Macro-regional scale of silver production in Iberia during the 1st millennium BC in the context of Mediterranean contacts.

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Abstract

The extraction of silver has been traditionally considered one of the main incentives for the Phoenician expansion through the Mediterranean and their settlement in Iberia. In this paper we approach the organization of silver production in Iberia during the Early Iron Age through the study of productive evidence currently available and the development of Lead Isotope Analysis (LIA). Previous results (Hunt, 2003; Stos Gale 2001; Kassianidou, 1992) are considered in the light of new data. The extraction of silver from complex minerals is conspicuously intensified in Southwest Iberia. Imports of exogenous lead, needed for the extraction of silver from these complex minerals, stand out. Flows of lead come in from other Iberian regions such as Gádor, Cartagena/Mazarrón, Linares or even the mining district of Molar-Belmunt-Falset (MBF) in Catalonia. This picture reveals an organization of silver production much more complex than initially thought, with the needed articulation of an exchange network of raw materials at a macro-territorial scale embracing almost all Iberia. Socioeconomic implications that control of these distributions networks of lead could have had are also discussed.

Keywords: Silver, Metallurgy, Lead Isotope Analysis, Early Iron Age, Iberia, Phoenicians.

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. In the case of the Mediterranean during the Early Iron Age, historical sources recurrently point out the abundance of 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).

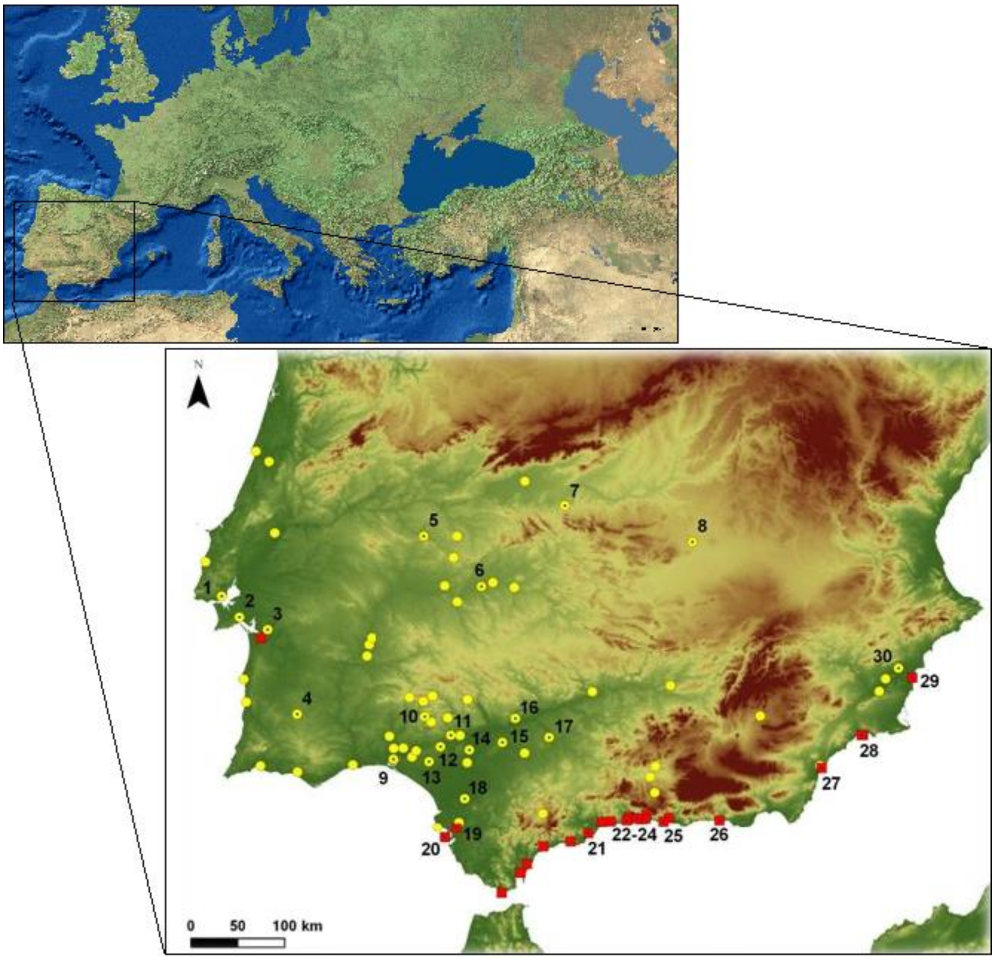

Fig. 1. Main Phoenicians (squares) and indigenous (dots) sites. Those mentioned in the text are in italics. 1. Olisipo 2. Setúbal 3. Alcácer do Sal 4. Ourique 5. La Aliseda 6. Medellín 7. Casa del Carpio 8. Palomar del Pintado 9. Huelva 10. Riotinto 11. Aznalcóllar 12. Tejada La Vieja 13. San Bartolomé 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.

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, Frankestein 1997, Neville 2007, Aubet 2009, 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, their consolidation and the production of surpluses to support this trade (Aubet 2009, Rafel et al. 2010). 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 already 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 as they played not a minor role.

In the case of the Mediterranean societies of the Late Bronze Age and Early Iron Age, the World Systems' theory has been a frequent explicative model when studying colonial contexts (e.g. Harding 1993, Gilman 1993, Sherratt 1993, 1994, and Kristiansen 2000). This concept implies an interdependent relation between the core and the periphery and therefore what happens in one would have an effect on the other. In this sense, the effect of the core on the peripheries must be deeper than a superficial change in consumption patterns and affect structural spheres as for instance their strategies of exploitation (Gilman 1993). To be able to develop a thorough approach, a detailed assessment of the social and economic bases of both societies in collision is needed, something also strengthen by the latest postcolonial approaches. The technological development of both societies, the organization of production in all the spheres or the different mechanisms of exploitation in both societies must be understood especially when these contacts do not occur between equally societies.

We are aware of the magnitude and complexity of colonial studies (for a review of different approaches in Iberia see Armada et al. 2008); addressing all the aspects of colonial contacts in Early Iron Age Iberia is far beyond the scope of this paper. Our focus is to delve in the study of Iberian silver production, mainly in the Southwest, and the role it could have played in the context of colonial contacts. Therefore, our aim is not to redraw our understanding of the Phoenician colonization but to present an analysis of the broad silver production system to rethink some aspects of these Iberian hybrid colonial contexts. In this sense we will keep the traditional classification of 'indigenous Late Bronze Age/Early Iron Age sites' —characterized for a previous occupation, disperse population 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.

In order to address the role played by the exploitation of silver in this colonial context, all the archaeological evidence of silver production available from South-western 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 Southern Iberia suffered substantial transformations which should be related with the Mediterranean contacts, especially the Phoenicians. On the one hand a new technology is developed, both in terms of metal extraction itself and objects manufacture. This technological change is mirrored in a completely different archaeological record: during the Early/Middle Bronze Age, a large amount of silver objects is documented in Iberia, especially in the Southeast (assessing more than 800 items, Murillo-Barroso 2013) however, not a single evidence of silver production has been documented yet, as silver is exclusively extracted by melting native silver and smelting silver chlorides (Bartelheim et al. 2012, Murillo-Barroso 2013). These objects, however, were mostly manufactured by mechanical deformation of silver wires or plates. None of the complex manufacture techniques documented in the Early Iron Age such as engraving, chasing, granulation and specially soldering were implemented at that time (Murillo-Barroso 2013). During the Late Bronze Age/Early Iron Age, happening to meet the first Mediterranean contacts, this scenario changes and a sophisticated manufacture techniques as well as a new complex silver extractive technology —cupellation, with tons of metallurgical debris recovered in archaeological contexts— are developed.

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 bouillon. 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 act as silver 'collector' extracting silver from other impurities which will pass to the slag. If argentiferous lead minerals are being used as the primary ore (like the generalised use of argentiferous galena), lead is already present in the mineral, however, if the argentiferous minerals have low lead contents, 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 lead oxide –PbO– is the main component) is obtained. Due to its lower surface tension, PbO will be absorbed by the cupel and will impregnate it while the silver (and gold) collected previously by lead, as noble metals with higher surface tension, will not be oxidised and will remain at the top of the cupellation vessel forming a button. This process will be carried out several times to refine the silver and 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% which can reach 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 silver collector (Hunt 2003: 392). Moreover, lead can be added also during the cupellation and refining steps to act as an oxidizing agent. Thus, lead becomes a decisive resource for the extraction of silver; as essential as the argentiferous ore itself: without lead imports silver could not had been extracted.

Having into account the aforementioned rudimentary and straightforward Iberian metallurgy, it seems unlikely that Iberians metallurgist come to extract silver from jarosite which largely differ from the native silver and silver chlorides sources that were in use during the Bronze Age. They also differ from the main raw materials employed in most of Europe and the Mediterranean (argentiferous lead sulphurs or carbonates) (Meyers 2003). Nonetheless, silver extraction from complex jarosite was known in the Mediterranean: jarosite 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). All this

[1] Proper cupels are made of lime and bone ashes to absorb lead oxide (PbO). In Early Iron Age 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 is 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' or 'litharge cakes'.

coupled with the fact that first actual evidences of cupellation (i.e. cupellation hearth materials) appear in archaeological contexts where Phoenician remains are also present (Hunt 2003, 2005, Renzi et al. 2012), drives to suggest that this knowledge was transmitted by oriental metallurgists.

Furthermore, silver technology is modified not only qualitatively but also quantitatively, especially in the Iberian Southwest. Some estimation has been made for the slag production volume in the Southwest: traditionally, the estimated figure of 16.310.250 metric tonnes of slag (mainly silver but also copper slag) in Rio Tinto has been assumed (cf. Rothenberg et al. 1989: 58). Regarding to silver debris of the Tartessian period, estimations lower down to four (Fernández Jurado & Ruiz Mata 1985: 24) or six (Rothenberg et al. 1989: 69) 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 silver slag levels (7th-5th centuries BC) are more than one metre thick (Rothenberg et al. 1989: 62), in Aznalcóllar mining district, 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 the site of El Castillo de Doña Blanca (Ruiz Mata 1989: 237). This is also the first time that trade of silver by-products (mainly cupellation hearths materials) is documented, being the shipwreck of Mazarrón the best example (Negueruela et al. 2004). That amount of silver debris accumulated and its trade 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 South-western 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.

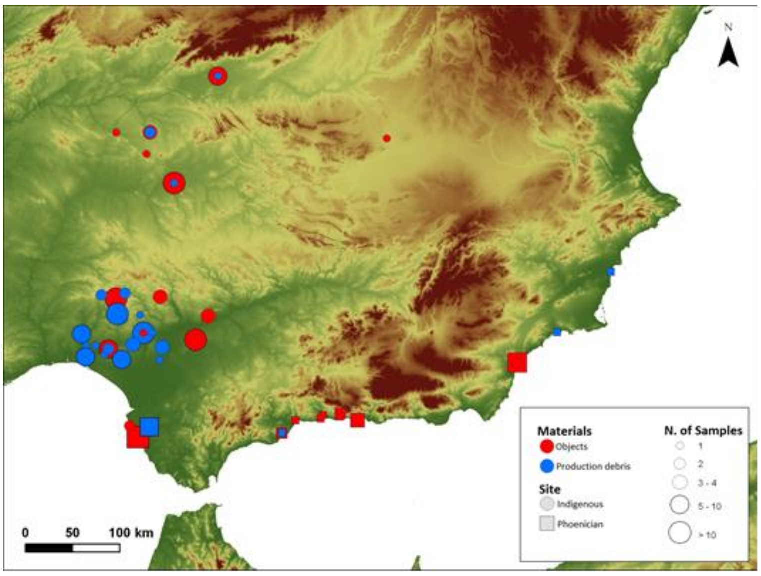

Fig. 2. Distribution of silver production debris and objects in Iberia.

***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*	*Bouillon*	*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
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

Nevertheless, this significant increase of metallurgical remains contrasts with the scarcity of silver objects in the archaeological record. Only 95 silver objects have been recovered dating between 9^{th}-6^{th} century BC, with an estimated weight of 1365g. This disparity is evident not only when compared to earlier periods (c. 800 objects figuring c. 3 k in the Bronze Age Argaric society) but also when compared 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). In this paper we will address the way in which this production system was organized in Iberia from a comprehensive perspective. As it is known that foreign lead was needed in the Southwest in order to extract the silver, an attempt on determining lead provenance is made. We try to attend all evidence of South-western silver extraction with a wide-ranging perspective which includes Iberia as a whole in an all-embracing silver production system.

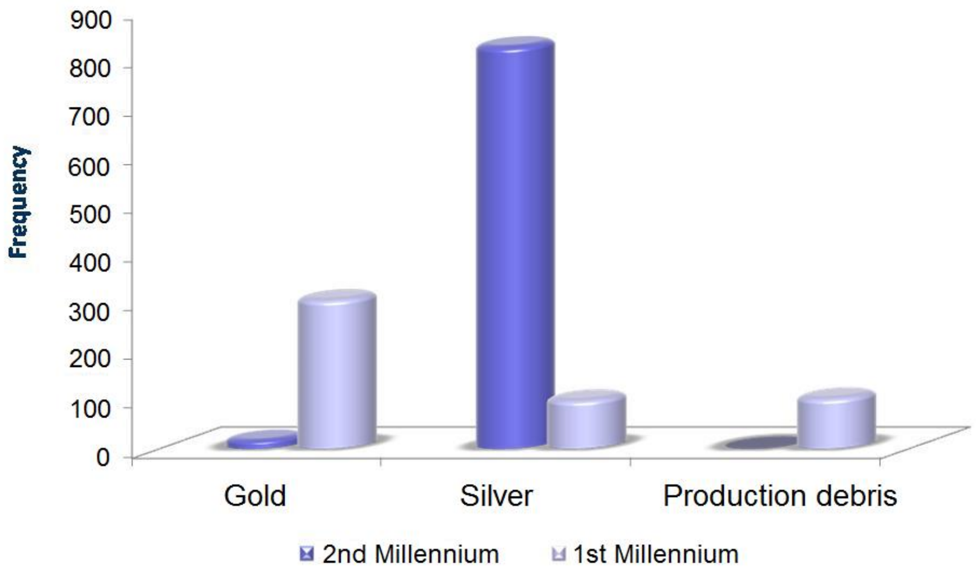

Fig. 3. Quantification of silver and gold evidence in Iberia. The volume of silver production debris is not quantified, as it is not usually reported. In the graph, only bibliographic references to different silver by-products are quantified.

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, Santos Zaldegui et al. 2004, Stos-Gale & Gale 2009, Pernicka 2014) and we will not discuss them; we will just stress the fact that once the mineral is deposited, its isotopic composition will not be modified 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 take into account when dealing with archaeological materials: co-smelting and recycling metals can modify their isotopic proportions. In our case study, foreign lead was added to South-western argentiferous ores and therefore the isotopic proportions of archaeological remains will be a mixture of both. This fact makes difficult but not impossible sourcing some archaeological materials. When only two different ores have been mixed up, samples will be aligned between these two ores in all graphs, as we will see below, but if metals are systematically recycled the distortion of their isotopic signature would probably makes impossible to determine their provenance.

In this paper, we will review the results of 113 Lead Isotope Analysis (LIA) of silver production debris from the Southwest published up to now (see Table 1). We also present the analyses of 28 silver objects (Table 2). Analyses collected from the literature were conducted by TIMS and the results that we present here were conducted by MC-ICP-MS (see Klein et al. 2009 for methodological questions). However, results of both techniques are comparable (Baker et al., 2006).

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

Regarding geological samples, c. 700 LIA of the main lead mining districts of the Iberian Peninsula are available with clear identification of the Pyritic Belt, the Ossa-Morena and Central zones, the Southeast (Murcia and Almeria provinces), Linares or Catalonia (most data is 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 discuss the isotopic signature of the final objects later on.

Regarding samples of the production debris recovered in archaeological sites from the Iberian Southwest, the sources that can be proposed are as follow (see fig. 10 for locations of the mining districts referenced):

a) The Pyritic Belt.

Cupellation hearth materials from the city of Huelva, Castillo de Aznalcóllar (Seville) or Castillo de Doña Blanca (Cádiz) as well as free silica slag from Rio Tinto (Huelva) match with the isotopic field of the Pyritic Belt, clearly showing the exploitation of these resources (Hunt 2003, Anguilano et al. 2010) not only because of the amount of silver debris in this area, as shown in Fig. 2, but also because of their isotopic concordance (Fig. 4). However, this is not the only source 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 bivariate diagrams. 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 diagrams, 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 ratios (Fig.5). Indirect proof of mining works in MBF during the 7th century BC is given by some lead production debris found in the site of El Calvari which have an isotopic concordance with MBF mining district (Rafel et al. 2010).

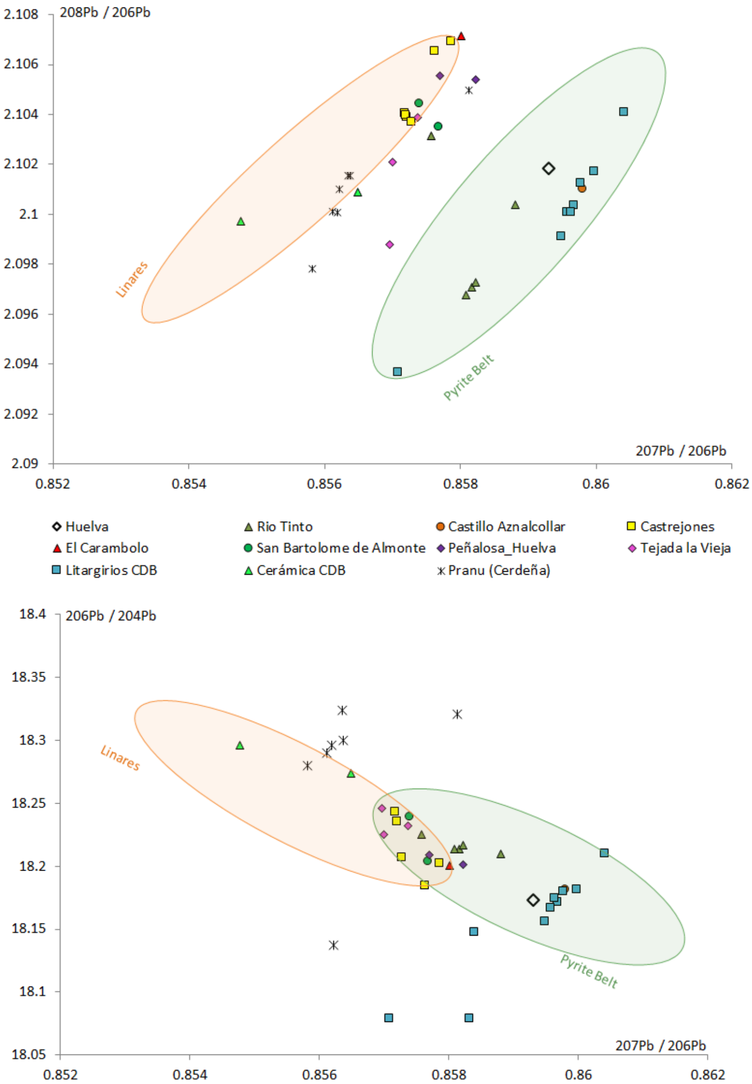

Fig. 4. Isotopic fields of the Pyritic Belt and Linares and Southwestern silver production debris.

d) Azuaga.

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

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

South-eastern 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 sample of 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 materials is plotted 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 sample of cupellation hearth which matches the Pyritic Belt isotopic field indicates that at least in this case ores were not mixed up. On the other hand, the sample of 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 sample of galena found in Huelva comes from Gádor, it seems more likely 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.

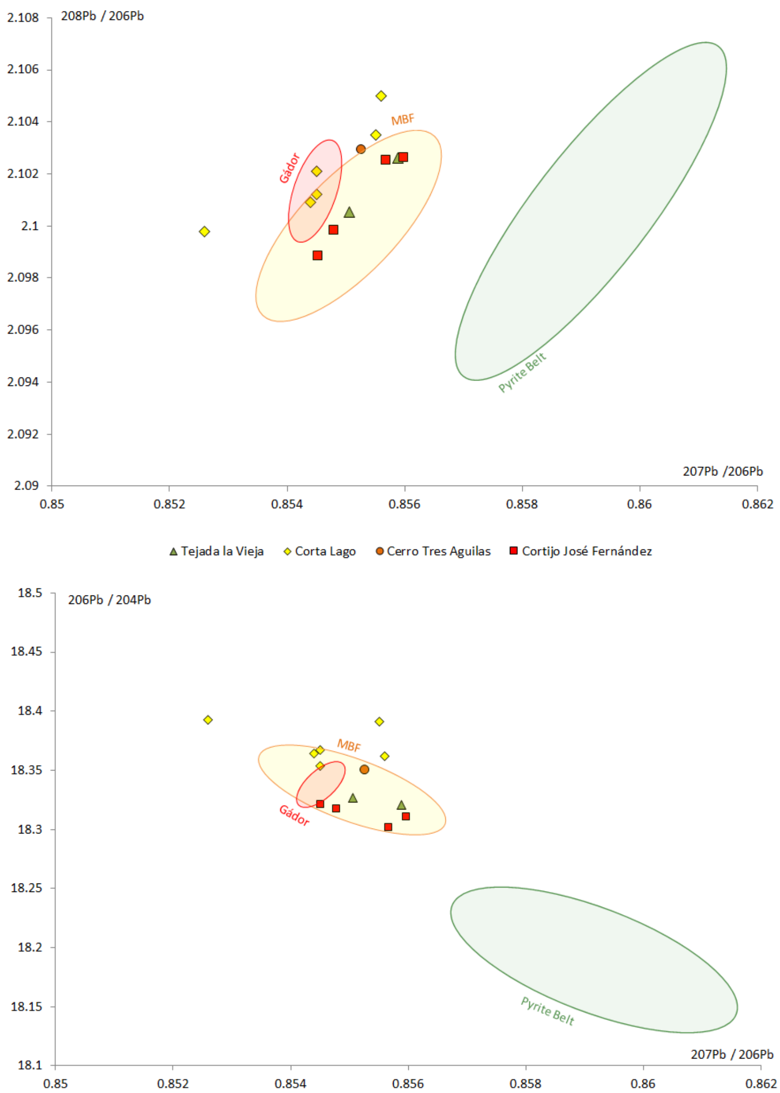

Fig. 5. Isotopic fields of the Pyritic Belt, Gador and MBF mining district and Southwestern silver production debris.

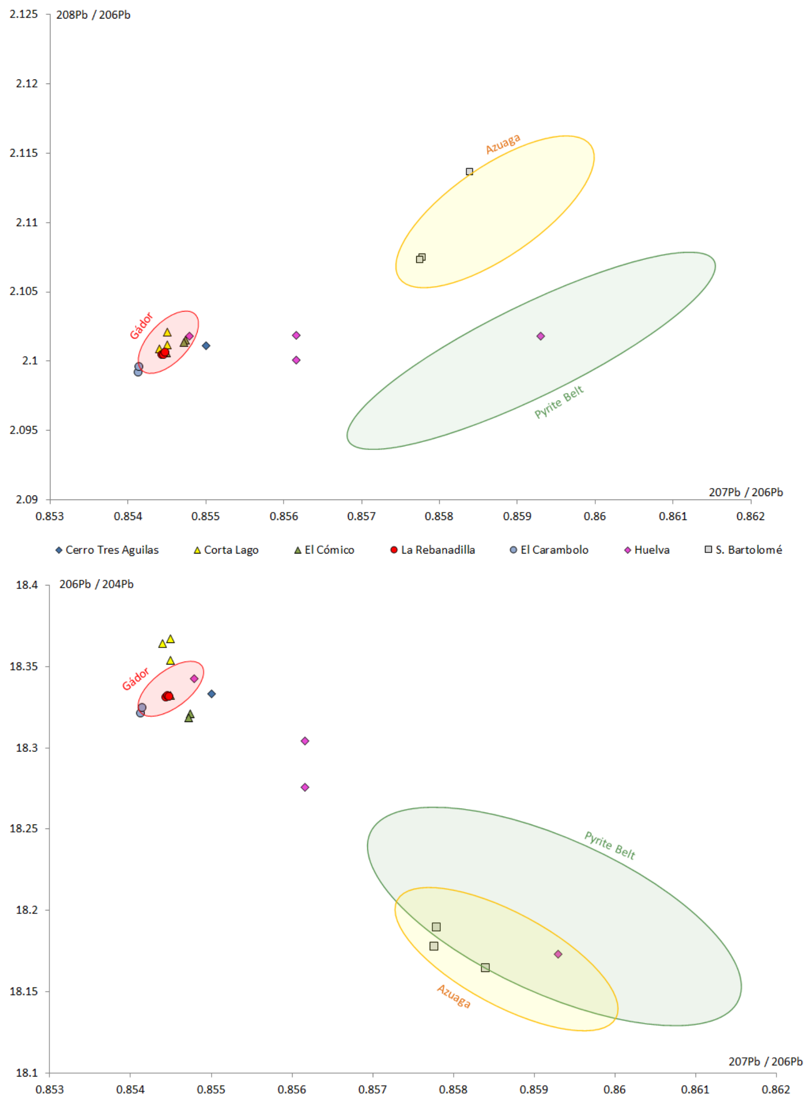

Fig. 6. Isotopic fields of the Pyritic Belt and Gádor and Southwestern silver production debris.

One lead drop and one lead trapezium from El Carambolo recently analysed could also fit into Gádor'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.

Some 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 cupellation by-products from Corta Lago (Rio Tinto) are aligned in all axes between the isotopic fields of the Pyritic Belt and Cartagena/Mazarrón (Anguilano et al. 2010). This evidences the addition of lead (or the reuse of litharge cakes) from

Murcia to extract the silver of the South-western 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 South-eastern lead for the extraction of silver from the jarositas of the Pyritic Belt in Roman times (Anguilano et al. 2010). Furthermore, cupellation hearth materials 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.

There are however some other materials whose precise origin cannot be identified yet. Materials recovered in the site of Monte Romero 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 cupellation hearth materials 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, or because they have been mixed with ores from mining districts still to be isotopically characterized.

Altogether, we can assess the provenance of 60% of the samples with high probability (isotopic concordance in all bivariate diagrams). The other 40% may correspond to some mixtures hard to establish, although regardless of their specific provenance, they show the addition of imported lead. All these analyses show in fact the preeminent use of exogenous lead, as only 38% of the samples analysed show a concordance with the isotopic field of the Pyritic Belt. When added, the most common provenance of lead is the Southeast (Gádor, Cartagena and Mazarrón) although further provenances such as Linares and Catalonia have also been detected (Table 3).

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

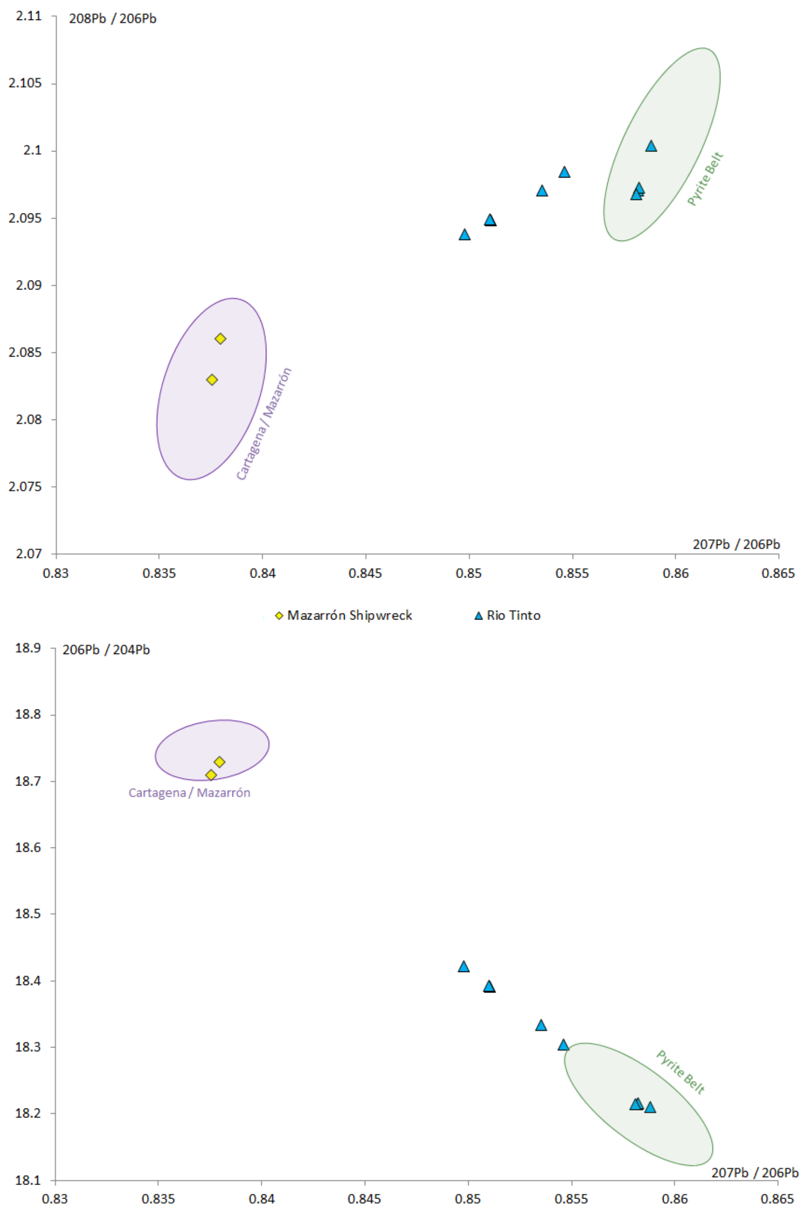

Fig. 7. Isotopic fields of the Pyritic Belt and the Southwest (Cartagena & Mazarrón) and Southwestern silver production debris. Note the alignment of the samples.

Regarding 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 bending scarabs, Egyptian hieroglyphs or amulets holder what raised the possibility of being imported. Their specific provenance is hard to establish as silver has suffered several steps where lead (which can be from different provenances) is added: during the smelting of jarosites and in the successive steps of cupellation and refining. Moreover, silver can be reused and recycled being its isotopic signature even more altered. However some insights can be made.

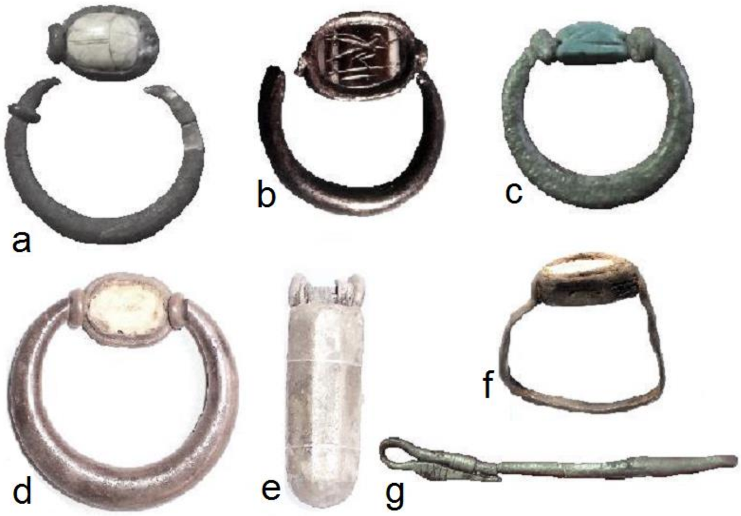

Fig. 8. Analysed silver objects. a) Ring with Egyptian hieroglyph from Lagos (Málaga), b) Ring with Egyptian hieroglyph from Cerro del Villar (Málaga), c) Ring with Egyptian hieroglyph from Jardín (Málaga), d) Pendant from Laurita (Granada), e) Amulet holder from Laurita (Granada), f) Ring from Palacio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

There are only two objects which match in all axes with a known isotopic field: one ring from La Rebanadilla (Málaga) and another from La Ayuela (Cáceres) coincide with the isotopic field of Linares. One ring from Laurita (Granada) also falls in all axes in the isotopic field of MBF (Fig. 9).

However what draws the attention is that all silver samples are aligned between the isotopic fields of Cartagena/Mazarrón and Linares/Gádor/MBF. They are aligned in between the main lead resources identified in silver by-products, so even if their isotopic signatures might be altered and their decoration is of 'oriental-style', these objects were most probably produced from Iberian resources. That also shows that even if they were produced using South-western silver ores, their isotopic signature will be that of the lead (or the mixture of lead ores) added in their manufacturing and not that of the South-western argentiferous ore. There is only one sample, a decorated vessel from Casa del Carpio, which falls apart from the alignment of all samples and could have a foreign origin, something that was already proposed on the basis of its manufacture techniques (Pereira 2005). Another bronze vessel with a characteristic typology of the Central-Eastern Mediterranean was found in this burial (Armada, 2006-2007) reinforcing the idea of a foreign princess buried in an indigenous context (Ruiz-Gálvez, 1992).

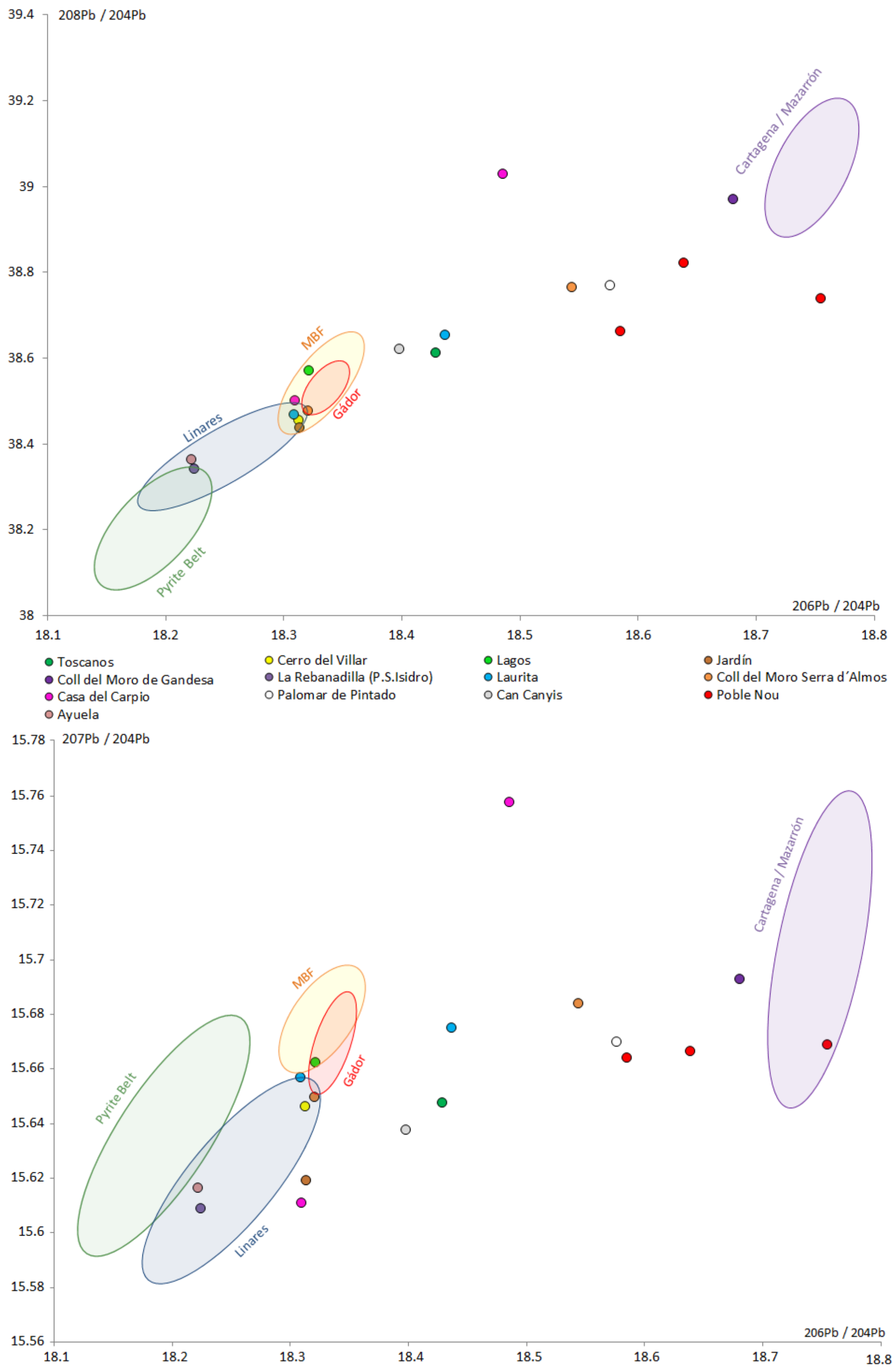

Fig. 9. Isotope ratios of silver objects aligned between the main lead deposits in Iberia.

Discussion.

In this paper we have tried to evaluate all archaeological evidence of silver production, especially in South-western Iberia, to approach the production system of silver from a comprehensive point of view on the basis of provenance analyses. As mentioned above, the first issue which stands out is the disparity between the amounts of production debris accumulated and the amounts of finished silver objects documented in the archaeological record. The intensification of silver production does not seem to have had a direct impact on Iberian sites, as silver objects found are proportionately few. According to Rovira's estimations (1995), for the extraction of 1 kilo of silver from the jarosite minerals of the Pyritic 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 Southwest in some million tons which, even if overestimated is far beyond the needed to produce one kilo of silver. The aforementioned abundance of gold indicates that the shortage of silver does not respond to 'archaeographical' problems but to a context in which the intensification of silver production is not having a direct impact on Iberian populations in terms of silver accumulation. In Early Iron Age, gold continued to be, as in the Late Bronze Age, the main metal of prestige between the elites of Western Iberia (Perea 2005). This fact could support the idea of the Phoenician settlers' interest in Iberian metals, especially silver, which would be exported to the eastern metropolis (Frankestein 1997; Aubet 2009).

The organization of production that we observe seems to respond well to a production with some planning and a macro-regional scale. On the one hand, intense mining works are detected in the Pyrite Belt area, which concentrates most of the silver production debris in contexts in which indigenous elements are abundant but always with the presence of Phoenician remains (Hunt 2003, 2005, Fernández Jurado 1995, Renzi et al. 2012), especially when the Phoenician presence in Huelva is documented from the late 10th-mid-9th century BC (González de Canales et al. 2006, Nijboer & Van der Plicht, 2008). It is in these contexts that cupellation is clearly documented in Iberia for the first time. Nonetheless, the fact that the cupellation appears before or after is irrelevant in itself from a socioeconomic point of view if it is not framed in a broader context. In that sense, even if cupellation would have been an indigenous innovation and not a technological knowledge transferred by the Phoenicians, it remained in a domestic sphere at a low scale production until the 1st millennium, with the Phoenicians clearly settled in Iberia, when we observe a significant intensification of silver production as evidenced by the abundance of documented metallurgical debris, slag heaps or storage and trade of silver by-products. Actually, this trade of silver debris can also be considered as an evidence of a concern in optimizing the production.

This increase of silver production is also consequent with a recent paleo-environmental study which shows the impact of metallurgical intensification by a substantial increase on lead pollution in the Southeast during Early Iron Age caused by metallurgical activities (García-Alix et al. 2013: 454).

On the other hand it is at that time when 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 this area for the extraction of silver had already been proposed by others due to the low lead content of some of the minerals of the Pyritic Belt (Craddock 1995: 216-221, Hunt 2003). Lead Isotope Analyses allow proposing a number of sources for that exogenous lead, expanding the scale of production of silver to 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 evidences of silver by-products are concentrated in the Southwest of Iberia, mostly in contexts where indigenous sites are predominant, the distribution and trade of lead, on the other hand, seems to have been controlled by the Phoenicians – either as mineral such as the galena from Gádor found in Huelva, or as litharge cakes, such as the ones carried in the shipwreck of Mazarrón (Negueruela et al. 2002) or accumulated in the site of Castillo de Doña Blanca (Ruiz Mata, 1989) – who, through the direct control on lead distribution, could exert indirect control on the production of silver. This is probably what Diodorus Siculus (V, 35, 4; Warmington, 1970) referred 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 is structured in such a way that the lead needed for the extraction of silver in the Southwest is imported from the mining areas of Ossa Morena, the Southeast, Linares, or Catalonia. Both the intensification of silver mining and especially the organization of silver production at such a large scale seem to respond to some planning, requiring financial support from the state or a powerful and organized social sector capable to establish a network-wide productive system.

In the construction of these trade networks various products, not just silver or lead, were involved, and the specific paths followed in the distribution of these elements and how they combine are still to be established. The kind of relationship/dependency kept between Phoenicians coastal sites themselves that allowed the supply of lead and that allowed the building of that macro-territorial system of production is essential to understand the system's success, as an entire circuit and a trade network is set comprising both, coastal and inland settlements.

In relation to the imports of lead to the Southwest, the Guadalquivir River could have been a path from Linares, and from Azuaga via its tributary Bembezar River, while maritime routes could have articulated the arrival of lead from Gádor, Cartagena/Mazarrón and MBF (Fig. 10). The site of Castulo, close to 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 other Mediterranean sites

(Montero-Ruiz et al. 2012); therefore, lead from MBF could have reached the Southwest through their contacts with Linares.

These connection networks and trade also had an impact in North-eastern 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. 10th and the beginnings of the 8th century BC. In the earliest phases these two settlements coexisted with some other small sites dispersed along the region. However, it is during the 7th century BC when the first evidences of lead smelting in these two sites as well as a concentration process oriented to better control and reinforce the exploitation of this mining district is detected (Armada et al. 2013). Nonetheless, the fact that lead from MBF is not locally distributed in the Northeast but channelled to Southern Iberia is extremely revealing, as well as the chronological coincidence of the beginnings/consolidation of its exploitation and the Phoenicians commercial expansion (Rafel 2011-12). It is also significant that the abandonment of these sites in the half of the 6th century BC coincides with the crisis of the Phoenicians' trade in the region.

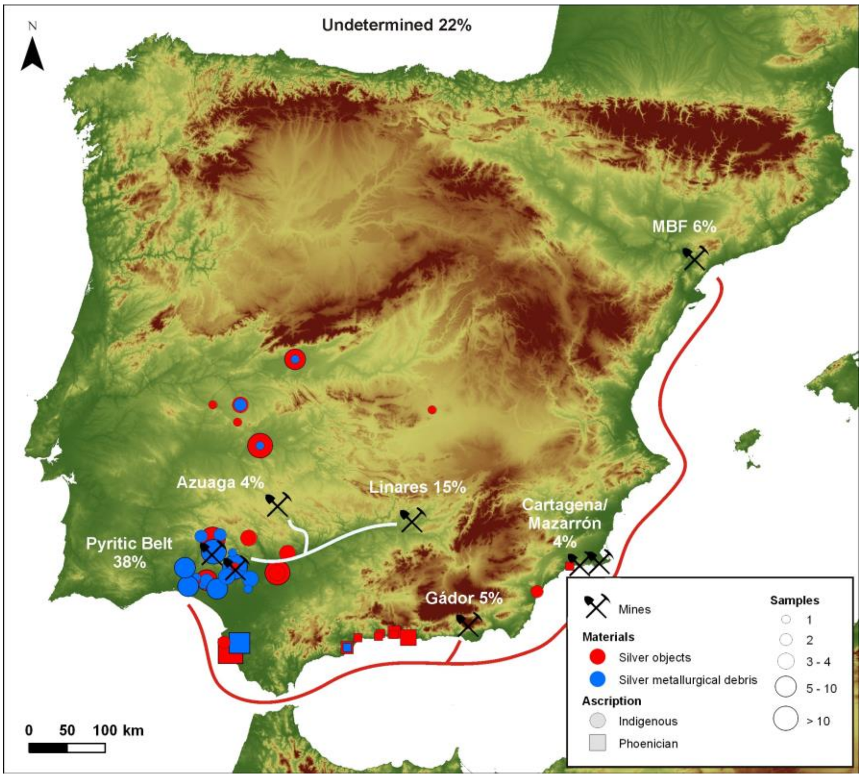

Fig. 10. Location of sites with silver remains analysed and mines of provenance. Broadly, two main connection networks are proposed: a fluvial one through the Guadalquivir River and a maritime one through coastal sites.

This South-western extensive production linked to the exploitation of jarosite contrasts with another way to extract silver from argentiferous galena, which is documented in the Southeast and Ibiza (Ramón et al. 2011). This last system, more self-sufficient as foreign lead is not needed, did not generate an impact as evident as the South-western one. One exception would be La Fonteta, where galena from Gádor was imported to attend the necessity of lead for a de-silvering process of argentiferous copper minerals (Renzi et al. 2009, 2012).

This context of orientalising silver production seems consistent with that proposed for contacts between indigenous communities and Phoenicians under colonial trade and unequal exchange as means of transferring wealth from one social formation to another (Wagner 1995; 2013). In this context two different societies (a domestic one with incipient stratification and a mercantile one with a developed State) come into collision, being the household maintained while benefiting the mercantile system of production and its colonial interests (Wagner 2013).

In the case of silver production, the Phoenicians would have articulate, through emerging elites (and to some extent dependents of the colonizers), native labour force for mining and smelting. This fact would have allowed these emerging elites to use the trade and connections with the settlers to maintain a position of power and prestige within the indigenous communities. This indigenous development of stratification should therefore be integrated in the broader context of commercial Phoenicians' expansion: indigenous groups, to some extent stratified and with some control to connection and commercial networks, would have been reached by Phoenicians as being the ones able to guarantee their wanted flow of exchanges (Vives-Ferrándiz, 2008: 115). Their control on redistribution would have also favoured the Phoenicians as they were able to mobilize the workforce they demanded in the form of raw materials (Wagner 1995). These colonial encounters are understood as facilitators of internal socioeconomic developments (Aubet, 2005: 118; Ruiz-Gálvez, 2005: 252). Actually, it might be easier for the colonizers to co-opt local emerging elites and to incorporate their pre-existing trade networks and their political organization systems to their own interest than get settled in contexts in which the links through which they could articulate the exploitation of the territory were absent .

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 metal) as well as sophisticated and extensive organization from the mining works, smelting, cupellation to the transport of silver ingots to the coast. It would have implied supervision and specialised administration at each stage of the process as well as a sort of pacts or agreements with the local elites in a context in which mechanisms of emulation by the indigenous elites could have played an important role in their consolidation (Gilman, 1993). Both the administrative structure of this system 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, to confirm the hypothesis of a transfer of silver to the eastern sites, isotopic concordance between the silver objects from the East and Iberian mineralization is needed. Stos-Gale (2001) raised the possibility with the study of hack silver but materials available had no precise chronology and the concordance with South-western silver ores could be later (2nd century BC). At this moment, only one Greek silver drachma from Mileto dated around 500 BC (Desaulty et al. 2011) offers a possible match with Linares. Given the possibility that the silver had been extensively recycled, this isotopic concordance may no longer be seen, but in any case, this test is yet to be done.

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