MACRO-REGIONAL SCALE OF SILVER PRODUCTION IN IBERIA DURING THE 1^{ST} MILLENNIUM BC. IN THE CONTEXT OF MEDITERRANEAN CONTACTS.

Mercedes Murillo-Barroso
CCHS-CSIC
C/Albasanz, 26-28
28037, Madrid.
mercedes.murillo@cchs.csic.es

Ignacio Montero-Ruiz
CCHS-CSIC
C/Albasanz, 26-28
28037, Madrid.
ignacio.montero@cchs.csic.es

Nuria Rafel
Universidad de Lleida
Pl. Víctor Siurana, 1
25003, Lleida
nrafel@historia.udl.es

Mark A. Hunt Ortiz
Universidad de Sevilla
C/ María Padilla s/n
41013, Sevilla
mhunt@us.es

Xosé-Lois Armada
Incipit-CSIC
San Roque 2
15704, Santiago de Compostela
loisarmada@yahoo.es

INTRODUCTION

Noble metals have traditionally been considered as markers of prestige and inequality and therefore, its exploitation susceptible to be driven and controlled by elites. Historical sources recurrently point out abundant silver resources as a cause or incentive for the Phoenicians' expansion throughout the Mediterranean and especially their arrival and settlement in Iberia (Fig. 1). Diodorus Siculus' (V, 35, 1; Warmington, 1970) statement of Iberian silver mines being "the most abundant and most excellent known sources of silver" is well known. But more appealing he also uttered that "the natives were ignorant of the use of the silver, and the Phoenicians, as they pursued their commercial enterprises and learned of what had taken place, purchased the silver in exchange for other wares of little if any worth. And this was the reason why the Phoenicians, as they transported this silver to Greece and Asia and to all other peoples, acquired great wealth" (Diodorus Siculus, V, 35, 4; Warmington, 1970). Archaeological evidence of Phoenician trade in the Iberian Atlantic and Mediterranean coasts between the 9th and the 6th centuries BC is conspicuous (Sherratt & Sherratt 1993, Neville 2007, Dietler & López-Ruiz, 2009) although the specific routes and articulation of these networks are still to be addressed. Local communities would have received oil, wine, food products, crockery, textiles, etc. in exchange for their products, what would have contributed to the display of power by local elites, to their consolidation and to the production of surpluses to support this trade (Rafel et al. 2010: 176). Therefore, their exposure to an external factor such as the Phoenicians and the way in which they interacted with them is of crucial importance to understand the processes of social change operating in the Mediterranean during the Early Iron Age. Although social changes observed in local communities are ultimately the result of their internal development, relations and contradictions, external factors such as the Phoenicians colonization are unavoidable when studying the case of Southern Iberia during the 1st Millennium BC.

We are aware of the magnitude and complexity of colonial studies; addressing all the aspects of colonial contacts in Iberia is far beyond the scope of this paper. Our focus is to delve in the study of Iberian silver production, mainly of the Southwest, in the context of colonial contacts. Therefore, our aim is not to redraw our understanding of colonial contexts but to present an analysis of the broad silver production system to rethink some aspects of Iberian hybrid colonial contexts. In this sense we will keep the traditional classification of ‘indigenous LBA/EIA sites’ —characterized for a previous occupation, disperse population, rounded dwellings or huts and poor urbanism— or ‘Phoenicians foundations’ —new settlements with more concentrated population and developed urbanism— (Fig. 1) being aware that this is an extremely normative classification which do not consider the dynamic and hybrid characteristic of many of these contexts.

All the archaeological evidence of silver production available from Southwestern Iberia is reviewed in the light of last lead isotopic information. Based on provenance study developed by Lead Isotope Analysis (now on LIA) of silver production debris, objects and minerals, we propose a macro-regional production system of silver embracing the South, East and Northeast of Iberia.

ARCHAEOLOGICAL EVIDENCE

During the Late Bronze Age/Early Iron Age silver production in Iberia suffered substantial transformations which should be related with the Mediterranean contacts, especially the Phoenicians. On the one hand a new technology is developed. During the Early/Middle Bronze Age, a large amount of silver objects is documented in Iberia, especially in the Southeast (assessing 792 items, Murillo-Barroso 2013: 233) however, silver is exclusively extracted by melting native silver and smelting silver chlorides (Murillo-Barroso 2013, Bartelheim et al. 2012). During the Late Bronze Age/Early Iron Age, happening to meet the first Mediterranean contacts, this scenario changes and a new complex silver extractive technology is developed: cupellation.

This technology does not seem to follow the path of neither the silver nor the copper-based Iberian metallurgy –quite rudimentary, straightforward, open-air metallurgy without the addition of any flux (Murillo-Barroso & Montero-Ruiz 2012, Renzi et al. 2012, Rovira 2002). Moreover, the argentiferous raw materials exploited in the

Iberian Southwest (argentiferous jarosite) implied an added difficulty to the inherent complexity of the cupellation process.

Cupellation is a two-steps process: smelting of argentiferous ore using lead as a collector of noble metals, and cupellation of silver-lead buillon. Minerals can be roasted before being smelted to partially convert lead sulphide into lead oxide, as proposed at Laurion (Conophagos, 1989), adding one step more to the cupellation process, but in Antiquity it is generally a two-steps process. Smelting is carried out in furnaces under reducing atmosphere. In this step, the presence of lead is crucial as silver is more soluble in lead than other metals (for example copper). Therefore, lead will extract silver from other impurities which will pass to the slag. If argentiferous lead minerals are being used as the primary ore, lead is already present in the mineral, however, if the argentiferous minerals have low lead content, it has to be added in the smelting process to 'collect' the silver. As a result, a silver-lead bouillon and some slag are produced (Bachmann, 1993: 489). Due to the higher density of the bouillon, it will be placed on the bottom of the furnace with the slag 'flowing' over it. Once the bouillon is recovered, it has to be de-silvered in a second step: the cupellation. This process consists on oxidize the lead in a cupel[1] under high temperatures and an oxidising atmosphere. More lead is added as a reagent in the cupellation process and as a result, a mass of litharge (where PbO is the main component) is obtained. Silver and gold collected previously by lead, as noble metals, will not be oxidised and will remain at the bottom of the cupellation vessel. This process of silver refining will be carried out several times to achieve 99% pure silver, as documented in the archaeological context.

Consequently, lead constitutes an essential element in silver extraction and it will have a decisive impact in the organization of silver production in Iberia. As we have stated, most of silver by-products are concentrated in the Iberian Southwest where silver is being extracted from argentiferous jarosite. Jarosite is a complex ferric sulphate whose composition is quite variable, with silver levels between 0.02%-0.31% with exceptions up to 0.7% Hunt Ortiz, 2003: 208) and lead levels between 0.01% and 8.9% with exceptions up to 47,9% Pb (for a compilation of composition analyses of jarosite from the Iberian SW see: Murillo-Barroso, 2013: 195-197). Despite having some lead-rich samples, in most areas of the Pyritic Belt, argentiferous jarosite is deficient in lead and hence it had to be added to act as a collector (Hunt 2003: 392). Thus, lead becomes a decisive resource for the extraction of silver; as essential as the argentiferous ore itself.

Given the rudimentary and straightforward nature of Iberian metallurgy in the Bronze Age, it seems unlikely that the Iberian metallurgists progressed unaided to extracting silver from jarosite, the source of which differs greatly from those of the native silver and silver chlorides that were in use. It also differs from the main raw materials employed in most of Europe and the Mediterranean (argentiferous lead sulphates or carbonates) (Meyers 2003). Nonetheless, silver extraction from complex jarosite was known in the Mediterranean: jarosites were exploited in Cyprus (Tylecote 1987, 88; Hunt 1987, 149) and silver was extracted from complex argentiferous lead and antimony sulphosalts in Siphnos (Wagner et al. 1980; Pernicka et al. 1985). This experience, coupled with the fact that the first actual evidence of cupellation (i.e. cupellation hearth materials) appears in archaeological contexts where Phoenician remains are also present (Hunt 2003; 2005; Renzi et al. 2012), leads one to suggest that this knowledge was transmitted by metallurgists originating from further east.

Furthermore, silver technology is modified not only qualitatively but also quantitatively, especially in the Iberian Southwest. Some assessment has been made of the slag production volume in the Southwest: traditionally, the estimated figure is of 16,310,250 metric tonnes of slag (mainly silver but also copper slag) at Rio Tinto (cf. Rothenberg et al. 1989, 58). With regard to silver debris of the Tartessian period it has been estimated in 4 (Fernández Jurado & Ruiz Mata 1985: 24) or 6 (Rothenberg et al. 1989: 66) million metric tons of slag. Even if these assessments are over quantified, the fact is that this is the time when we find slag and debris heaps for the first time: in Rio Tinto orientalising (seventh–fifth centuries BC) silver slag levels are more than one metre thick (Rothenberg et al. 1989: 62), in Aznalcóllar mine zone only in the Northeast area of the site of Castrejones more than 50 kilos of slag were recovered (Hunt 2003: 202) and ‘hundreds of kilos’ of litharge were recovered in one room in El Castillo de Doña Blanca site (Ruiz Mata 1989: 237). This is also the first time that trade of silver by-products (mainly litharge) is documented, being the shipwreck of Mazarrón the best example (Negueruela et al. 2004). That amount of silver debris indicates a significant intensification of silver production. Silver by-products, which were completely absent from the archaeological record during the Bronze Age, are now conspicuous (Table 1). They are mainly concentrated in the Southwestern Iberia, in archaeological contexts where the indigenous materials are abundant (Fig. 2). However, as we will see bellow, the silver production system cannot be restricted to the Southwest nor the indigenous communities, as its scale increased to limits hitherto unknown.

Nevertheless, this significant increase of metallurgical remains contrast with the scarcity of silver objects in the archaeological record. Only 95 silver objects have been recovered dating between 9th-6th century BC, with an estimated weight of 1365g. This disparity is evident not only when comparing to earlier periods (792 objects figuring 2730g in the Bronze Age) but also when comparing to other metals such as gold (Fig. 3). Only the gold Carambolo treasure features more than double that all silver as once: 2950g (Murillo-Barroso, 2013: 257-260). The idea that Phoenicians strengthen the extraction of silver to meet the demand of silver of the oriental settlements does not seem too unreasonable in the light of the evidence (Sherratt & Sherratt 1993, Frankenstein 1997).

We will now address the way in which this production system was organized in Iberia from a broad perspective. As it is known that lead had to be brought to the south-west in order to extract the silver, an attempt will be made to determine its provenance. We will try to review all the evidence of silver extraction in the south-west within a wide-ranging perspective: one which embraces all of Iberia in an extended system of silver production.

METHODOLOGY

To assess the organization of metal production, we have a useful tool such as the Lead Isotope Analysis (LIA) which can provide provenance adscription of archaeological remains. The analysis is based on the proportions of the four lead stable isotopes in each mineral deposit: 204Pb, 206Pb, 207Pb and 208Pb. The basis of this analysis have been broadly explained elsewhere (Hunt 2003, Stos-Gale & Gale 2009, Santos Zaldegui et al. 2004) and we will not discuss them; we will just stress the fact that once the mineral is deposited, its isotopic composition will not be modify in further metallurgical processes becoming its ‘fingerprint’. Hence, by comparing the isotopic composition of archaeological and geological samples, we can assess the provenance of archaeological items.

There is, however, one aspect that we have to be careful with when dealing with archaeological materials: re-melting and recycling metals can modify its isotopic proportions. In our case study, lead was, in some cases, added to Southwestern argentiferous ores and therefore the isotopic proportions of archaeological remains will not be that of the Southwestern ores neither that of the lead added but a mixture of both. This fact makes it difficult but not impossible to source some objects. When only two different ores are involved, the value will be aligned between those of the two ores in question on the graph, as we will see below. But if metals are systematically and repeatedly recycled, then the accentuated distortion of their isotopic signature would probably make it impossible to determine their provenance(s).

In this paper, we will review the results of 113 LIA of silver production debris from the south-west published to date (see Table 1). We also present the analyses of 18 silver objects (Table 2). Those analyses collected from the literature were conducted by TIMS, whilst the results that we present here were conducted by MC-ICP-MS (see Klein et al. 2009 for methodological questions). The results of the two techniques are comparable (Baker et al. 2006).

With regard to the geological samples, some 700 LIA of the main lead-mining districts of the Iberian Peninsula are available: these clearly differentiate the Pyrite Belt, the Ossa-Morena and Central zones, the south-east (Murcia and Almeria provinces), Linares and Catalonia (most data are available in Oxalid; references included in Gener et al. 2014, 159).

RESULTS

As we have stated, the main problem with these materials is not the lack of samples but the practice of mixing different minerals which will alter the isotopic signature of the samples analysed. To begin with, we will analyse all the production debris and briefly discuss the isotopic signature of the final objects later on. Provenances of production debris identified are as follow.

a) The Pyritic Belt.

Cupellation hearth materials from the city of Huelva, free silica slag from Rio Tinto (Huelva) or litharge from Castillo de Aznalcóllar (Seville) or Castillo de Doña Blanca (Cádiz) match with the isotopic field of the Pyritic Belt, clearly showing the exploitation of these resources (Hunt 2003, Anguilano et al. 2010) not only by the amount of silver debris in this area, as shown in Fig. 2, but also by their isotopic concordance (Fig. 4). However, these are not the only sources documented.

b) Linares.

Lead from Linares (Jaén) is probably being imported to the Southwest, as free silica slag from Los Castrejones, El Carambolo (Seville), El Castillo de Doña Blanca (Cádiz) and Peñalosa (Huelva) match with the isotopic field of Linares in all axes. Other samples of slag from San Bartolomé, Rio Tinto, Peñalosa and Tejada la Vieja (Huelva) fall between the isotopic fields of Linares and the Pyritic Belt in all axes, what could represent a mixture between both ores (Fig. 4).

c) Molar- Bellmunt-Falset (MBF) mining district, Catalonia.

The addition of lead from MBF can also be suggested by some slag from Tejada la Vieja, Corta Lago (Huelva) and Cortijo de José Fernández (Sevilla), although slag from Corta Lago are peripheral in some axes (Fig.5). Indirect proof of mining works in MBF during the 7th century BC is given by lead production debris found in the site of El Calvari which have an isotopic concordance with MBF mining district (Montero-Ruiz et al. 2010).

d) Azuaga.

Three samples from San Bartolomé match in all axes with Azuaga lead mines in the North Eastern metallogenic belt of Ossa Morena (Fig. 6).

e) The Southeast (Cartagena/Mazarrón and Gádor).

Southwestern ores (mainly Cartagena, Mazarrón and Gádor) also played an important role in silver extraction.

Gádor's isotopic signature, which has already been identify in cupellation hearth materials from La Fonteta, Alicante (Renzi et al. 2009), is also observed in the Southwest. Lead from Gádor can clearly be identified by one non-argentiferous galena found in the city of Huelva. Moreover, two slag samples from Huelva fall between the isotopic fields of Gádor and the Pyritic Belt in all axes and one sample of cupellation hearth material is plot in the isotopic field of the Pyritic Belt (Fig. 6). Nonetheless, Huelva constitutes an example of lead being added only when needed: on the one hand argentiferous lead rich ores have been documented (up to 50-70% Pb, Fernández Jurado 1988-1989: 190), and the cupellation hearth which matches in all axes with the Pyritic Belt isotopic field indicates that ores were not mixed up. But on the other hand, one non-argentiferous galena found in Huelva comes from Gádor being a clear evidence of lead imports. The two slag samples which fall in an area between Gádor and the Pyritic Belt could therefore be a result of the mixture. In an earlier approach to these samples, it was proposed that the only isotopic fields compatible with these slag were Pranu and Sa Marchesa in Sardinia, as their isotopic fields are plotted between Gádor and the Pyritic Belt (Hunt 2003: 256). As we now know that the galena found in Huelva comes from Gádor, it seems more probable that these slags which fall between Gádor and the Pyritic Belt are in fact a mixture of these two ores instead of having a Sardinian provenance, although this latter option cannot be completely rejected.

One lead drop and one lead trapezium from El Carambolo recently analysed could also fit into Gador's isotopic field although one of them is slightly peripheral and the metallogenic belt of Olivenza-Monesterio Belt (OMB) in Ossa Morena cannot be discarded either (Hunt et al. 2010). However, being Fe-Cu the main mineralization of OMB (Tornos et al. 2004: 145), Gádor, whose galena is not argentiferous, seems to be a more probable provenance.

Lead drops from La Rebanadilla (Málaga) and El Cómico (Cádiz), which are currently under study, also match with Gádor isotopic field in all axes, what shows the significance of this mining district during the Early Iron Age.

Slag and litharge from Corta Lago (Rio Tinto) align in all axes between the isotopic fields of the Pyritic Belt and Cartagena/Mazarrón (Anguliano et al. 2010). This evidences the addition of lead (or the reuse of litharge) from Murcia to extract the silver of the Southwestern ores and constitutes a clear example of the samples' alignment as a consequence of the mixture of two ores (Fig. 7). Three Roman lead ingots found in the same site with the inscription *Carthago Nova* on them and identical provenance shows the continuity in the imports of Southeastern lead for the extraction of silver from the jarositas of the Pyritic Belt in Roman times (Anguilano et al. 2010). Furthermore, litharge found in the Mazarrón shipwreck also confirms the exploitation of Cartagena/Mazarrón ores as they match with their isotopic fields (Renzi et al. 2009).

f) Indeterminate Provenance.

Monte Romero's materials also show a clear alignment indicating the addition of foreign lead to the Pyritic Belt ores, although the origin of this second ore cannot be identified yet (Fig. 5). Moreover, there are still some litharge from Castillo de Doña Blanca and Rio Tinto or slag from Peñalosa, Cerro de las Tres Águilas or San Bartolomé de Almonte for whom a possible provenance cannot be proposed yet either because the mixture of ores have been more intense and have completely alter their isotopic signatures, either because they have been mixed with ores from mining districts still to be isotopically characterized.

Thus, we can assess the provenance of 60 per cent of the samples with high probability (isotopic concordance in all bivariate diagrams). The other 40 per cent may correspond to some mixtures difficult now to read: regardless of their specific provenance, they do show the addition of imported lead. All these analyses show, in fact, that the use of exogenous lead was a dominant feature: only 38 per cent of the samples analysed show a match with the isotopic field of the Pyrite Belt. When lead is added, its most common origin is the south-east (Gádor, Cartagena and Mazarrón), although others such as Linares and Catalonia have also been detected (Table 3).

As regards the silver objects, artefacts from Catalonia, Alicante, Toledo, Sevilla, Cáceres and the Mediterranean coast (Laurita, Cerro del Villar, Toscanos, La Rebanadilla and Jardín) have been analysed (Fig. 8). Most of them have an 'oriental-style' decoration: rings with scarabs, Egyptian hieroglyphs and amulet-containers raise the possibility of their being imported. Their specific provenance is hard to establish as the silver, in its extraction, has gone through several phases where lead (which can be from different provenances) was added: namely, during the smelting of jarosites and in the successive steps of cupellation and refining.

Moreover, silver itself can be reused and recycled, so altering its isotopic signature further. However, some observations can be made. There are only two objects which match in all their axes with a known isotopic field: one ring from La Rebanadilla (Málaga) and another from LaAyuela (Cáceres) lie within the isotopic field of Linares. Another ring from Laurita (Granada) also falls in all axes in the isotopic field of MBF (Fig. 9).

However, what draws one's attention is that all the silver samples are aligned between the isotopic isotopic fields of Cartagena/Mazarrón and Linares/Gádor/MBF. They sit between the main sources of lead already identified in silver by-products: so even if their isotopic signatures have been 'distorted' and their decoration is of 'oriental-style', these objects were most probably produced from Iberian materials. It is also the case that even if they were from south-west silver ores, their isotopic signature will be that of the lead (or the mixture of lead ores) added in their manufacture. It will not be that of the south-west argentiferous ore itself. There is only one sample, a decorated vessel from Casa del Carpio, which diverges from the alignment of all the others: this could have a foreign origin, as has already been proposed on the basis of its production techniques (Pereira 2005). Another bronze vessel of a characteristic central-east Mediterranean type was found in this burial (Armada 2006–7), thus reinforcing the idea of a foreign 'princess' buried in a native context (Ruiz-Gálvez 1992). Another example of foreign silver, possibly coming from the eastern Mediterranean, is the necklace from the Iron Age hoard found in the Palacio III megalithic complex. In this hoard, local as well as northern European to eastern and western Mediterranean raw materials were found together in a reused megalithic structure showing the hybrid character of these colonial societies (Murillo-Barroso et al. 2015).

DISCUSSION

In this paper, we have tried to evaluate through provenance analysis all classes of archaeological evidence for silver production, and especially that of south-west Iberia, in order to consider the system of silver production from a broad perspective. As mentioned above, the first issue which stands out is the disparity between the large volume of accumulated production debris and the small number of finished silver objects documented in the archaeological record. The intensification of silver production does not seem to have had a direct impact on the appearance of silver objects on Iberian sites: these remain proportionately few. According to Rovira's estimations (1995), for the extraction of 1 kg of silver from the jarosite minerals of the Pyrite Belt, 2 tons of ore would have been needed. We have quantified 1365 g of silver, so if Rovira's estimations are correct, less than 3 tons of ore would have been enough. However, silver slag has been estimated in the south-west at several million tons: even if this is an overestimate, it is far beyond that needed to produce 1 kg of silver. The above-mentioned abundance of gold indicates that the shortage of silver is not connected with any archaeological circumstances surrounding their recovery, but rather reflects a situation in which the intensification of silver production did not translate into silver accumulation on the part of the Iberian population. In the Early Iron Age, gold continued to be, as in the Late Bronze Age, the main metal of prestige amongst the elites of west Iberia (Perea 2005). These facts may support the idea that the Phoenician settlers' interest lay in obtaining Iberian metals, especially silver, for export to the eastern metropolis (Frankenstein 1997; Aubet 2009).

The organization of production that we observe seems to correspond well to one based on some degree of planning and conducted on a macro-regional scale. On the one hand, intensive mining works are detected in the Pyrite Belt area: this leads to the concentration of most of the silver production debris in contexts in which indigenous elements are abundant but Phoenician remains are always present (Hunt 2003; 2005; Fernández Jurado 1995; Renzi *et al.* 2012), especially so when the

Phoenician presence in Huelva is documented, i.e. from the late tenth to the mid-ninth centuries BC (González de Canales *et al*. 2006; Nijboer and van der Plicht 2008). It is in these contexts that cupellation is clearly documented in Iberia for the first time. The exact timing of its appearance is irrelevant in itself from a socioeconomic point of view: it must be framed within a broader context. Thus, even if cupellation were to have been an indigenous innovation and not acquired from the Phoenicians, it had remained at a low level of utilization within the domestic sphere until the first millennium, when the Phoenicians are clearly settling in Iberia. Only then do we observe a significant intensification of silver production as evidenced by the abundance of documented metallurgical debris, slag heaps or storage of and trade in silver by-products. Indeed, this trade in silver debris can also be considered as evidence of a concern to optimize the production rates. This increase in silver production also fits with a recent palaeo-environmental study: it has demonstrated a substantial increase in metallurgical activities in the south-east during the Early Iron Age (García-Alix *et al*. 2013, 454) from the augmented levels of lead pollution. It is, moreover, at this time that we witness an expansion of the scale of production to territorial limits hitherto unknown in the Iberian Peninsula. The need to import foreign lead to the south-west for the extraction of silver has already been proposed by others, who have observed the low lead content of some of the minerals of the Pyrite Belt (Craddock 1995, 216–21; Hunt 2003). Lead Isotope Analysis permits the identification of a number of likely sources for that exogenous lead, expanding the scale of silver production to embrace almost the entire south and east of Iberia. The control and distribution of this lead would have played an important role in the organization of silver production, as it became a strategic resource for silver extraction. Although most of the evidence of silver by-products is concentrated in the south-west of Iberia, mainly in contexts where indigenous sites are predominant, yet the distribution of and trade in lead seem to have been controlled by the Phoenicians – either as minerals such as the galena from Gádor found in Huelva, or as litharge cakes, such as those carried in the shipwreck of Mazarrón (Negueruela *et al*. 2004) or accumulated at the site of Castillo de Doña Blanca (Ruiz Mata 1989). In this way, the Phoenicians could exert indirect control on the production of silver. This is probably what Diodorus Siculus (V, 35, 4; Warmington 1970) referred to in his metaphor on the

Phoenicians' exchange in Iberia: '[. . .] they would hammer the lead off the anchors and have the silver perform the service of the lead'.

The production system was structured in such a way that the lead needed for the extraction of silver in the south-west was imported from the mining areas of Ossa Morena, the south-east, Linares and Catalonia. Both the intensification of silver mining and especially the organization of silver production on such large scales would have demanded planning; they would also have required financial support from either the state or a powerful and organized sector in society capable of setting up a widespread network to facilitate the production system.

In the construction of these trade networks, various products, not only silver or lead, were involved. The specific paths followed in the distribution of these elements and how they combine are still to be established. A comprehension of the kind of relationship/dependency between those Phoenician coastal sites that achieved the supply of lead and forged the creation of the macro-territorial system of production is essential to understanding the system's success,both as a whole and as a trade network comprising both coastal and inland settlements. In order to facilitate the importation of lead to the south-west, the Guadalquivir River could have acted as a routeway from Linares, and also from Azuaga via its tributary the Bembezar River, while maritime routes could have ensured the arrival of lead from Gádor, Cartagena/Mazarrón and MBF (Fig. 10). The site of Castulo, close to the Linares mining district, probably played an important role in the lead exploitation of Linares. Copper from Linares has also been identified in the MBF area and at other Mediterranean sites (Montero-Ruiz *et al*. 2012); thus, lead from MBF could have reached the south-west through their contacts with Linares.

These networks and the trade they facilitated also had an impact on the north-east communities. The origins of the sites of Puig Roig and Calvari del Molar, located close to important copper and lead mines, date back to the mid-tenth and the beginning of the eighth centuries BC. In their earliest phases, these two settlements coexisted with other small sites dispersed throughout the region. In the seventh century BC, the first evidence of lead smelting at these two sites is detected, as well as a process of nucleation that was arranged so as better to control and reinforce the exploitation of this mining district (Armada *et al*. 2013). The fact, then, that lead from MBF was not locally distributed in the north-east but was channelled to south Iberia is extremely revealing. It may well be no coincidence that the beginnings/consolidation of the exploitation of the lead is contemporary with Phoenician commercial expansion (Rafel 2011–12). It is also surely significant that the abandonment of these sites in the second half of the sixth century BC coincides with the crisis in Phoenician trade in the region. The extensive production in the south-west linked to the exploitation of jarosite contrasts with another method of extracting silver from argentiferous galena, which is documented in the south-east and Ibiza (Ramón *et al*. 2011). This last system, more self-sufficient as 'outside' lead is not needed, did not generate as great an impact as did that of the south-west. The one exception would be La Fonteta, where galena from Gádor was imported to handle the lead required in the process of extracting silver from argentiferous copper minerals (Renzi *et al*. 2009; 2012).

This environment and the manner in which the Iberian silver production was conducted for the primary benefit of the eastern partner seem consistent with that behaviour proposed in contacts between indigenous communities and the Phoenicians under colonial circumstances: the unequal exchange acts as a means of transferring wealth from one social structure to another (Wagner 1995; 2013). In this context, two different societies (a domestic one with incipient social stratification and a mercantile one with a developed State) come into collision: the native set-up is maintained, but for the most part acts to the benefit of the mercantile system and its colonial interests (Wagner 2013).

In the case of silver production, the Phoenicians would have organized, through the emerging local elites (who become to some extent dependent on the colonizers), the native labour force required for mining and smelting. This set-up would have allowed the emerging elites to exploit the trade and the connections with the settlers in order to maintain a position of power and prestige within their indigenous communities. To that extent, then, this local development of stratification should

therefore be integrated into the broader context of the commercial expansion of the Phoenicians: the natives, to some extent socially stratified and with some control over the links behind the commercial networks, would have been cultivated by the Phoenicians, who were able to guarantee the desired flow of exchanges (Vives-Ferrándiz Sánchez 2008, 115). Their control over redistribution would also have favoured the Phoenicians, as they were able to mobilize the workforce they demanded (Wagner 1995). These colonial encounters are to be understood as the facilitators of internal socioeconomic developments (Aubet 2005, 118; Ruiz-Gálvez 2005, 252). However, it might have been easier for the colonizers to co-opt the local emerging elites and to subsume their pre-existing trade networks and their political organization systems into their own rather than having to forge their own from scratch.
As already stated by Aubet (2006), this production system would have required considerable infrastructure (in terms of maritime and inland trade networks to ensure continuous flows of the metals), as well as sophisticated and extensive organization for the mining activities, the smelting and cupellation operations, and the transport of silver ingots to the coast. It implies supervision and specialized administration at each stage of the process, as well as pacts or agreements with the local elites: mechanisms of emulation by the indigenous elites could have played an important role in their consolidation (Gilman 1993). Such an administrative structure as well as the scope of this trade would have implied the direct involvement of the political institutions of Tyre (Aubet 2006, 106; Armada *et al*. 2008).

However, in order to confirm the proposed hypothesis – that of a transfer of silver to the eastern sites, isotopic matches between silver objects made in the east and the Iberian mineral deposits are needed. Stos-Gale (2001) raised the possibility in her study of hack silver, but the materials available had no precise dates attached to them and so their noted correspondence with the south-west silver ores could be later (e.g. second century BC). At present, only one Greek silver drachma from Miletus dated to around 500 BC (Desaulty *et al*. 2011) offers a possible match with the Linares source. Given the possibility that the silver had been extensively recycled, finding this isotopic concordance may no longer be retrievable. However, the attempt is yet to be made.

Acknowledgements

This research has been carried out as part of the R & D projects 'Links between local resources and metallurgical production: Southern Catalonia as a contrasting model' (HAR2010-21105-C02-02) and 'Social, technological and economic processes of mineral extraction in El Priorat (Catalonia): a diachronic perspective'(HAR2010-21105-C02-01) funded by the Spanish Ministry of Economy and Competitiveness. It has also been supported by a Marie Curie Intra European Fellowship within the 7th European Community Framework Programme ('Society, Metallurgy and Innovation: The Iberian Hypothesis' SMITH project, PN623183).

REFERENCES

ANGUILANO, L., REHREN, TH., MÜLLER, W. and ROTHENBERG, B. 2010: The importance of lead in the silver production at Riotinto (Spain). *Archaeosciences. Revue d'Archéométrie* 34, 269–76.

ARMADA, X.L. 2006–7: Vasos de bronce de momentos precoloniales en la Península Ibérica: algunas reflexiones. *Revista d'Arqueologia de Ponent* 16–17, 270–80.

ARMADA, X.L., RAFEL, N. and MONTERO-RUIZ, I. 2008: Contactos Precoloniales, Actividad Metalúrgica y Biografías de Objetos de Bronce en la Península Ibérica. In CELESTINO, S., RAFEL, N. and ARMADA, X.-L. (eds.), *Contacto Cultural entre el Mediterráneo y el Atlántico (siglos XII–VIII ane) La precolonización a debate* (Madrid, CSIC), 465–508.

ARMADA, X.-L., RAFEL, N., GRAELLS, R. and ROQUÉ, R. 2013: Orígenes del urbanismo y dinámicas sociales en el Bronce Final de Cataluña meridional: El Avenc del Primo (Bellmunt del Priorat, Tarragona). *Trabajos de Prehistoria* 70(2), 278–94.

AUBET, M.E. 2005: El 'orientalizante': un fenómeno de contacto entre sociedades desiguales. In CELESTINO, S. and JIMÉNEZ, J. (eds.), *El Periodo Orientalizante, Vol. I* (Mérida, CSIC, Anejos de AespA XXXV), 117–28.

AUBET, M.E. 2006: On the organization of the Phoenician colonial system in Iberia. In RIVA, C. and VELLA, N.C. (eds.), *Debating Orientalization. Multidisciplinary Approaches to Change in the Ancient Mediterranean* (London–Oakville, Monographs in Mediterranean Archaeology 10), 94–109.

AUBET, M.E. 2009: *Tiro y las colonias fenicias de Occidente. Tercera edición actualizada y ampliada* (Barcelona).

BACHMANN, H.G. 1993: The archaeometallurgy of silver. In FRANCOVICH, R. (ed.), *Archeologia delle Activittrí Estrattive e Metallurgiche* (Firenze), 487–97.

BAKER, J., STOS, S. and WAIGHT, T. 2006: Lead Isotope Analysis of archaeological metals by Multiple-Collector Inductively Coupled Plasma Mass Spectrometry. *Archaeometry* 48(1), 45–56.

BARTELHEIM, M., CONTRERAS, F., MORENO, A., MURILLO-BARROSO, M. and PERNICKA, E. 2012: The silver of the south Iberian El Argar Culture: a first look into production and distribution. *Trabajos de Prehistoria* 69(2), 293–309.

BLANCO, A. and ROTHENBERG, B. 1981: *Exploración Arqueometalúrgica de Huelva (EAH)* (Barcelona).

CONOPHAGOS, C.E. 1989: La technique de la coupellation des Grecs anciens au Laurium. In MANIATIS, Y. (ed.), *Archaeometry. Proceedings of the 25th Symposium* (Amsterdam), 271–89.

CRADDOCK, P.T. 1995: *Early Metal Mining and Production* (London).

DESAULTY, A.-M., TELOUKA, PH., ALBALATA, E. and ALBARÈDEA, F. 2011: Isotopic Ag–Cu–Pb record of silver circulation through 16th–18th century Spain. *Proceedings of the National Academy of Sciences* 108, 9002–7.

DIETLER, M. and LÓPEZ-RUIZ, C. (eds.) 2009: *Colonial Encounters in Ancient Iberia: Phoenician, Greek, and Indigenous Relations* (Chicago).

DOMERGUE, C. 1987: *Catálogo de minas y fundiciones antiguas de la Península Ibérica* (Madrid).

FERNÁNDEZ JURADO, J. 1987: *Tejada la Vieja: Una ciudad protohistórica* (Huelva, Huelva Arqueológica IX).

FERNÁNDEZ JURADO, J. 1988–9: Aspectos de la Minería y la Metalurgia en la Protohistoria de Huelva. *Huelva Arqueológica* X–XI, 177–214.

FERNÁNDEZ JURADO, J. 1995: Economía Metalúrgica de Tartessos. In *Tartessos 25 años después 1968–1993* (Jerez de la Frontera, Biblioteca de Urbanismo y Cultura), 411–16.

FERNÁNDEZ JURADO, J. and RUIZ MATA, D. 1985: La metalurgia de la plata en época tartésica. *Pyrenae* 21, 23–44.

FERNÁNDEZ JURADO, J., GARCÍA SANZ, C. and RUFETE, P. 1992: Prospección con sondeo en Peñalosa (Escacena, Huelva). In *Anuario Arqueológico de Andalucía 1990, Vol. II* (Sevilla), 185–90.

FRANKENSTEIN, S. 1997: *Arqueología del colonialismo* (Barcelona).

GARCÍA-ALIX, A., JIMENEZ-ESPEJO, F.J., LOZANO, J.A., JIMÉNEZ-MORENO, G., MARTINEZ-RUIZ, F., GARCÍA, L., ARANDA JIMÉNEZ, G., GARCÍA, E., RUIZ-PUERTAS, G. and SCOTT, R. 2013: Anthropogenic impact and lead pollution throughout the Holocene in southern Iberia. *Science of the Total Environment* 449, 451–60.

GENER, M., MONTERO-RUIZ, I., MURILLO-BARROSO, M., MANZANO, E. and VALLEJO, A. 2014: Lead provenance study in medieval metallic materials from Madinat al-Zahra (Medina Azahara, Córdoba). *Journal of Archaeological Science* 44, 154–63.

GILMAN, A. 1993: Cambio cultural y contacto en la Prehistoria de Europa Mediterránea. *Trabajos de Prehistoria* 50, 103–11.

GÓMEZ RAMOS, P., MONTERO-RUIZ, I. and ROVIRA LLORENS, S. 1998: Metalurgia Protohistórica extremeña en el marco del suroeste peninsular. In RODRIGUEZ DÍAZ, A. (coord.), *Extremadura Protohistórica: Paleoambiente, Economia y Poblamiento* (Cáceres, Universidad de Extremadura), 97–117.

GONZÁLEZ DE CANALES, F., SERRANO, L. and LLOMPART, J. 2004: *El emporio fenicio precolonial de Huelva, ca. 900–770 a.C.* (Madrid).

GONZÁLEZ DE CANALES, F., SERRANO, L. and LLOMPART, J. 2006: The pre-colonial Phoenician emporium of Huelva ca 900–700 BC. *Babesch* 81, 13–29.

HARDING, A. 1993: Europe and the Mediterranean in the Bronze Age: cores and peripheries. In SCARRE, C. and HEALY, F. (eds.), *Trade and Exchange in Prehistoric Europe* (Oxford), 153–60.

HUNT, M.A. 1987: La recuperación de la plata del Speiss en Río Tinto. *Huelva en su Historia* 2, 147–60.

HUNT, M.A. 2003: *Prehistoric Mining and Metallurgy in South West Iberian Peninsula* (Oxford, BAR Int. Ser. 1188).

HUNT, M.A. 2005: Plata de Tartessos: producción y dispersion. In CELESTINO, S. and JIMÉNEZ, J. (eds.), *El Periodo Orientalizante, Vol. 2* (Mérida, CSIC, Anejos de AespA XXXV), 1241–8.

HUNT, M.A., MONTERO RUIZ, I., ROVIRA, S., FERNÁNDEZ, Á. and RODRÍGUEZ, A. 2010: Estudio arqueométrico del registro de carácter metálico y metalúrgico de las campañas 2002–2005 en el yacimiento de 'El Carambolo' (Camas, Sevilla). In DE LA BANDERA, M.L. and FERRER, E. (eds.), *El Carambolo. 50 años de un tesoro* (Sevilla, Universidad de Sevilla), 271–95.

KASSIANIDOU, V. 1992: *Monte Romero (Huelva), a Silver Production Workshop of the Tartessian Period in SW Spain* (Unpublished Ph.D. Thesis, Institute of Archaeology, University College London).

KLEIN, S., DOMERGUE, C., LAHAYE, Y., BREY, G.P. and VON KAENEL, H.M. 2009: The lead and copper isotopic composition of copper ores from the Sierra Morena (Spain). *Journal of Iberian Geology* 35(1), 59–68.

KRISTIANSEN, K. 2000: *Europe Before History* (Cambridge, New Studies in Archaeology).

MEYERS, P. 2003: Production of silver in antiquity: ore types identified based upon elemental composition of ancient silver artifacts. In VAN ZELST, L. (eds.), *Patterns and Process* (Suitland–Maryland, Smithsonian Center for Materials Research and Education), 271–88.

MONTERO-RUIZ, I., RAFEL, N., ROVIRA, M.C., ARMADA, X.L., GRAELLS, R., HUNT, M., MURILLO, M., RENZI, M. and SANTOS, M. 2012: El cobre de Linares (Jaén) como elemento vinculado al comercio fenicio en el Calvari del Molar (Tarragona). *Menga. Revista de Prehistoria de Andalucía* 3, 167–86.

MURILLO-BARROSO, M. 2013: *Producción y Consumo de Plata. Un Análisis Comparativo entre la Sociedad Argárica y los Primeros Asentamientos Orientalizantes en el Sur de la Península Ibérica* (Granada, Universidad de Granada).

MURILLO-BARROSO, M. and MONTERO-RUIZ, I. 2012: Copper ornaments in the Iberian Chalcolithic. Technology versus social demand. *Journal of Mediterranean Archaeology* 25(1), 53–73.

MURILLO-BARROSO, M., MARTINÓN-TORRES, M., GARCÍA SANJUÁN, L., WHEATLEY, D., HUNT ORTIZ, M.A., FORTEZA GONZÁLEZ, M. and HERNÁNDEZ ARNEDO, M.J. 2015: New objects in old structures. The Iron Age hoard of the Palacio III megalithic funerary complex (Almadén de la Plata, Seville, Spain). *Journal of Archaeological Science* 57, 322–34.

NEGUERUELA, I., GONZÁLEZ, R., SAN CLAUDIO, M., MÉNDEZ, A., PRESA, M. and MARÍN, C. 2004: Mazarrón-2: el barco fenicio del siglo VII a.C. Campaña de noviembre 1999/marzo 2000. *Estudios Orientales* 5–6, 453–84.

NEVILLE, A. 2007: *Mountains of Silver and Rivers of Gold. The Phoenicians in Iberia* (London).

NIJBOER, A.J. and VAN DER PLICHT, H. 2008: The Iron Age in the Mediterranean: recent radiocarbon research at the University of Groningen. In BRANDHERM, D. and TRACHSEL, M. (eds.), *A New Dawn for the Dark Age? Shifting Paradigms in Mediterranean Iron Age Chronology* (Oxford, BAR Int. Ser. 1871), 103–18.

PEREA, A. 2005: Mecanismos identitarios y de construcción de poder en la transición Bronce-Hierro. *Trabajos de Prehistoria* 62(2), 91–103.

PEREIRA, J. 2005: Entre la fascinación y el rechazo: la aculturación entre las propuestas de interpretación del Periodo Orientalizante. In CELESTINO, S. and JIMÉNEZ, J. (eds.), *El Periodo Orientalizante, Vol. 1* (Mérida, CSIC, Anejos de AespA XXXV), 167–88.

PÉREZ MACÍAS, J.A. 1996: *Metalurgia extractiva Prerromana en Huelva* (Huelva, Universidad de Huelva).

PERNICKA, E. 2014: Provenance determination of archaeological metal objects. In ROBERTS, B.W. and THORNTON, C.P. (eds.), *Archaeometallurgy in Global Perspective* (New York), 239–68.

PERNICKA, E., LUTZ, C., BACHMANN, H.G., WAGNER, G.A., ELITZSCH, C. and KLEIN, E. 1985: Alte Blei-Silber- Verhuttung auf Sifnos. In WAGNER, G.A. and WEISGERBER, G. (eds.), *Silber, Blei und Gold auf Sifnos* (Bochum, Deutsches Bergbau-Museum, Der Anschnitt, Beiheft 3), 185–99.

RAFEL, N. 2011–12: La cuenca minera del Baix Priorat (Tarragona): explotación y distribución en época colonial. Recursos locales versus recursos alóctonos. In AUBET, M.E. and SUREDA, P. (eds.), *Interacción social y comercio en la antesala del colonialismo* (Barcelona, Universitat Pompeu Fabra), 71–85.

RAFEL, N., MONTERO-RUIZ, I., CASTANYER, P., AQUILUÉ, X., ARMADA, X.-L., BELARTE, M.C., FAIRÉN, S., GASULL, P., GENER, M., GRAELLS, R., HUNT, M., MARTIN, A., MATA, J.M., MORELL, N., PÉREZ, A., PONS, E., RENZI, M., ROVIRA, M.C., ROVIRA, S., SANTOS, M., TREMOLEDA, J. and VILLALBA, P. 2010: New approaches on the archaic trade in the north-eastern Iberian Peninsula: exploitation and circulation of lead and silver. *Oxford Journal of Archaeology* 29(2), 175–202.

RAMÓN, J., RAFEL, N., MONTERO-RUIZ, I., SANTOS, M., RENZI, M., HUNT, M. and ARMADA, X.L. 2011: Comercio Protohistórico: El registro del Nordeste peninsular y la circulación de mineral de plomo en Ibiza y el Bajo Priorato (Tarragona). *Saguntum* 43, 55–81.

RENZI, M., MONTERO-RUIZ, I. and BODE, M. 2009: Non-ferrous metallurgy from the Phoenician site of La Fonteta (Alicante, Spain): a study of provenance. *Journal of Archaeological Science* 36, 2584–96.

RENZI, M., ROVIRA, S. and MONTERO-RUIZ, I. 2012: Riflessioni sulla metalurgia fenicia dell'argento nella Penisola Iberica. *Notizie Archeologiche Bergomensi* 20, 185–94.

ROTHENBERG, B., GARCÍA, F., BACHMANN, H.G. and GOETHE, J.W. 1989: The Rio Tinto enigma. In DOMERGUE, C. (ed.), *Minería y Metalurgia en las Antiguas Civilizaciones Mediterráneas y Europeas, Vol. I* (Madrid, Instituto de Conservación y Restauración de Bienes Culturales), 57–69.

ROVIRA, S. 1995: De Metalurgia Tartésica. In *Tartessos 25 años después 1968–1993* (Jerez de la Frontera, Biblioteca de Urbanismo y Cultura), 475–506.

ROVIRA, S. 2002: Early slags and smelting by-products of copper metallurgy in Spain. In BARTELHEIM, M., PERNICKA, E. and KRAUSE, R. (eds.), *Die Anfänge der Metallurgie in der Alten Welt/The Beginnings of Metallurgy in the Old World* (Rahden/Westfalia), 83–98.

RUIZ-GÁLVEZ, M.L. 1992: La novia vendida. Orfebrería, herencia y agricultura en la Prehistoria de la Península Ibérica. *Spal* 1, 219–51.

RUIZ-GÁLVEZ, M.L. 2005: *Der Fliegende Mittlemeermann*. Piratas y héroes en los albores de la Edad del Hierro. In CELESTINO, S. and JIMÉNEZ, J. (eds.), *El Periodo Orientalizante, Vol. 1* (Mérida, CSIC, Anejos de AespA XXXV), 251–75.

RUIZ MATA, D. 1989: Huelva: Un foco temprano de Actividad Metalúrgica durante el Bronce Final. In AUBET, M.E. (ed.), *Tartessos. Arqueología Protohistórica del Bajo Guadalquivir* (Barcelona), 209–43.

RUIZ MATA, D. and FERNÁNDEZ JURADO, J. 1986: *El yacimiento Metalúrgico de Época Tartésica de San Bartolomé de Almonte (Huelva)* (Huelva, Huelva Arqueológica VIII).

SANTOS ZALDEGUI, J.F., GARCÍA DE MADINABEITIA, S., GIL IBARGUCHI, J.I. and SÁEZ, R. 2004: Los isótopos de plomo en arqueología: metodología analítica y ejemplos de aplicación. In MARTÍN CALLEJA, J., FELIU ORTEGA, M.J. and EDREIRA SÁNCHEZ, M.C. (eds.), *Avances en arqueometría 2003* (Cádiz, Universidad de Cádiz), 25–34.

SHERRATT, A. 1993: What would a Bronze-Age world system look like? Relations between temperate Europe and the Mediterranean in later prehistory. *Journal of European Archaeology* 1(2), 1–57.

SHERRATT, A. 1994: Core, periphery and margin: perspectives on the Bronze Age. In MATHERS, C. and STODDART, S. (eds.), *Development and Decline in the Mediterranean Bronze Age* (Sheffield, Sheffield Archaeological Monographs 8), 335–45.

SHERRATT, S. and SHERRATT, A. 1993: The growth of the Mediterranean economy in the early first millennium BC. *World Archaeology* 24(3), 361–78.

STOS-GALE, Z.A. 2001: The impact of the natural sciences on studies of hacksilver and early silver coinage. In BALMUTH, M.S. (ed.), *Hacksilver to Coinage: New Insights into the Monetary History of the Near East and Greece* (New York, American Numismatic Society), 53–76.

STOS-GALE, Z.A. and GALE, N.H. 2009: Metal provenancing using isotopes and the Oxford archaeological lead isotope database (OXALID). *Archaeological and Anthropological Sciences* 1(3), 195–213.

TORNOS, F., INVERNO, C.M.C., CASQUET, C., MATEUS, A., ORTIZ, G. and OLIVEIRA, V. 2004: The metallogenic evolution of the Ossa-Morena Zone. *Journal of Iberian Geology* 30, 143–81.

TYLECOTE, R.F. 1987: *The Early History of Metallurgy in Europe* (London).

VIVES-FERRÁNDIZ SÁNCHEZ, J. 2008: Intercambios y consumo en espacios coloniales: dos casos de estudio entre el Ebro y el Segura (siglos VIII–VI a.C.). In GARCIA I RUBERT, D., MORENO MARTÍNEZ, I. and GRACIA ALONSO, F., (eds.), *Contactes. Indígenes i fenicis a la Mediterrània occidental entre els segles VIII i VI ane* (Barcelona, Ajuntament d'Alcanar, Signes disseny i comuncació), 113–34.

WAGNER, C.G. 1995: Fenicios y Autóctonos en Tartessos. Consideraciones sobre las relaciones coloniales y la dinámica de cambio en el Suroeste de la Península Ibérica. *Trabajos de Prehistoria* 52(1), 109–26.

WAGNER, C.G. 2013: Tartessos and the Orientalising elites. In CRUZ, M., GARCÍA, L. and GILMAN, A. (eds.), *The Prehistory of Iberia: Debating Early Social Stratification and the State* (New York), 337–57.

WAGNER, G.A., GENTNER, W., GROPENGIESSER, H. and GALE, N.H. 1980: Early Bronze Age lead-silver mining and metallurgy in the Aegean: the ancient workings on Siphnos. In CRADDOCK, P.T. (ed.), *Scientific Studies in Early Mining and Extractive Metallurgy* (London, British Museum Occasional Paper 20), 63–86.

WARMINGTON, E.H. 1970: *Bibliotheca Historica* (Cambridge, MA, Loeb Classical Library).

FIGURES

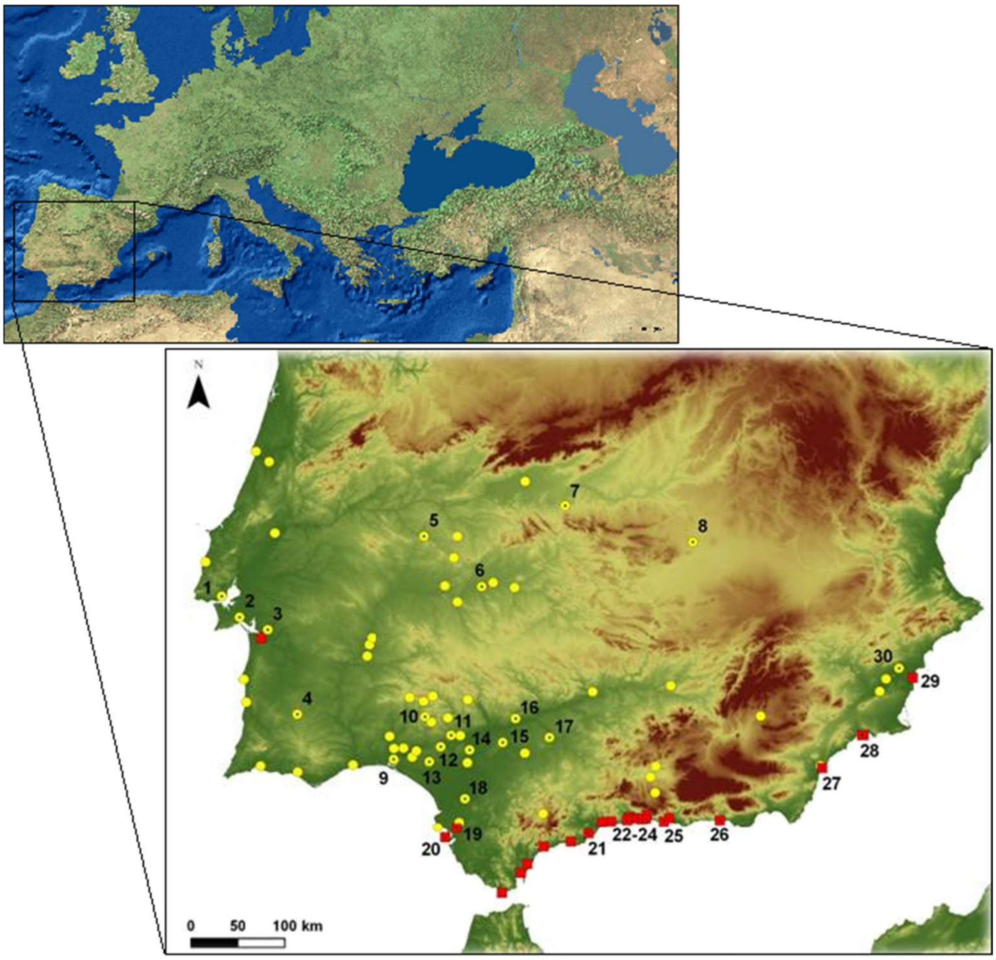

Fig. 1. Main Phoenicians (red) and indigenous (yellow) sites. Those mentioned in the text are in italics. 1. Olisipo 2. Setúbal 3. Alcácer do Sal 4. Ourique 5. La Aliseda 6. Medellín *7. Casa del Carpio 8. Palomar del Pintado 9. Huelva 10. Riotinto 11. Aznalcóllar 12. Tejada La Vieja 13. San Bartolomé de Almonte 14. El Carambolo* 15. Carmona 16. Setefilla 17. Écija 18. Lebrija *19. Castillo de Doña Blanca 20. Cádiz 21. Cerro del Villar 22. Toscanos* 23. Morro de Mezquitilla 24. Chorreras 25. Almuñécar 26. Abdera 27. Villaricos 28. Punta de Gavilanes *29. La Fonteta* 30. Peña Negra.

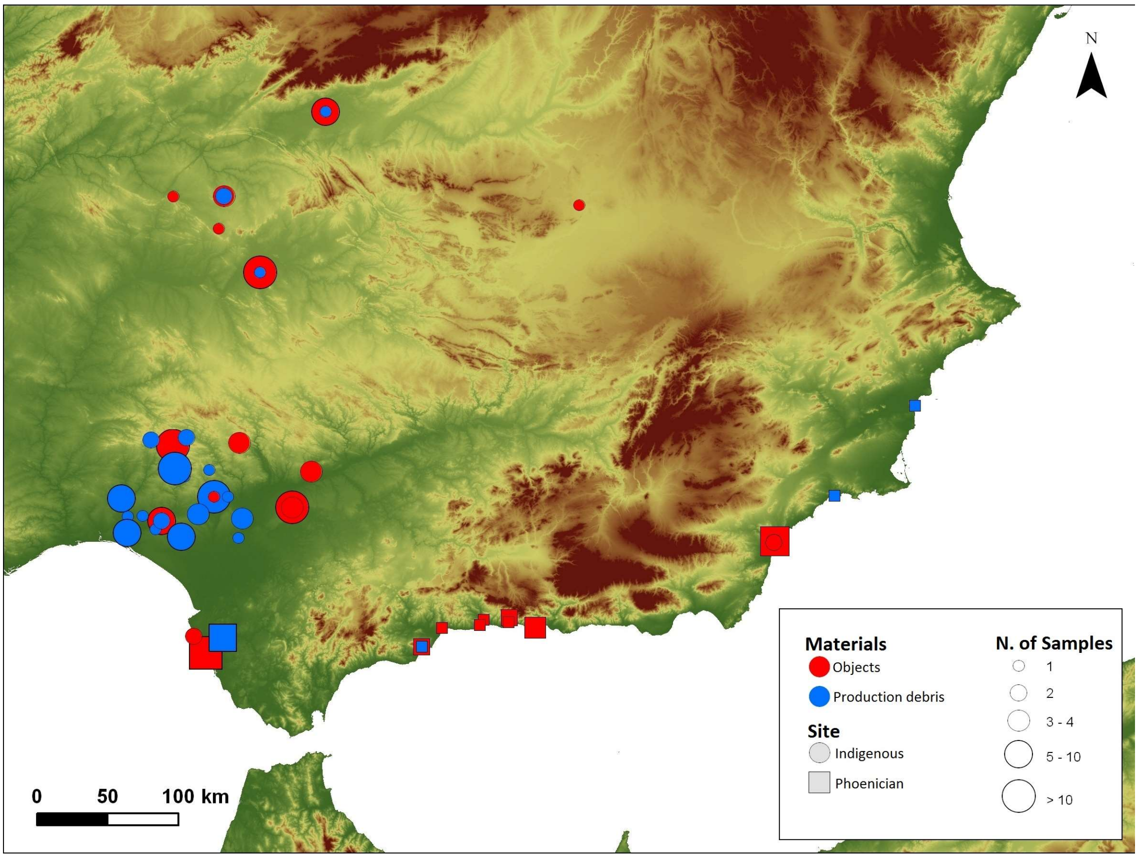

Fig. 2. Distribution of silver production debris and objects in Iberia.

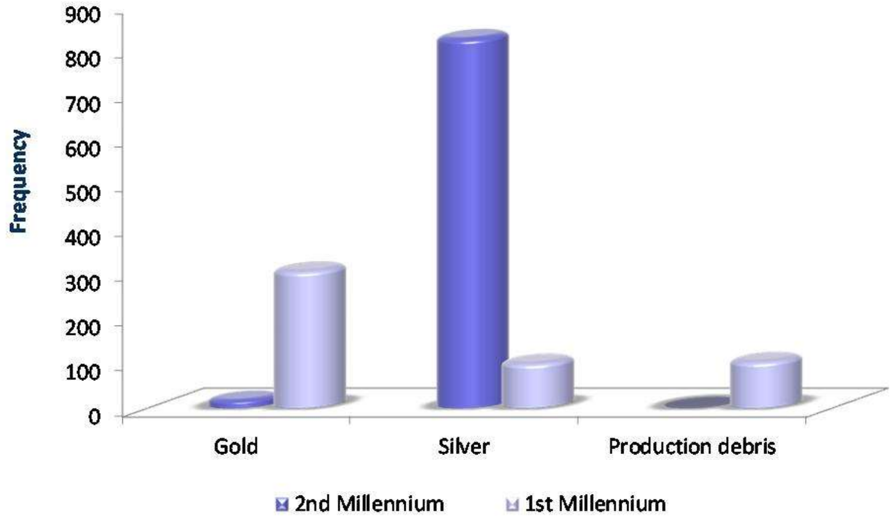

Fig. 3. Quantification of silver and gold evidence in Iberia. The volume of silver production debris is not quantified, as it is not usually reported. In the graph, only bibliographic references to different silver by-products are quantified.

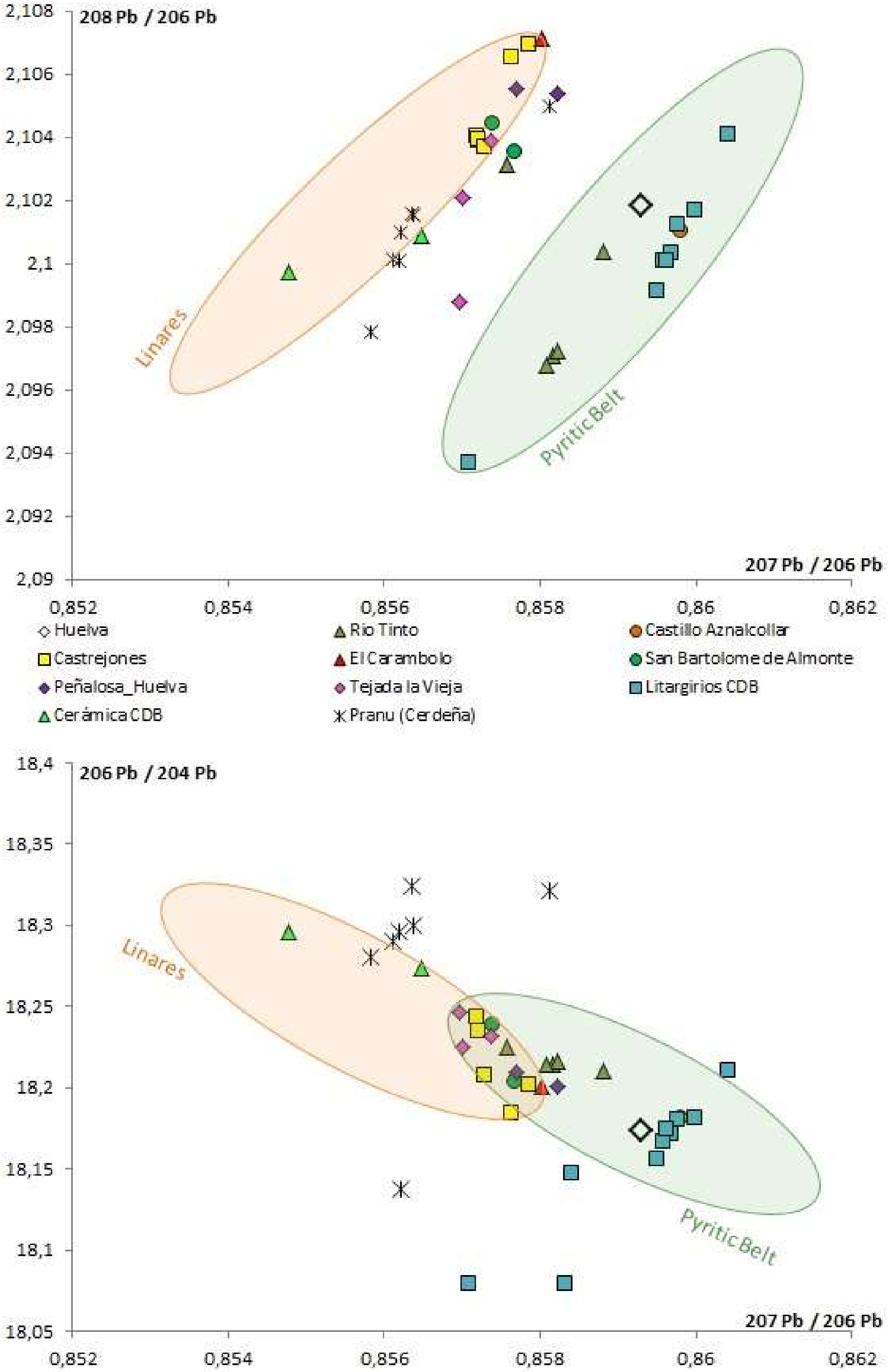

Fig. 4. Isotopic fields of the Pyritic Belt and Linares and Southwestern silver production debris.

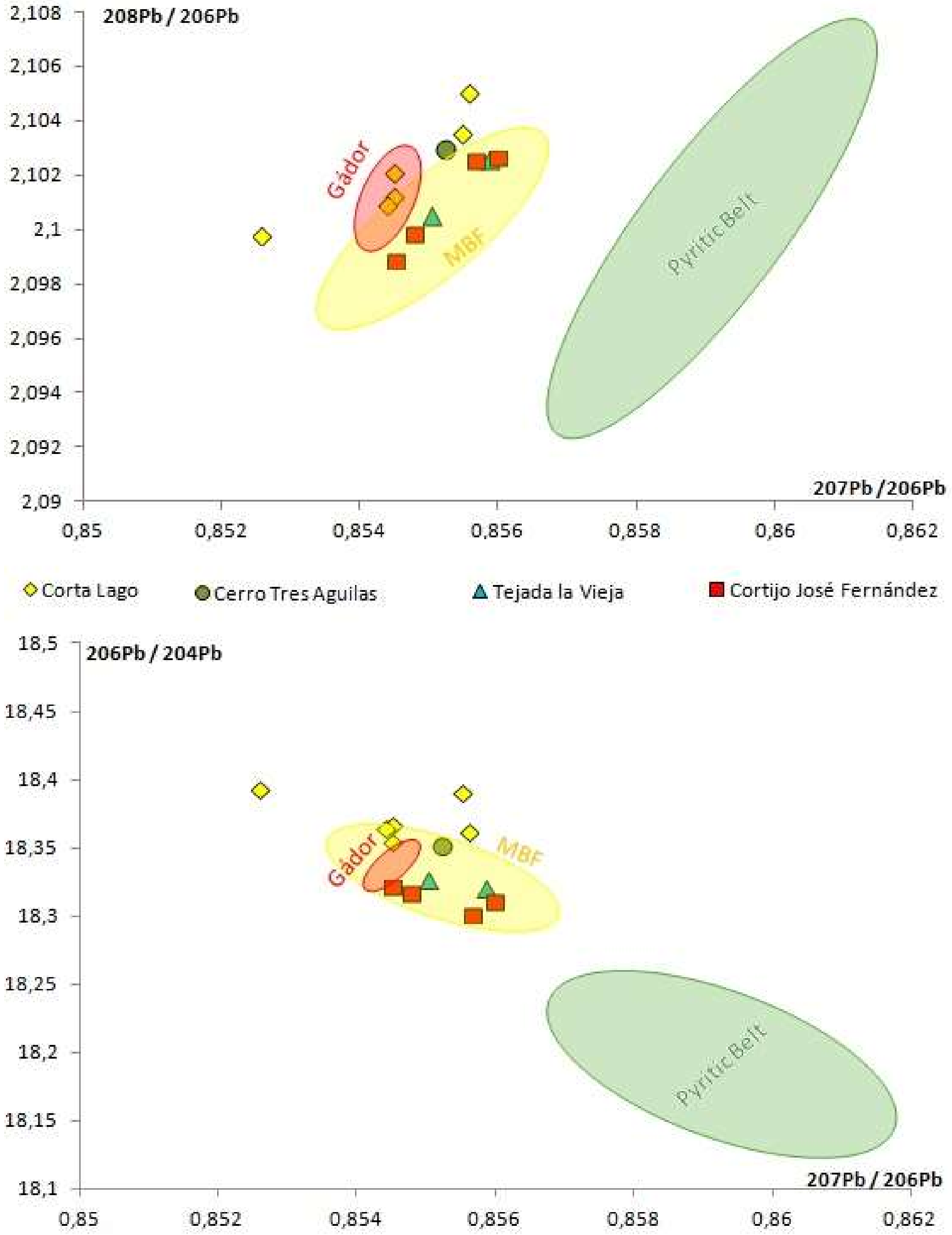

Fig. 5. Isotopic fields of the Pyritic Belt, Gador and MBF mining district and Southwestern silver production debris.

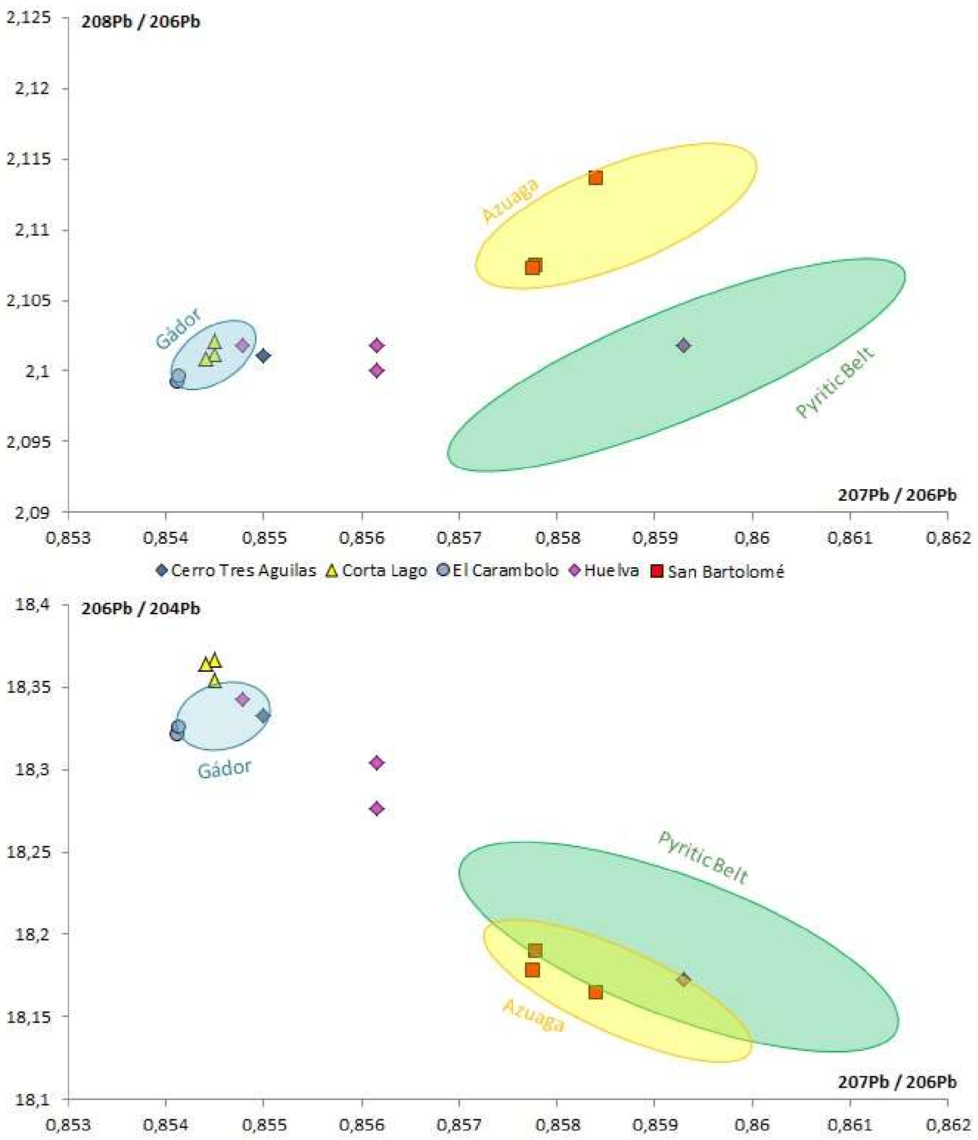

Fig. 6. Isotopic fields of the Pyritic Belt and Gádor and Southwestern silver production debris.

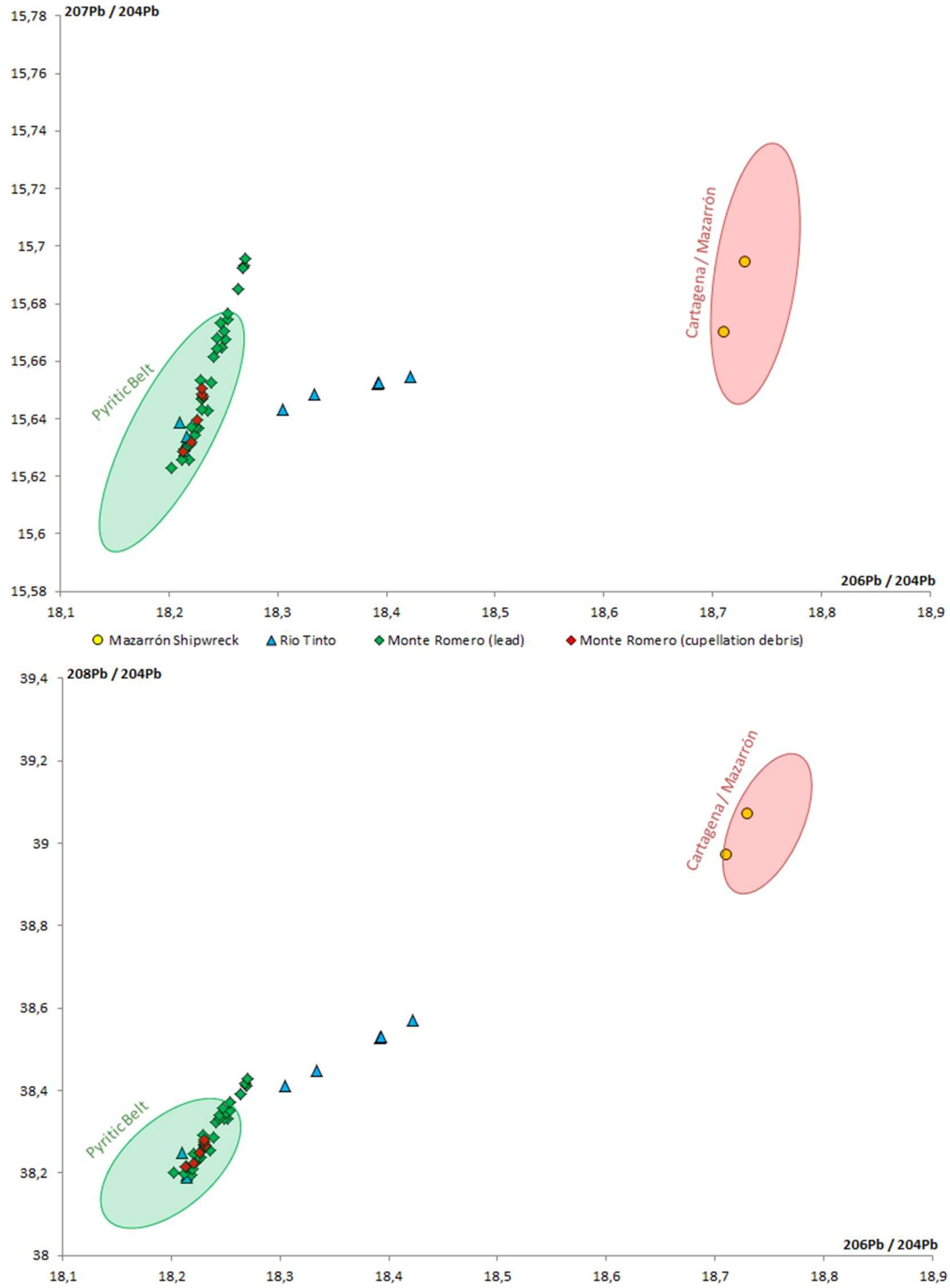

Fig. 7. Isotopic fields of the Pyritic Belt and the Southwest (Cartagena & Mazarrón) and Southwestern silver production debris. Note the alignment of the samples.

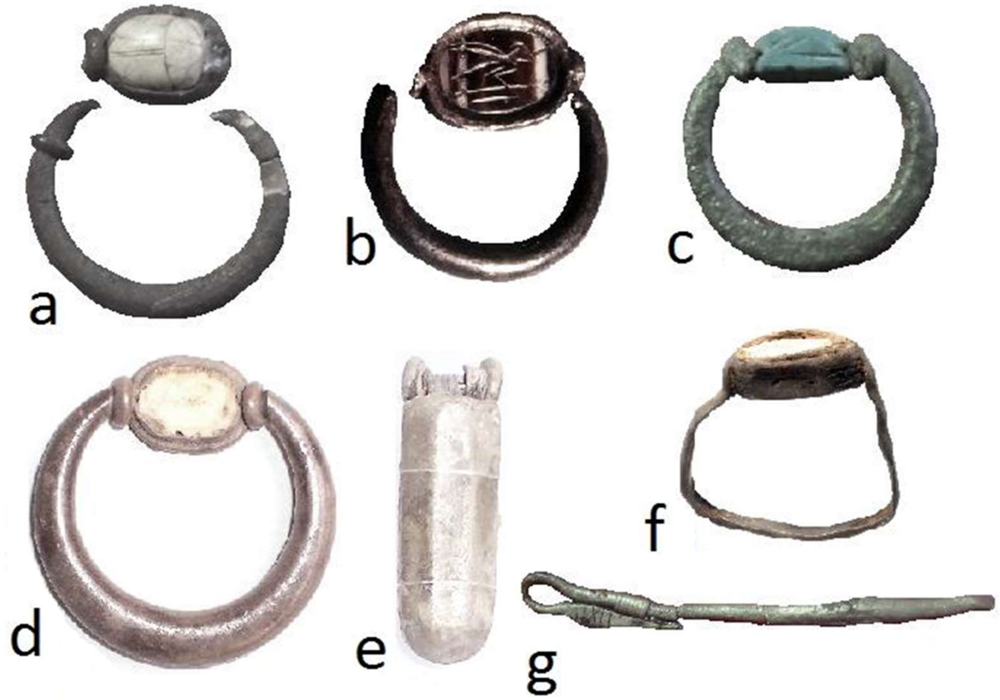

Fig. 8. Analysed silver objects. a) Ring with Egyptian hieroglyph from Lagos (Málaga), b) Ring with Egyptian hieroglyph from Cerro del Villar (Málaga), c) Ring with Egyptian hieroglyph from Jardín (Málaga), d) Pendant from Laurita (Granada), e) Amulet holder from Laurita (Granada), f) Ring from Palacio III (Sevilla), g) Possible fibula from Toscanos (Málaga).

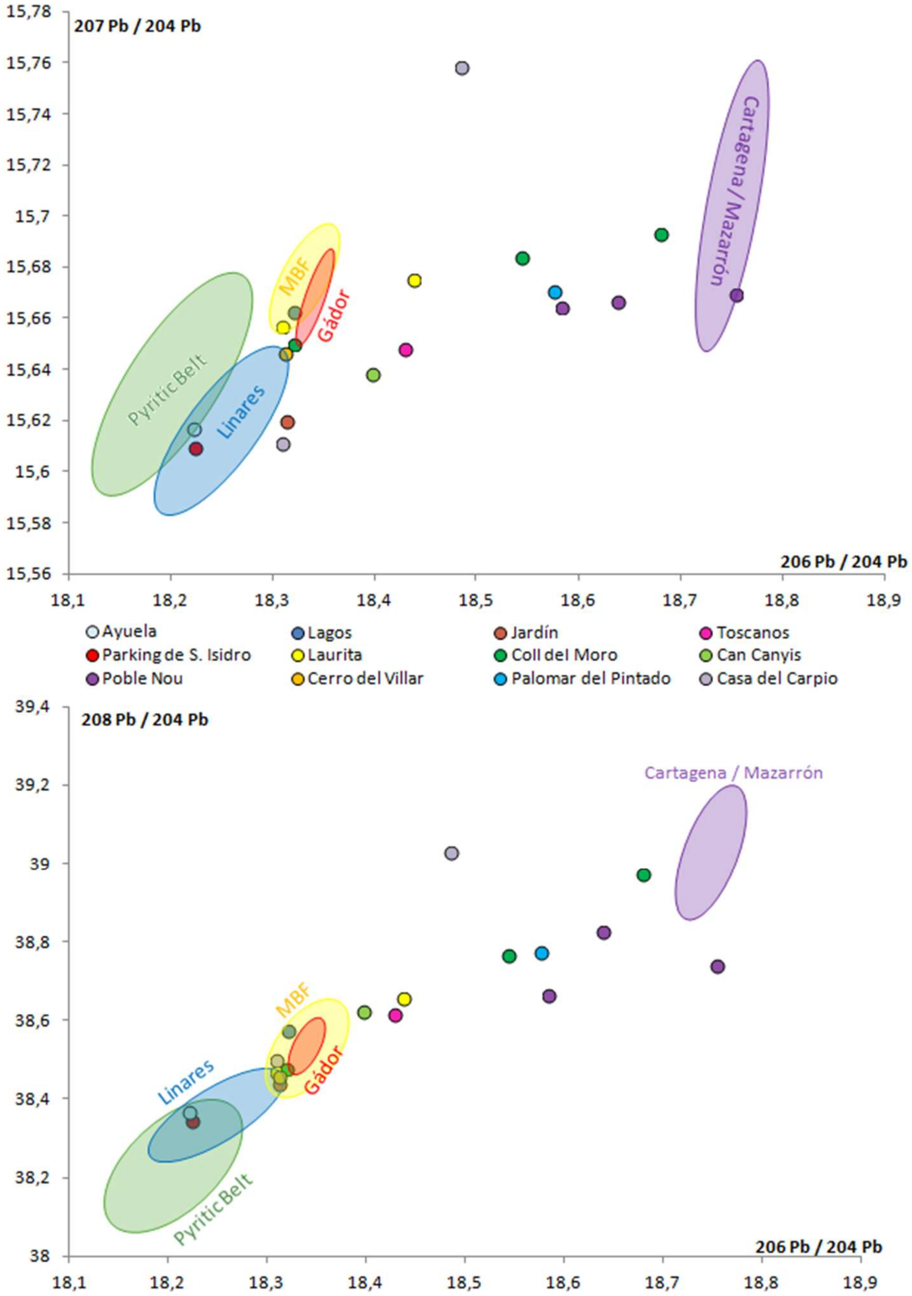

Fig. 9. Isotope ratios of silver objects.

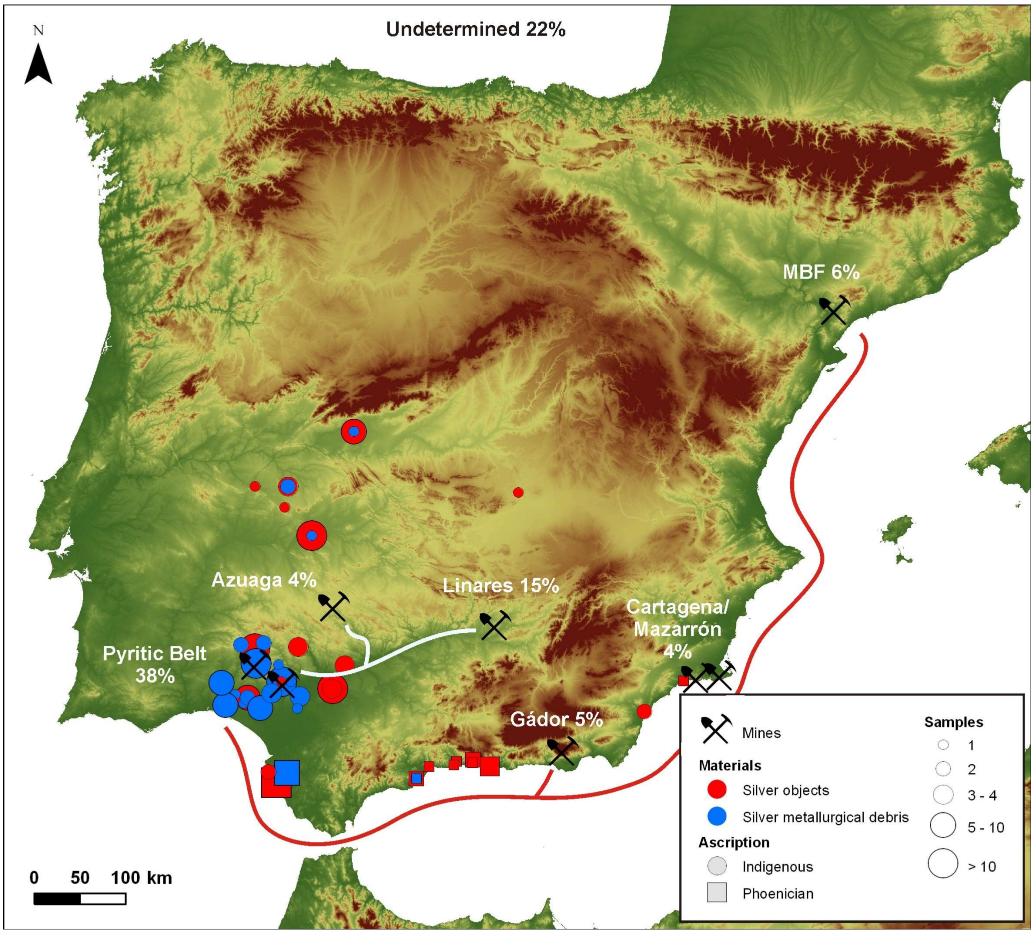

Fig. 10. Location of sites with silver remains analysed and mines of provenance. Broadly, two main connection networks are proposed: a fluvial one (light blue line in the figure) through the Guadalquivir River and a maritime one (red line) through coastal sites.

Table 1. Summary of all silver production debris of the Iberian Southwest. Numbers in brackets are the amount of LIA. References in brackets refer to where LIA results were published, when different from the archaeological publication. All LIA results are compiled in Murillo-Barroso 2013: 357-361.

Site	Ore	Lead (ore/ metallic)	Grinder/ hammer	Slagged pottery	Tapped Slag	FS Slag	Cupellation hearth	Litharge	Buillon	Crucible	Furnace	Nozzles	References
Cabezo de las Asonadas						X							Pérez Macías 1996
Casetillas						X					X		Hunt 2003
Castillo de Aznalcóllar						X (1)							Hunt 2003
Castillo de Doña Blanca				X (2)			X	X (10)				X	Hunt 2003
Castrejones	X	X (met)	X (h)	X		X (6)			X				Hunt 2003
Cerro del Viento						X							Hunt 2003
Cerro de la Matanza						X							Hunt 2003, Pérez Macías 1996
Cerro Tres Águilas						X (3)							Hunt 2003
Cerro Salomón		X met?	X (h)		X	X				X		X	Blanco & Rothenberg 1981
Corta del Lago (RT)	X (10)	X met? (1)		X	X	X (9)		X (8)		X	X?	X	Blanco & Rothenberg 1981, (Anguilano et al. 2010)
Cortijo de José Fdez.						X (4)							Hunt 2003
El Carambolo		X met (3)				X (1)							Hunt et al. 2010
El Pozancón						X							Hunt 2003
El Risco		X met							X				Gómez Ramos et al. 1998
El Tejar						X							Hunt 2003
Gerena						X							Hunt 2003
Hondurillas						X							Hunt 2003
Huelva		Xore(1) &met	X (g)	X (1)		X (1)	X (1)		X		X	X	Fernández Jurado 1988-1989, González de Canales et al. 2004, (Hunt 2003)
La Lapa						X							Hunt 2003
La Obra						X							Hunt 2003
Las Mesas				X		X							Hunt 2003
Monte Romero	X	X (28)		X	X	X	X (6)				X	X	Kassianidou 1992
Niebla				X		X				X?			Hunt 2003, Pérez Macías 1996
Peñalosa				X		X (5)						X	Fernández Jurado et al. 1992, (Hunt 2003)
Pico del Oro			X (g)			X						X	Pérez Macías 1996-1997

Quebrentahuesos			X (g)	X	X	X		X		X	X?	X	Blanco & Rothenberg 1981
San Bartolomé	X	X met	X (g)	X		X (7)	X			X	X?	X	Ruiz Mata & Fernández Jurado 1986, (Hunt 2003)
San Platón						X							Pérez Macías 1996
Tejada la Vieja			X (g)	X (3)		X (2)					X?	X	Blanco & Rothenberg 1981, Fernández Jurado, 1987; 1990, (Hunt 2003)
Tharsis			X (h)			X	X			X		X	Domergue 1987
Torre del Viento						X							Hunt 2003
Torreón de la Dehesilla						X							Hunt 2003

Table 2. Lead Isotope Analysis of Orientalizing silver objects.

Site	**Type**	**ID**	**208/206**	**207/206**	**206/204**	**207/204**	**208/204**
Cerro del Villar	Scarab ring	A/CE06642	2,09997	0,85447	18,31212	15,6463	38,4556
Lagos	Scarab ring	A/CE06828	2,10537	0,85491	18,32120	15,6625	38,5718
Jardín	Scarab ring	A/CE10053	2,09894	0,85290	18,31280	15,6195	38,4378
Toscanos	Fibula?	A/CE09606	2,09530	0,84911	18,42862	15,6476	38,6129
San Isidro Parking	Earring	UE72533	2,10407	0,85653	18,22356	15,6090	38,3432
Laurita	Ring	CE08316	2,10120	0,85517	18,3086	15,6570	38,4701
Laurita	Scarab ring	CE08310	2,09668	0,85022	18,4366	15,6751	38,6556
Coll del Moro Serra d´Almos	Earring	5047	2,10028	0,85424	18,3199	15,6497	38,477
Coll del Moro de Gandesa	Bracelet	327 2927 CMG M87	2,08617	0,84013	18,6801	15,6936	38,9696

Coll del Moro Serra d´Almos	Ingot	5879	2,09053	0,84579	18,544	15,684	38,765
Can Canyis	Disc	PA13534	2,09924	0,84998	18,3979	15,6378	38,6226
Poble Nou	Ring	OO3399	2,08037	0,84286	18,5845	15,6641	38,6627
Poble Nou	Pendant	OO3397	2,08298	0,84054	18,6385	15,6665	38,8236
Poble Nou	Bracelet	O011021	2,06566	0,83549	18,7544	15,669	38,7402
Palomar de Pintado	Ring	PA13524	2,08708	0,84355	18,5761	15,6701	38,7708
Casa del Carpio	Vessel	AA 1477	2,111	0,852	18,485	15,758	39,029
Casa del Carpio	Bracelet	AA 1493	2,103	0,853	18,309	15,611	38,501

Table 3. Provenance proposed (and proportions) of silver production debris from the Iberian Southwest.

Mining District	% of samples
Undetermined	22
MBF or Gador	6
MBF	6
Linares + Pyritic Belt	6
Linares	9
Gádor + Pyritic Belt	2
Gádor	3
Pyritic Belt	38
Cartagena/Mazarrón + Pyritic Belt	4
Azuaga	4

---

[1] Proper cupels are made of lime and bone ashes to absorb PbO. In Protohistoric contexts, so-called ‘cupels’ are actually ceramic vessels, usually porous and sometimes with shells as temper in order to increase their absorption capacity. Sometimes cupellation could be carried out in holes. Lead reacts easily with silica forming lead silicates and therefore, to avoid that, ceramic vessels or holes on the ground should be covered by lime, ashes or carbonates which would absorb PbO. This litharge (enriched with the base-material) would adopt the shape of the vessel and is usually recorded in the archaeological literature as ‘cupels’ or ‘litharge’. In this paper we will use the more specific term ‘cupellation hearth materials’.