging from 2.9 % to 5.6 % compared to Cu 0.0 % to 0.30%). Thus, the samples have been reinterpreted as lead smelting slags. The discrepancy between the two sets of data can easily be explained as, copper slags are found in the vicinity of the hill on top of which the site is situated, but these are not connected with the ancient workshop and are believed to be much later in date.

The XRF analysis of the tap slags also revealed a high level of barium, averaging 10%. Furthermore, X-ray diffraction analysis of the slag samples indicated celsian ($Ba[Al_2Si_2O_8]$) as the main constituent, not fayalite (Fe_2SiO_4), one of the most common minerals found in ferrous slags (Bachmann 1982: 14), as initially expected.

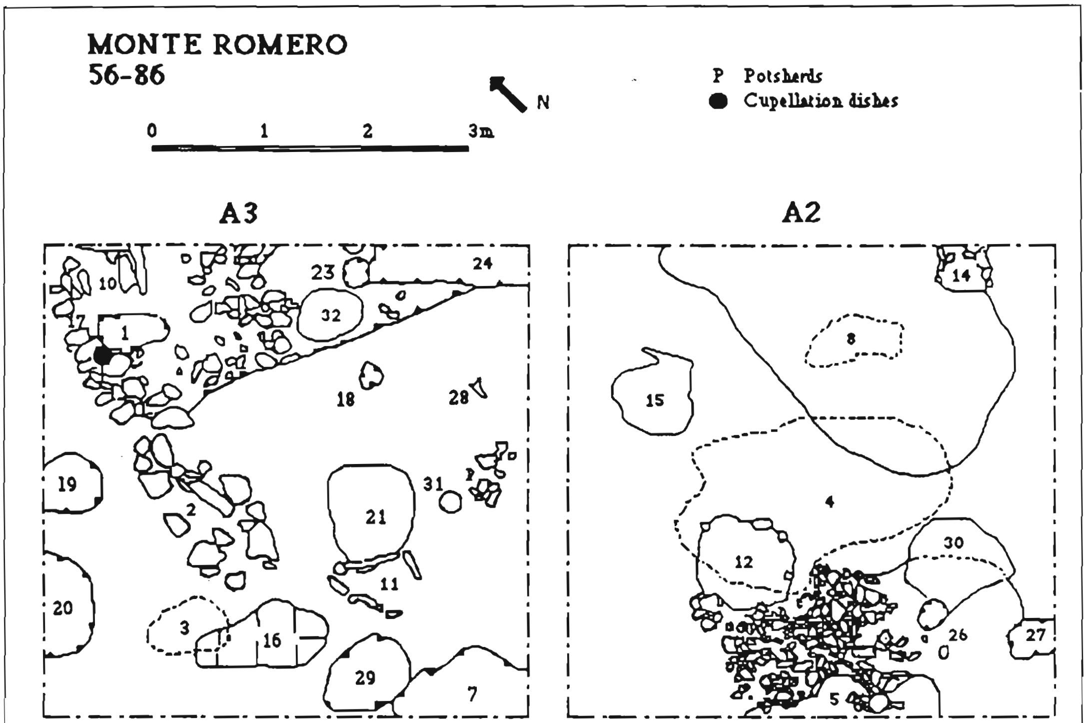

Fig. 3 Plan of the excavated area *(after Rothenberg et al. 1986)*

Barite, the barium sulphate mineral, serves as an excellent flux for lead smelting, as it facilitates the desulphuring of galena during the roasting process, while in smelting it reacts with any lead silicates formed, releasing the lead (Maréchal 1985: 30-31). As barite is not commonly found in the argentiferous ores of Monte Romero it is argued here that this property of barite was identified by the ancient metallurgists working at the site and that barite was deliberately added as a flux to the charge.

As expected the bulk chemical analysis of the 'free-silica' slag samples showed a great range in compositions. Some samples were silica-rich, with SiO_2 concentrations reaching as high as 50%, some were barium-rich with barium concentrations reaching 18%. One sample was found to be manganese rich. Microanalysis of the rock inclusions revealed that the variation in compositions is mainly due to the presence of different unreacted rock fragments. Thus the silica-rich samples contained significant amounts of unreacted quartz while the barium-rich examples contained unreacted barite. It seems, therefore, that the term 'free-silica' slags is not appropriate for all of these samples and 'slag balls' is perhaps what one should refer to them instead.

The identity of the minerals present in the slag matrix was determined by these inclusions. Thus in the barite-rich slag balls, celsian [$Ba(Al_2Si_2O_8)$] was once again the main crystalline phase. In contrast, in the silica-rich slag balls, hedenbergite [$CaFeSi_2O_6$] and anorthite [$CaAl_2Si_2O_8$] were the main minerals. It seems, therefore, that initially some reaction had taken place between the ore and the flux which led to the formation of these silicates. This was then followed by the introduction of more flux which did not have the opportunity to react and is, therefore, found in the form of these large inclusions.

In general, this type of slag has a very high lead concentration averaging ca. 10% but sometimes as high as 25%. Microanalysis of a number of samples showed that the lead is in the form of entrapped metallic prills, as well as, lead silicate glass which is the matrix component of the slag. The prills can often be observed with the naked eye in a fresh break.

In the initial publication of Monte Romero (Rothenberg *et al.* 1986) it was suggested that the slag balls were the product of the recycling of the cupèls and furnace linings, and that the rock inclusions acted as a sieve which facilitated the separation of the lead metal from the slag. Tylecote, on the other hand, suggested that the quartz crystals were used as a means of solidifying the slag and absorbing it as a sponge thus enabling the separation of the metal from the slag (Tylecote 1987: 306-307).

Percy (1870) describes a lead smelting process in which lime is added to the molten charge of the furnace in order to stiffen the molten charge, which is subsequently cooled and remelted with more lime. According to Percy (1870: 230) in the final stages of the smelt:

> "Lime is again added, the slag is pushed back from the surface of the lead and left to drain a little, the lead is tapped out and the slag is then raked out of the furnace in pasty lumps termed 'grey slag'".

The use of the lime, Percy argued was purely mechanical in other words to cool and solidify the slag. The removal of the slag as a solid enabled the lead metal to be exposed to the atmosphere of the furnace and thus the reactions could continue taking place. Furthermore, any lead trapped in the slag had the time to drain off and be collected (Percy 1870: 236-238).

It is suggested here, in support of Tylecote's idea, that the slag balls were the result of a similar process, where the silica and barite were used in the similar way as the lime. The charge was saturated with an excess of flux, in the form of quartz and barite, and as a result the slag cooled and solidified thus enabling its separation from the lead metal. The presence of a large amount of glass together with the quenched form of the crystals in the matrix support the suggestion that the slag had been rapidly cooled.

The fact that the slag balls contain so much lead, combined with the fact that a large group of complete balls was found stored in a pit in Square A3 (Locus 16) suggest that these slags were to be retreated at some point during the process. If the slag balls were recycled it is possible that the tap slags were produced during that secondary smelting process. The tapped slags, in contrast to the slag balls do not contain any lead silicates and may have been formed from the resmelting of the slag balls with more barite flux. This would have reacted with the lead silicates releasing the lead and forming a more fluid slag.

The XRF analysis of the speiss showed this to be mainly composed of copper (average = 31%), antimony (average = 17%) lead (average = 26%) iron (average = 9%) and arsenic (average = 4%). The speiss was also found to contain 0.5% of silver. The presence of speiss at Monte Romero is not surprising when the type of ore from the lode is taken into consideration: an excess of antimony and arsenic would have existed in the charge due to the presence of freibergite in the ore. Although, a model for the desilverization of speiss has been suggested by Craddock *et al.* (1987: 10), such a process does not seem to have been undertaken at Monte Romero: the samples of speiss analysed still contain a significant amount of silver.

Metallic lead was found at Monte Romero in the form of large flows with a ropy surface, as well as small droplets. Analysis of all the lead finds by AAS revealed that some of the lead was silver-rich (with silver concentrations of 5000 ppm), while some had a silver concentration lower than 1000 ppm and has, therefore, been defined as desilvered.

These results raise a number of questions. First, is there any relation between the silver concentrations of the sample and its size (large runner or droplet)? Second, is there a difference in their distribution within the excavated area, and finally, does their distribution reveal something about the organisation of activities or perhaps the process model?

In terms of silver concentration and size, all the finds which had a concentration of silver between 3000 and 5000 ppm are small droplets, while the majority of large pieces all contain about 1000 ppm of silver. All of the lead samples, came from Locus 1 of Square A3, the pit located within the structural remains which also contained complete, and fragmented, used cupellation dishes. Analysis of the cupels showed that these were almost completely composed of lead oxide (80%). It is therefore suggested that they were stored there awaiting retreatment. As the lead was stored in the same pit, it seems likely that lead and cupels were to be processed together.

The fact that the ore from Monte Romero is polymetallic may have meant that extra lead was needed to fully 'collect' the silver from the other mineral phases. As both silver-rich and desilvered lead were mixed together, and as it would have been impossible to readily distinguish between the two by eye, it is suggested here that all the contents of the pit were meant to be added to the smelting charge in order to assist in the formation of the silver-rich lead bullion.

The process model.

Having presented the analytical results, a process model which explains how these products were formed will be proposed. First, the available evidence will be summarised. The argentiferous ore from Monte Romero is a polymetallic ore containing lead, copper, antimony, iron, arsenic and sulphur. Although no examples of this ore have been recovered from the excavation it is believed that this would have been the ore used. There are two types of slag, tap slag and the slag balls, and speiss, all of which have to be fitted in the model. Also requiring explanation are the used cupellation dishes and the presence of two types of lead: silver-rich and desilvered.

The following model is suggested (Fig. 4). The polymetallic ore would initially have been roasted to drive off some of the sulphur present. Then, mixed with quartz and barite flux and charcoal, it would have been introduced as the charge to the smelting furnace. The products of this smelting process would have been slag, speiss and lead present in three layers in the furnace.

Separation of these three layers would have been difficult. Rather than being tapped, therefore, the slag was cooled and solidified by the addition of large inclusions of crushed rock and was removed in the form of slag balls. The speiss and lead would have been left in the furnace, where, upon cooling, speiss, having a higher melting point than lead, would have solidified and would have been removed in the form of plates. The lead would then be tapped out. The lead produced would have been silver-rich and would subsequently undergo desilverization.

The slag balls would still have contained a large amount of lead and would, therefore, have been re-treated. They would be crushed and mixed with more barite flux and thrown back into the smelting furnace. The barite would react with the lead silicates releasing the lead and forming a fluid tap slag. Any trapped metallic prills would also be released and trickle to the bottom of the furnace. Thus this step would produce a tap slag and more metallic lead.

The metallic lead from the two steps would then have undergone cupellation. The presence of slagged pottery from the site, whose analysis revealed that the slag was in fact layers of lead metal and of a mixture of copper and antimony, may be evidence of a 'drossing' step taking place previous to cupellation. In drossing, the lead metal is melted, and due to the low solubility of the other metallic impurities in molten lead and their lower specific gravity they float to the surface from where they can be removed. This will produce a more refined, silver-rich, lead which can then be cupelled. This process is perhaps the origin of the small droplets of silver-rich metallic lead recovered by excavation.

Cupellation took place in conical cupels with an average diameter of 12 cm. Although the best material for the manufacture of cupels and cupellation hearths is according to Percy (1870: 178) bone ash, this was not used in the preparation of the cupels from Monte Romero: XRF analysis of the cupels did not detect any phosphorus. The products would be silver, which is not found in the site and litharge, the lead oxide. The cupels found at Monte Romero are completely saturated in litharge. The fact that we find lead that does not contain much silver indicates that the litharge was reduced in a separate step to produce metallic lead.

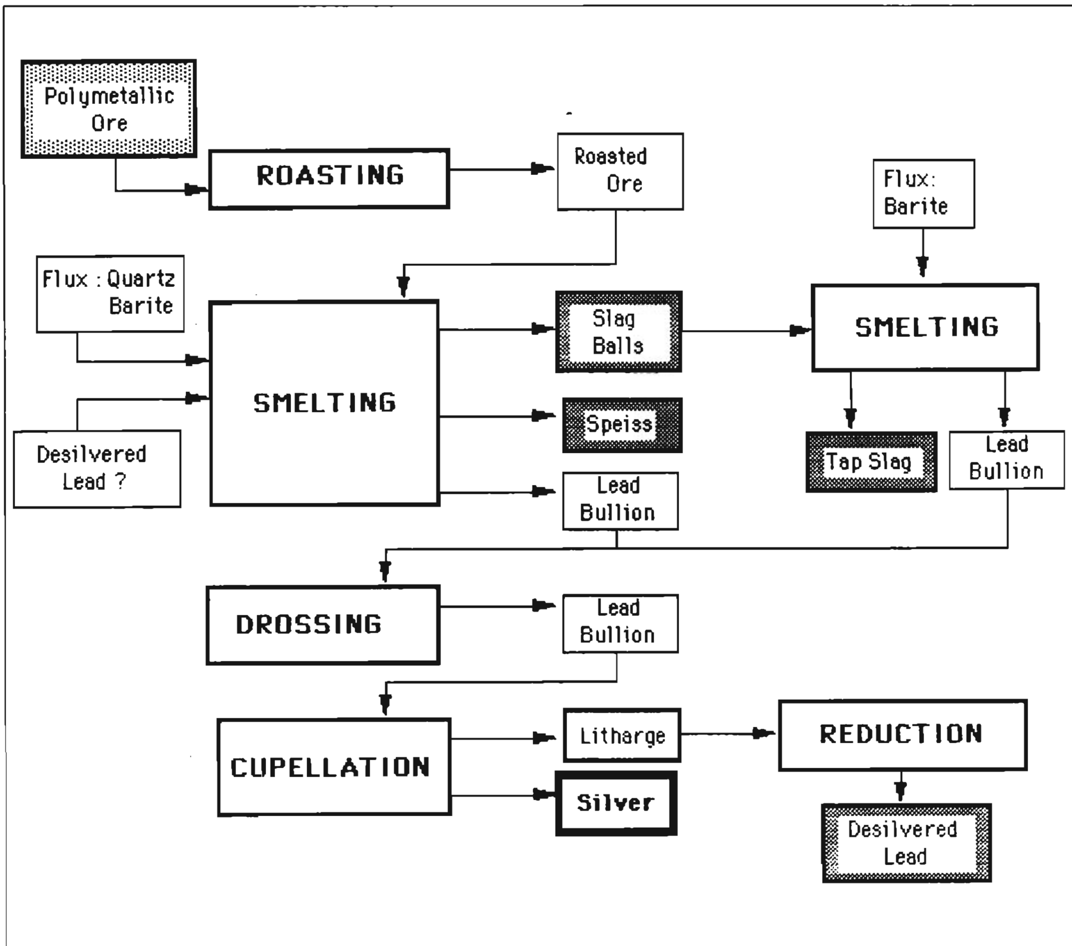

Fig. 4 Flow chart for suggested process model

It is possible that the lead would perhaps have been thrown back into the smelting furnace where it would act as a collector of the silver from the polymetallic ore.

Conclusions

The model proposed for the Monte Romero finds may seem rather complex for such a relatively early period. Nevertheless, it does agree best with the archaeometallurgical finds from the site.

This fairly sophisticated process, shows that the people working in the 7th century B.C. workshop of Monte Romero were competent metallurgists who were able to process even this type of complex ore to produce silver.

The site of Monte Romero offered a unique opportunity to investigate a silver workshop of this period. Unlike other workshops that have been excavated, such as that at San Bartolomé de Almonte (Ruiz Mata and Fernández Jurado 1986) it is located in close proximity to the mine, and shows all the different steps of the process, from beneficiation of the ore to cupellation. Also, unlike larger sites such as Rio Tinto, it was occupied for a single period, avoiding any problems of mixing finds belonging to processes of different periods.

Notes

1. Translated by C.H. Oldfather. The Loeb Classical Library. London: William Heinemann Ltd.

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