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Metallurgical vessels from the Phoenician site of La Fonteta (Alicante, Spain): a typological and analytical study

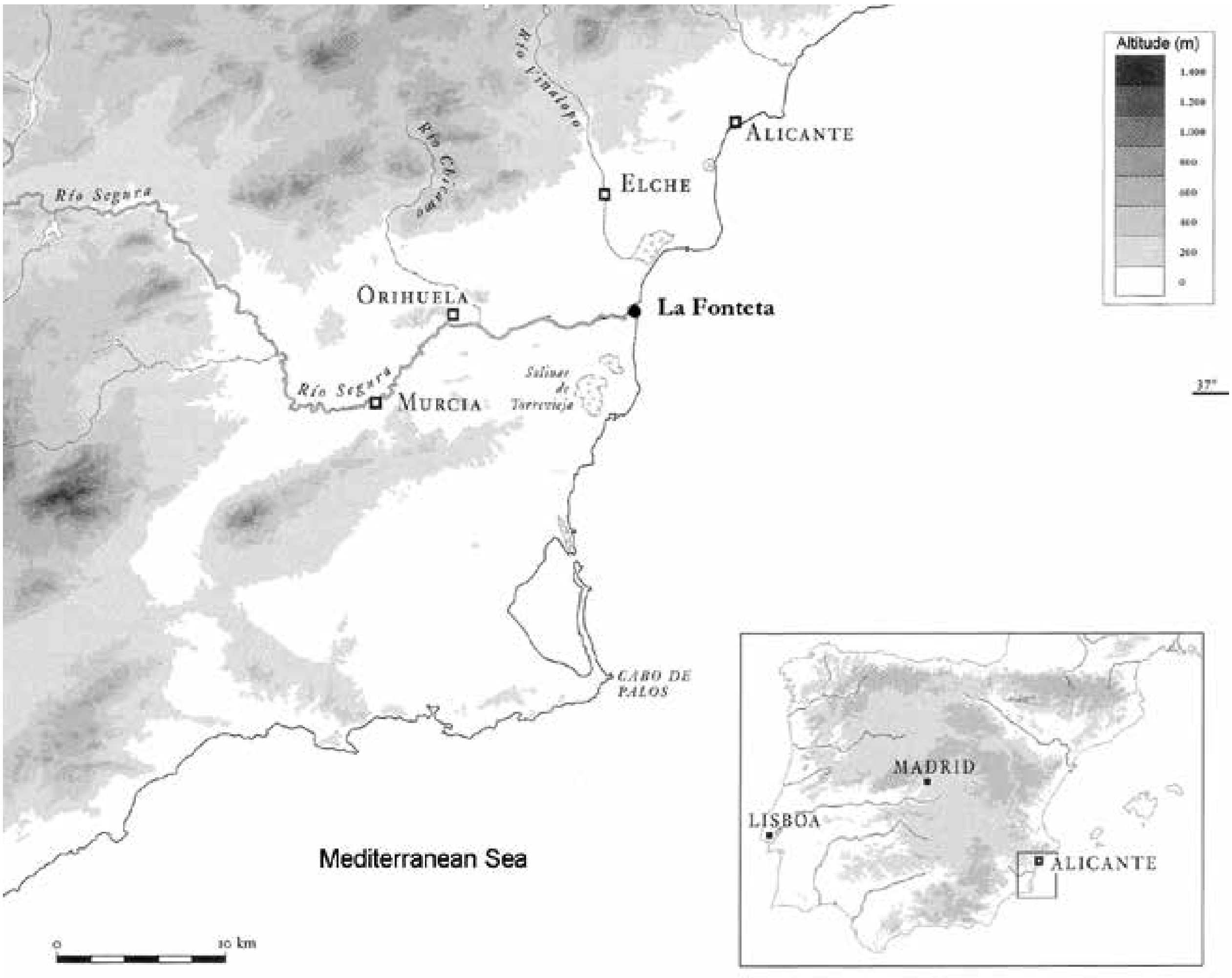
Introduction

In the Iberian Peninsula, the transition period between the Bronze Age and the Iron Age is characterised by important technological innovations that are generally associated with the arrival of the Phoenicians, such as the introduction of iron metallurgy and the use of the cupellation process for extracting silver from argentiferous ores.

However, despite the important introduction of these novel methods for making metal, the technological level documented at the western Phoenician colonies is not very different from the one known for previous periods.

At the beginning of the 1st millennium BC, ceramic vessels were still used to not only melt and alloy metals but for smelting ores as well, according to a tradition that in the Iberian Peninsula dates back to the end of

Fig. 1: Localization of the Phoenician site of La Fonteta.



the 5th millennium BC (Ruiz-Taboada & Montero-Ruiz 1999: 210). This tradition characterised copper-based metallurgy during the whole Bronze Age in Iberia and is documented until the Late Iron Age (Rovira-Llorens 2005; 2007).

In contemporary Near Eastern settlements, there is no evidence for the use of metallurgical vessels for primary production. This production method was carried out since the 3rd millennium BC with a more developed technology that employed complex furnaces to tap out the slag (Hauptmann 2007). Nevertheless, this advanced technology for obtaining copper was not introduced in the western Phoenician world. In the Iberian Peninsula tap slags are not documented until approximately the Roman period and, as mentioned before, the most common method of making copper-based metals is by the use of crucibles (Rovira-Llorens & Ambert 2002; Rovira-Llorens 2005; Renzi 2013: 201).

The Phoenician site of La Fonteta (Guardamar del Segura, Alicante), founded at the beginnings of the 8th century BC and abandoned in the mid-6th century BC[1], offers a good example of how common the use of metallurgical vessels is at the time. It yielded more than 200 fragments of ceramic vessels related to metal production, mainly for making bronze but also for copper smelting activities. This assemblage is the largest set of crucibles known so far on any Phoenician site.

La Fonteta is located inside the Natural Park of the sand dunes of Guardamar, on the right bank of the Segura estuary, 28 km south of Alicante (Fig. 1). It was a coastal settlement, although at present it is situated approximately 500 m from the sea due to coastal geological changes in the area (González-Prats 1999). This clear strategic position on the coast and next to a river ensured a good control over both a regional and a wider trade, as well as access to the natural resources available in the hinterland.

The habitat is surrounded by an impressive defence system with a possible original height of more than 12 m and a base thickness that goes up to 7 m. The construction of this wall allowed the archaeologists to set a clear distinction between two main occupation periods of the site: one before the erection of the precinct, called Archaic Fonteta (AF), and a later one that corresponds with Recent Fonteta (RF) (González-Prats 1999).

AF spans from the beginnings of the occupation sequence to the third quarter of the 7th century BC and includes phases I–III, while RF goes from the last quarter of the 7th century to the middle of the 6th century BC (phases IV–IX). In this last phase, the site was abandoned probably due to a major sand dune invasion that affected the settlement and its surroundings (González-Prats 2011).

During the archaeological excavations at the site, evidence of metal production activities –such as fire structures, slags and other debris – have been documented in several rooms. Metallurgy seems to have been an important aspect of La Fonteta's economy during its entire occupation sequence, although the majority of this evidence can be ascribed to the archaic phase (AF). The discovery of metallurgical waste deposits in some sectors dated to phases I-III noticeably increased the number of finds belonging to the archaic period (AF), providing a varied set of archaeological materials related to the production of both non-ferrous metals (copper, copper alloys, lead and silver) and of iron. The outstanding volume of finds – more than 400 fragments of tuyères, 200 parts of metallurgical vessels, 60 fragments of moulds and abundant slags (approximately 100 kg) – suggests that we are not dealing with a production for local consumption, but the final products were integrated in wider commercial networks (Renzi 2013). This feature of La Fonteta's economy is especially interesting if we consider that the settlement is situated in an area in which there are no known mineral deposits, at least not in its immediate surroundings (Renzi *et al.* 2009: 2588-2589).

Regarding RF, this period hardly provided any structural remains related to metallurgical activities, and the quantity of by-products collected, mainly slags and melting wastes, is appreciably lower than in the previous period. However, the size of the area excavated to date is still relatively small and it is not possible to determine if the difference recorded in the number of metallurgical finds between the two big occupation periods of La Fonteta (AF and RF) reflects a change in its economy or if metal production during RF was carried out in a different area of the site.

Metallurgical vessels: a typological classification

Although no complete crucibles have been found at La Fonteta, the large number of rims documented (approximately 50% of the finds) shows a broad typological variety, with different size and wall thickness. The majority of them are open vessels, circular in shape with a hemispheric body, but also deep crucibles have been documented. The diameter and the capacity are variable, and so are the types of rim and the thickness. Some crucibles show singular features such as pouring spouts, developed bases, handles and "ears" on the rim with a piercing, possibly for lifting and manipulating the crucible. However, due to the size of the fragments, it has not always been possible to determine their original dimensions and shape.

A superficial vitrification or a slaggy layer, of up to 1 cm in thickness, is present on the internal wall in a great many of these vessels. In all cases, these vessels were heated from inside. We also have two specimens that show clear evidence of having been re-used at least twice (Fig. 2). In one case (F50299), the used vessel was covered with a new layer of clay that clearly protrudes more than 1 cm from the rim of the orig-

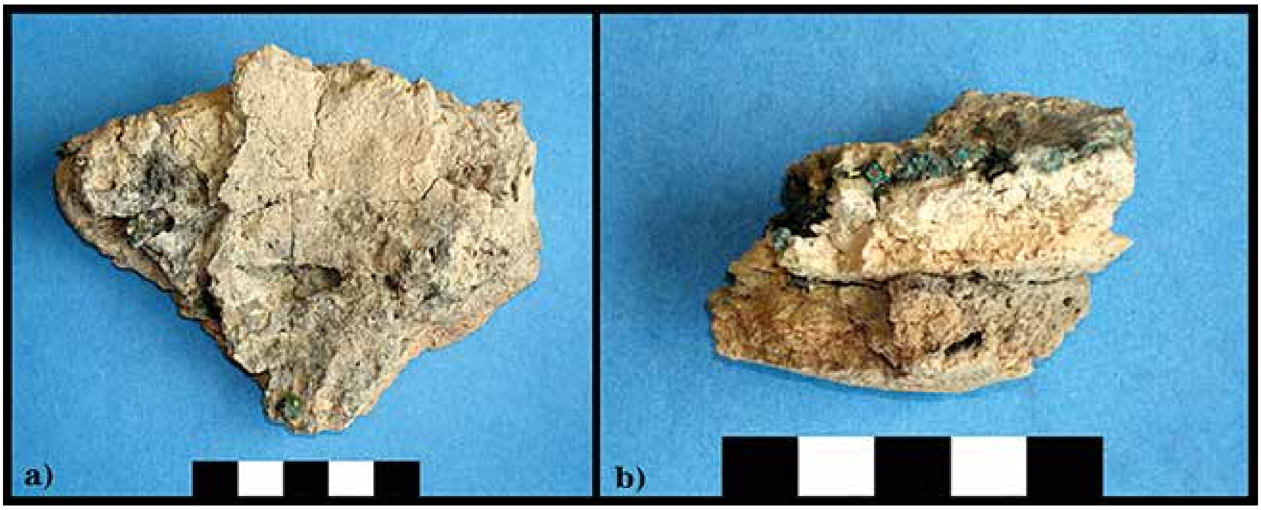
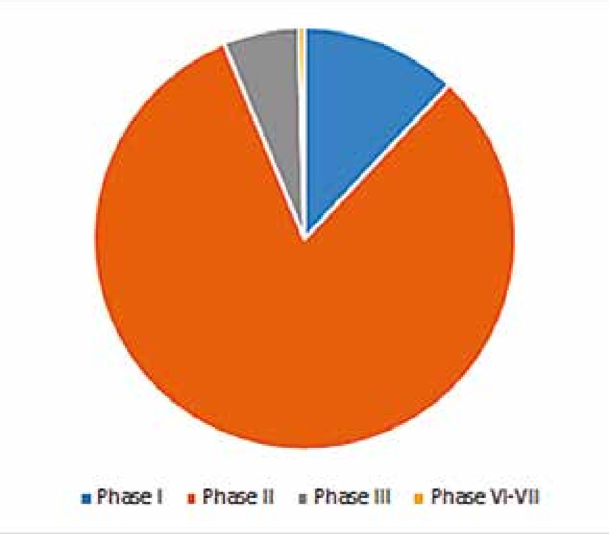


Fig. 2: Re-used metallurgical vessels from La Fonteta: a) F50299; b) F31204.

inal vessel (Fig. 2a), while in the other case (F31204) two overlapped used vessels can be observed (Fig. 2b).

With respect to the fabric used for manufacturing the metallurgical vessels from La Fonteta, two main types have been identified, in accordance to what has been documented for the tuyères (Renzi 2007; 2013: 93-100). The first one is characterized by reddish coarse clay mixed with little organic material and abundant mineral temper visible to the naked eye, including quartz grains (from now on reddish type). The second type has a lighter colour, varying from pinkish to beige, and with a more homogenous texture; in general, the clay is finer and is mainly tempered with organic material (beige type). In the section of some specimens, we can observe the colour of the fabric varying from light red/beige to dark grey, due to the thermal impact of the metallurgical process. When observing the colour and texture of the fabric of other specimens, it appears that they have only been exposed a little to fire and, in some cases; the thermal reaction of the clay is not visible on the preserved fragment.

Fig. 3: Chart showing the chronological distribution of the crucible fragments belonging to AF versus the ones from RF.



As far as the chronological distribution of the crucibles' fragments along the occupation sequence of the site is concerned, almost all of them can be assigned to the Archaic period (AF), in a similar way as the rest of the metallurgical materials collected at La Fonteta. The highest concentration of finds has been registered in Phase II (Fig. 3), and it seems that this intense metallurgical activity progressively decreases from Phase III onwards, being very scarce and almost inactive in the later occupation periods of the site.

However, it should be noted again that this view might not reflect the real situation as only a small part of the settlement has been excavated so far. Furthermore, regarding the total number of fragments found at La Fonteta, it cannot be excluded that some of them are part of the same vessels. This has been born in mind during the quantification of the fragments but in most cases, due to their small size, it could not be clearly determined. Only three fragments (F21124, F31127 and F31129) have been recognized as parts of the same crucible, based on the thickness of the walls, the fabric used and the nature of the slagged layer adhering to their inner surface (Renzi 2013: 120, Fig. 7.21). In addition, as we will see further on, the XRF analysis of the slagged layer on two of those fragments, F21124 and F31127 (F31129 could not be analysed), shows practically the same composition (Table 10), confirming what their macroscopic examination suggested. In this case, the three fragments have been counted as one.

Within the set of the metallurgical vessels collected at La Fonteta, more than 100 fragments correspond to rims, but only few have a recognizable profile or present diagnostic features that allowed us to propose a typological classification. Approximately 60 fragments have been selected for this study, including the biggest fragments of rim and the ones with specific characteristics.

Three main groups have been established according to the type of rim observed:

R1: flat rims (6 fragments)

R2: round rims (13 fragments)

R3: beveled rims (6 fragments)

Another attempt of classification established groups on the basis of certain diagnostic features that help to define their original morphology, such as the presence of a developed/straight base, a pouring spout, or handles.

DF1: with pouring spouts (4 fragments)

DF2: with handles or “ears” (13 fragments)

DF3: with a developed base (3 fragments)

DF4: cup-like vessels with a flat base (11 fragments)

Nevertheless, due to the lack of complete vessels and the often small size of the fragments, this classification has to be interpreted only as tentative. In fact, the great majority of the fragments that present one of the above-mentioned characteristics used to classify them in a certain group do not have the rim preserved. This does not allow establishing a correspondence between the type of rim and other diagnostic elements visible on a specific fragment (i.e. handles and a developed base). Only group DF2 has two specimens that preserved their rim and in both cases it is of the round type (R2), suggesting the existence of a positive relation between the presence of a certain diagnostic feature and a specific type of rim. However, with the information available so far, the proposed groups can only be interpreted as a tool for examining the main characteristics of the varied typologies of crucibles identified at La Fonteta.

Table 1: Summary of the main characteristics of the fragments belonging to groups R1-R3, established according to the type of rim.

Sample	Group	Rim type	Diameter	Wall thickness	Fabric
F21121	R1A	Flat	n/a	06 mm	Reddish
F50258	R1A	Flat	14 cm	08 mm	Beige
F11094	R1A	Flat	n/a	10 mm	Reddish
F10085	R1A	Flat	18 cm	10.2 mm	Reddish
F50299	R1A	Flat	18 cm	10.5 mm	Reddish
F50291	R1B	Flat	n/a	25 mm	Beige
F31099	R2A	Round	12 cm	07 mm	Reddish
F41402	R2A	Round	12 cm	08 mm	Beige
F41548	R2A	Round	12 cm	08 mm	Beige
F50161	R2A	Round	14 cm	09 mm	Reddish
F22200 bis	R2A	Round	18 cm	09.5 mm	Beige
F41526	R2A	Round	18 cm	10 mm	Reddish
F41741	R2A	Round	n/a	10 mm	Beige
F21134	R2A	Round	14 cm	10.3 mm	Beige
F12739	R2B	Round	n/a	11.5 mm	Beige
F62030	R2B	Round	15 cm	12 mm	Beige
F41531	R2B	Round	21 cm	14 mm	Beige
F41575	R2B	Round	20 cm	17 mm	Beige
F50261	R2	Round	n/a	n/a	Beige
F50165	R3A	Bevelled	n/a	06 mm	Beige
F50621	R3A	Bevelled	10 cm	06 mm	Beige
F62062	R3A	Bevelled	16 cm	10 mm	Beige
F41410-1	R3B	Bevelled	20 cm	14 mm	Beige
F41374	R3B	Bevelled	n/a	19 mm	Beige
F41585	R3B	Bevelled	n/a	22 mm	Beige

Regarding the three groups of vessels identified based on rim morphology, a different thickness of walls has been observed in each of them, forming two main variants:

A: thin walls (from 6 mm up to 10.5 mm)

B: thick walls (in the range between 11.5 mm and 25 mm)

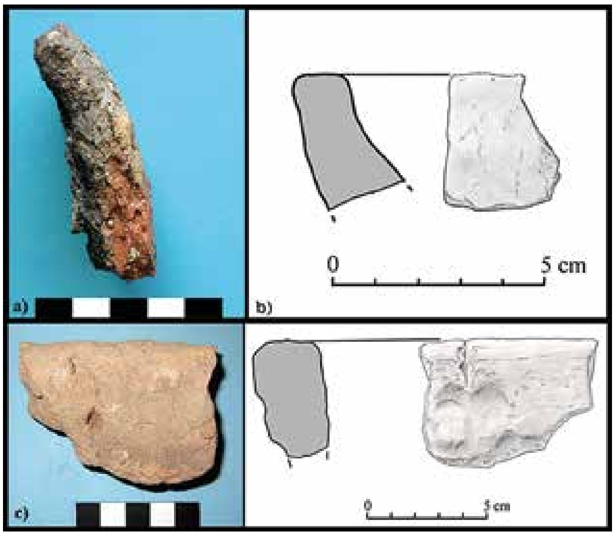
The main characteristics of the specimens belonging to each group are summarized in Table 1, including the thickness of the walls, the diameter (where it has been possible to measure it) and the type of fabric used for manufacturing the crucibles.

In general, the variability of all the characteristics is quite high. The diameters vary between 10 and 21 cm while the thickness of the walls ranges from 6 to 25 mm. Not even the use of one of the two types of clay seems to correspond to a standardized choice. In almost all groups and their variants A-B, there is an undifferentiated use of both fabrics.

Concerning group **R1**, the body of the vessels with flat rims and thin walls (R1A) seems to be hemispheric (Fig. 4a), although the small size of the fragments does not allow us to determine precisely their original morphology. The diameters vary between 14 and 18 cm.

Variant R1B includes only one specimen characterized by much thicker walls (Fig. 4b), measuring around 25 mm. Furthermore, the straight walls of the preserved part suggest that we are not dealing with a hemispheric vessel as in the case of variant R1A, but it could be oval shaped or oblong.

Fig. 4: Crucible fragments belonging to group R1: a) F21121 (R1A); b) F11094 (R1A); c) F50291 (R1B). Drawings: Félix García Díez.



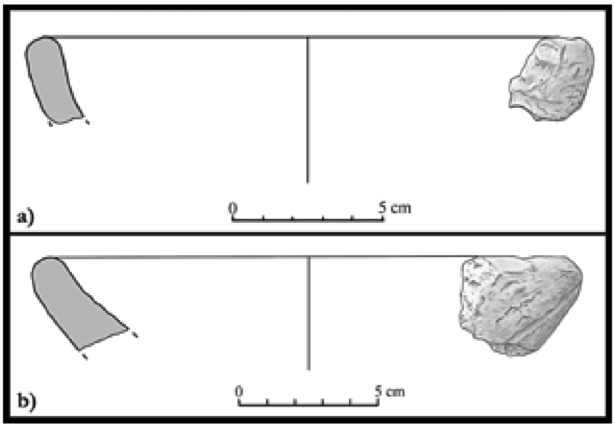


Fig. 5: Crucible fragments belonging to group R2: a) F22200 bis; b) F41526. Drawings: Félix García Díez.

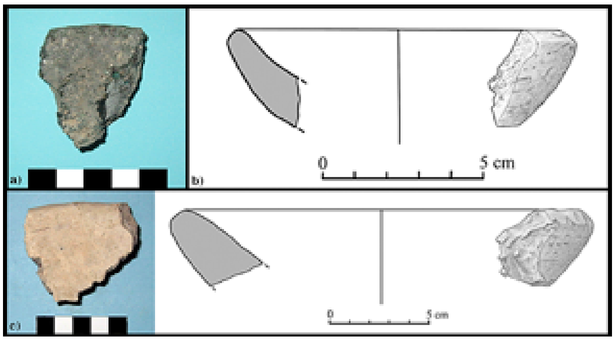
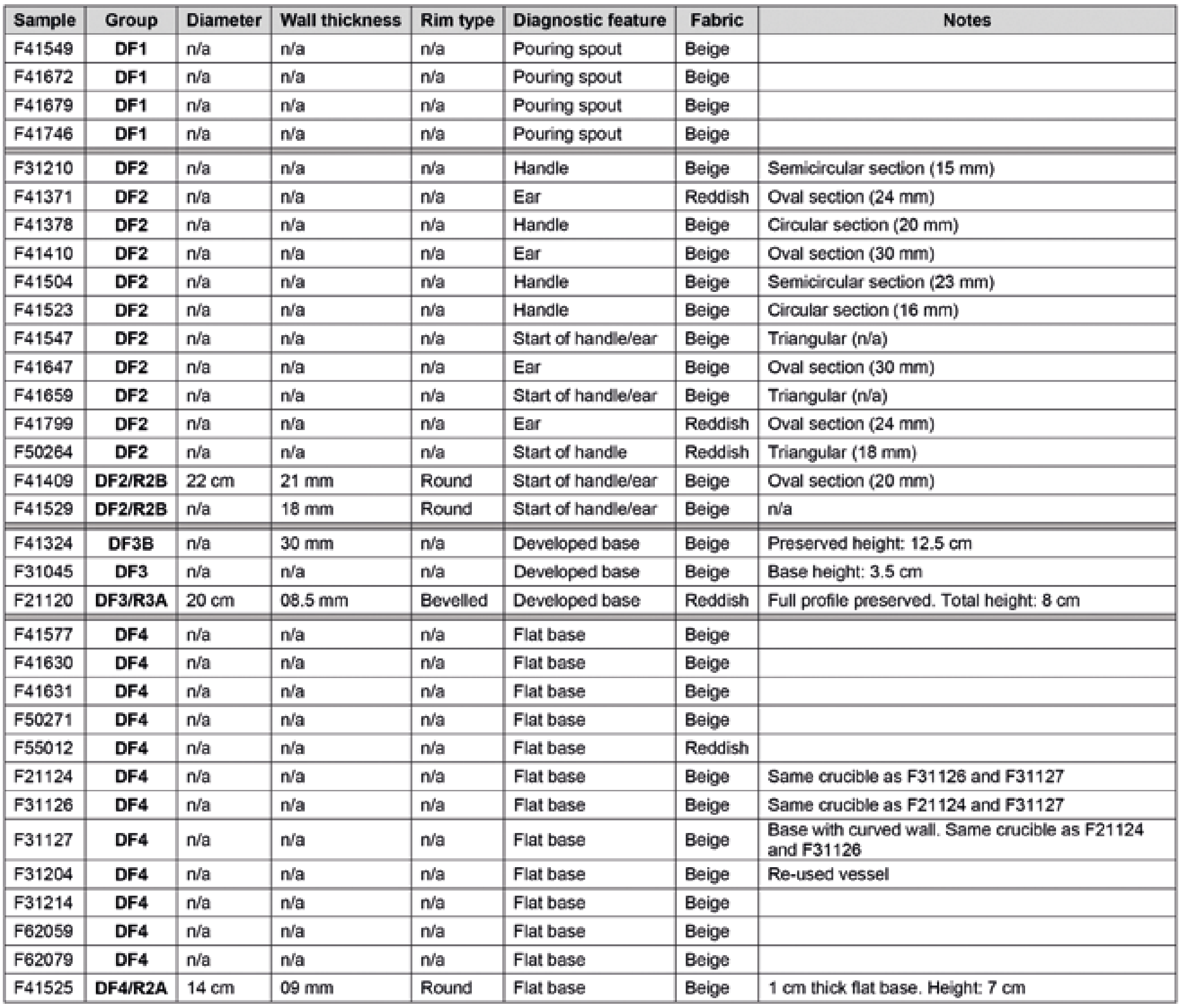


Fig. 6: Crucible fragments belonging to group R3: a) F50165 (R3A); b) F50621 (R3A); c) F41410-1 (R3B). Drawings: Félix García Díez.

R2 includes vessels with a round rim that show both thin (R2A) and thick walls (R2B). In all cases, these are open vessels with a bowl-like shape (Fig. 5a-b). The diameters vary between 12 and 18 cm for R2A, and between 15 and 21 cm for R2B.

Vessels with a bevelled rim form group **R3** (Fig. 6). Variant R3A shows diameters of 10-16 cm while the only fragment of variant R3B in which it could be measured,

Table 2: Summary of the main characteristics of the fragments belonging to groups DF1-DF4, established according to the type of rim.



Sample	Group	Diameter	Wall thickness	Rim type	Diagnostic feature	Fabric	Notes
F41549	DF1	n/a	n/a	n/a	Pouring spout	Beige	
F41672	DF1	n/a	n/a	n/a	Pouring spout	Beige	
F41679	DF1	n/a	n/a	n/a	Pouring spout	Beige	
F41746	DF1	n/a	n/a	n/a	Pouring spout	Beige	
F31210	DF2	n/a	n/a	n/a	Handle	Beige	Semicircular section (15 mm)
F41371	DF2	n/a	n/a	n/a	Ear	Reddish	Oval section (24 mm)
F41378	DF2	n/a	n/a	n/a	Handle	Beige	Circular section (20 mm)
F41410	DF2	n/a	n/a	n/a	Ear	Beige	Oval section (30 mm)
F41504	DF2	n/a	n/a	n/a	Handle	Beige	Semicircular section (23 mm)
F41523	DF2	n/a	n/a	n/a	Handle	Beige	Circular section (16 mm)
F41547	DF2	n/a	n/a	n/a	Start of handle/ear	Beige	Triangular (n/a)
F41647	DF2	n/a	n/a	n/a	Ear	Beige	Oval section (30 mm)
F41659	DF2	n/a	n/a	n/a	Start of handle/ear	Beige	Triangular (n/a)
F41799	DF2	n/a	n/a	n/a	Ear	Reddish	Oval section (24 mm)
F50264	DF2	n/a	n/a	n/a	Start of handle	Reddish	Triangular (18 mm)
F41409	DF2/R2B	22 cm	21 mm	Round	Start of handle/ear	Beige	Oval section (20 mm)
F41529	DF2/R2B	n/a	18 mm	Round	Start of handle/ear	Beige	n/a
F41324	DF3B	n/a	30 mm	n/a	Developed base	Beige	Preserved height: 12.5 cm
F31045	DF3	n/a	n/a	n/a	Developed base	Beige	Base height: 3.5 cm
F21120	DF3/R3A	20 cm	08.5 mm	Bevelled	Developed base	Reddish	Full profile preserved. Total height: 8 cm
F41577	DF4	n/a	n/a	n/a	Flat base	Beige	
F41630	DF4	n/a	n/a	n/a	Flat base	Beige	
F41631	DF4	n/a	n/a	n/a	Flat base	Beige	
F50271	DF4	n/a	n/a	n/a	Flat base	Beige	
F55012	DF4	n/a	n/a	n/a	Flat base	Reddish	
F21124	DF4	n/a	n/a	n/a	Flat base	Beige	Same crucible as F31126 and F31127
F31126	DF4	n/a	n/a	n/a	Flat base	Beige	Same crucible as F21124 and F31127
F31127	DF4	n/a	n/a	n/a	Flat base	Beige	Base with curved wall. Same crucible as F21124 and F31126
F31204	DF4	n/a	n/a	n/a	Flat base	Beige	Re-used vessel
F31214	DF4	n/a	n/a	n/a	Flat base	Beige	
F62059	DF4	n/a	n/a	n/a	Flat base	Beige	
F62079	DF4	n/a	n/a	n/a	Flat base	Beige	
F41525	DF4/R2A	14 cm	09 mm	Round	Flat base	Beige	1 cm thick flat base. Height: 7 cm

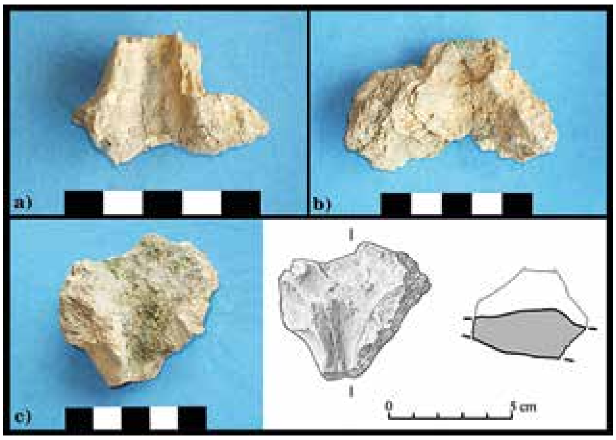


Fig. 7: Fragments of pouring spouts, forming group DF1: a) F41549; b) F41672: c) F41746 and F41679. Drawing: Félix García Díez.

has a diameter of 20 cm. The morphology of these crucibles is similar to the one of R2; most of them are bowl-shaped although the thickest fragment of R3B (with a wall thickness of 22 mm) could be part of a deeper vessel.

Regarding the grouping based on other diagnostic features, their main characteristics – including dimensions, diameter and type of fabric used – are shown in Table 2.

The fragments of pouring spouts form **DF1** (Fig. 7). This feature is normally associated with melting crucibles, as the spout would help to pour the metal more precisely into the moulds.

All identified fragments have been manufactured with clay of the beige type. The different size and width of those spouts suggest we are dealing with receptacles of various dimension and probably also with different types of vessels (Table 2). However, the lack of preserved body walls or rims does not allow one to propose a possible reconstruction of the morphology of those vessels.

Fig. 8: Fragments of handles and “ears”, forming group DF2: a) F31210, F41523; b) F41378, F41504; c) F41371, F41799; d) F41647.

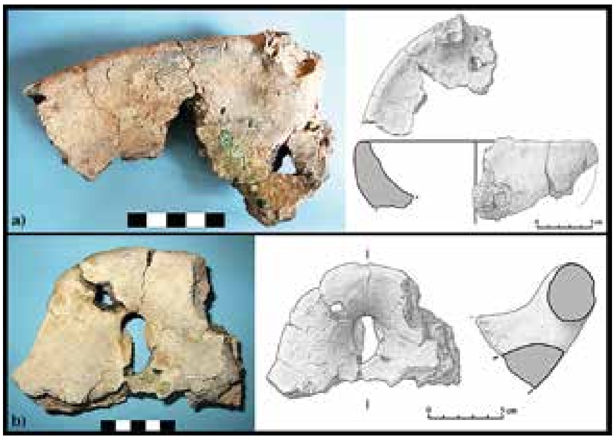


Fig. 9: Crucibles with “ears”, group DF2: a) F41409; b) F41410. Drawings: Félix García Díez.

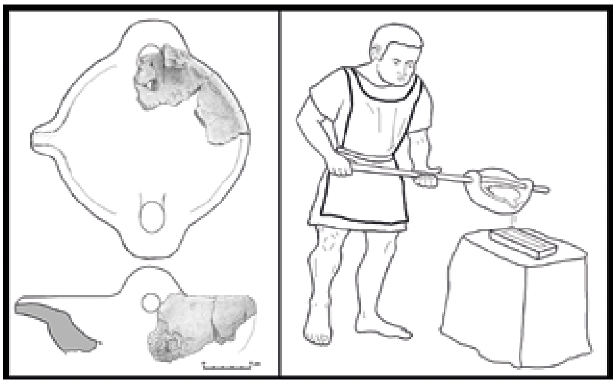
DF2 includes the fragments of handles and “ears”, features that would have helped to manipulate the vessels in an easier way (Table 2).

According to the characteristics of the fragments preserved, two different types of systems for handling the crucibles can be identified: small handles that have semi-circular or circular sections, and other elements of approximately circular shape with a central piercing and flattish-oval sections. The latter, that we have named “ears”, are bigger in size than the handles (Fig. 8).

Also for this group, no remains of the profile of the vessels are preserved. In fact, handles are fragile elements that easily break in the junction point with the vessel’s body, hindering the possibility of determining their original morphology. Nevertheless, it is likely that both the handles and the “ears” were in pairs on the vessels, one opposite to the other. While the small handles could have been located on either the walls or the rim of the crucible, according to the fragments found at La Fonteta, it seems that the “ears” always arise from the rim (Fig. 9).

Figure 10 shows a possible reconstruction of the morphology of these crucibles with “ears” on the rim. The drawing suggests the use of this kind of vessels for

Fig. 10: Possible reconstruction and use of a metallurgical vessel with handles or “ears”. Drawing: Félix García Díez.



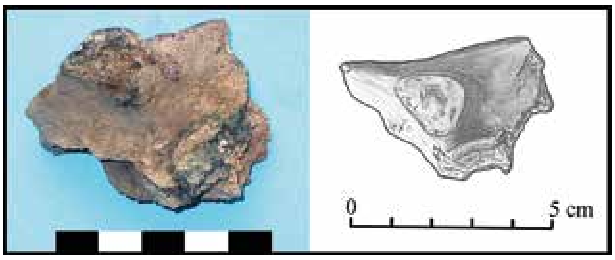


Fig. 11: Crucible with the start of a small nipple-shaped handle (group DF2). Drawing: Félix García Díez.

pouring the metal into a mold by inserting a rod horizontally in the “ears” to manipulate the crucible that, in this case, has a pouring spout like the crucibles DF1, for easing the casting operation.

Concerning the small handles, their size would hamper the insertion of a rod as a handle. Therefore, taking into account the high temperature reached by the ceramic vessel during the metallurgical process, it cannot be hypothesized that these handles were simple elements for picking up and holding it. Probably, thick leather or green sticks would have been used for handling the crucible and, if used in melting operations, for pouring the metal into the moulds. The practice of using green sticks for both removing the vessel from fire and for casting operations is documented by the painting of the famous Egyptian 18th dynasty tomb of Rekhmire at Thebes (Davies 1943: plate 52). In the case of the La Fonteta crucibles, the green sticks could have been introduced in the handles forming a loop to lift and hold the vessel.

In addition, another fragment (F50264) has different characteristics and could possibly document a third system of handling the crucible. It is the start of a small handle with a triangular section (Fig. 11) manufactured with fabric of the reddish type and recalls the nipple-shaped appendixes known on pottery from Neolithic and Bronze Age peninsular contexts.

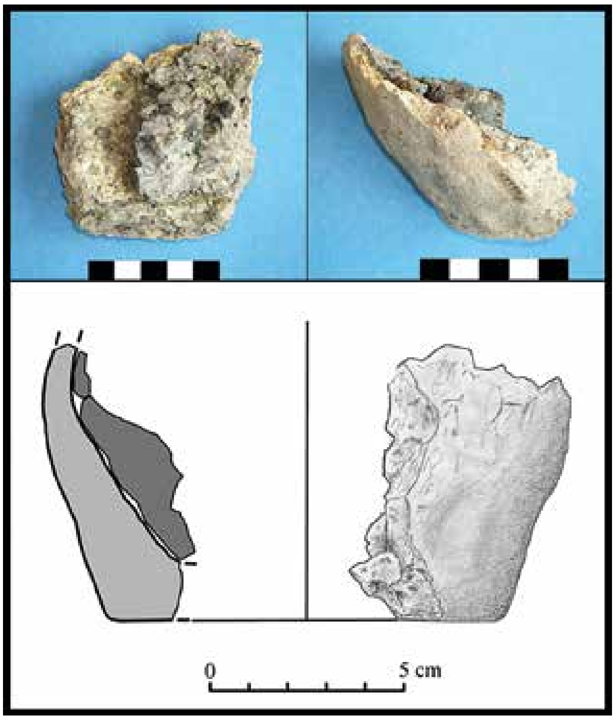
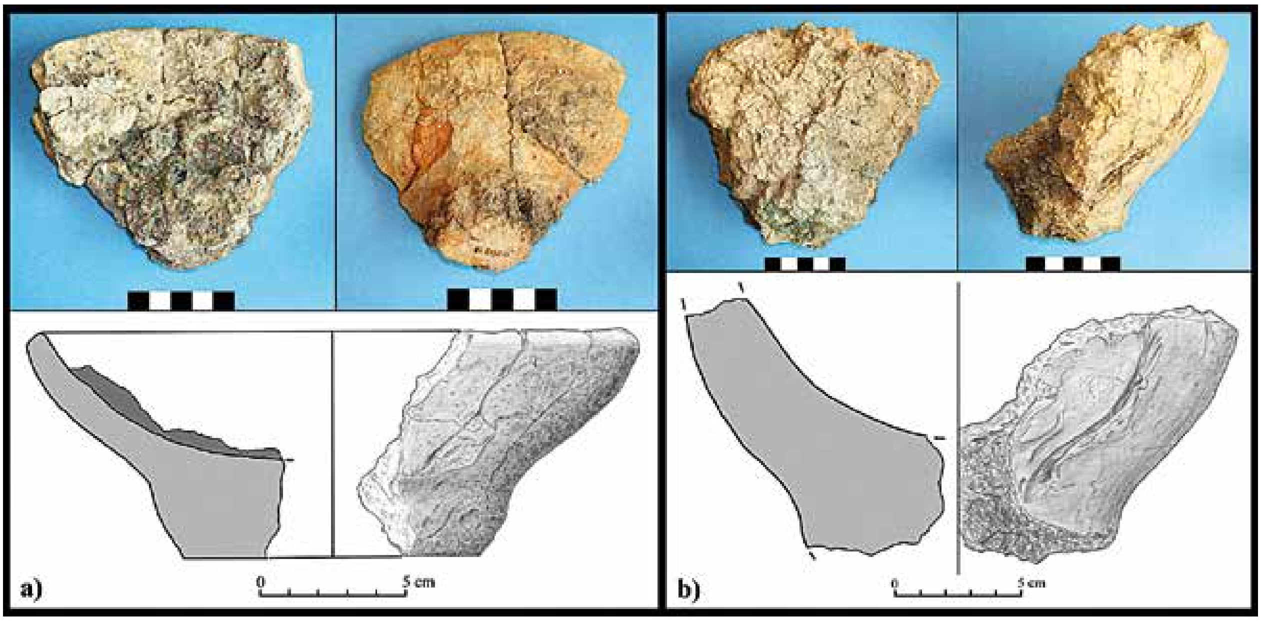


Fig. 13: Crucible belonging to group DF4: F41525. Drawing: Félix García Díez.

DF3 is formed by crucibles with a flat developed base (Fig. 12). In general, the lack of profile of these vessels does not allow a reconstruction of their original morphol-

Fig. 12: Crucibles belonging to group DF3: a) F21120 (DF3A); b) F41324 (DF3B). Drawings: Félix García Díez.



ogy. However, in two cases there is almost half a section of the crucible preserved, and one of them corresponds to a bowl-shaped vessel (Fig. 12a) and the other one to a more closed form, like a "cup" (Fig. 12b).

The bowl-shaped vessel has a bevelled rim, thin walls and a diameter of approximately 20 cm, while in the case of the "cup" there is no rim preserved and the walls are noticeably thick, around 30 mm (Table 2).

Finally, group **DF4** includes vessels with a cup-like morphology and a flat base. Twelve fragments have been attributed to this group but, as mentioned before, two of them are part of the same vessel, reducing the number of specimens with this shape to eleven (Table 2). Only in one case (F41525) there is a large portion of vessel preserved that suggests its original morphology. The walls are thin and show a central marked curve that narrows towards the rim, of which only a small fragment is still visible (Fig. 13). This is of the round type and the diameter of the vessel is approximately 14 cm.

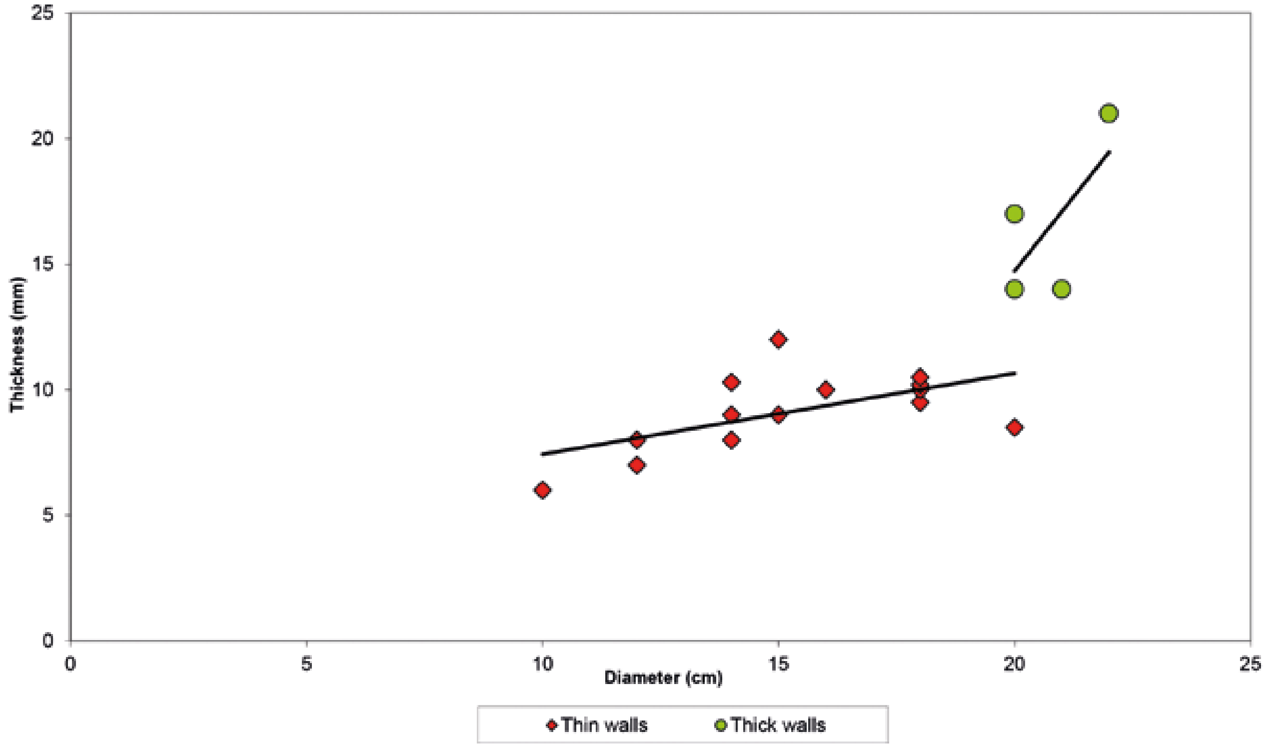
The other fragments just preserve part of the base with, in some cases, the start of the body vessel. As for the rims, this assemblage highlights the variety of typology, dimension and thickness of the walls of the metallurgical vessels used at La Fonteta.

In this group a fragment with evidence of re-use has also been identified (F31204). It is a base with two overlapped layers of slag (see Fig. 2b). The base of the original vessel shows a thin metal-rich layer of slag that was covered and reshaped with abundant fresh clay. This new base is highly slagged, forming a layer that is more than 1 cm thick.

Concerning possible parallels for the types of crucibles documented at La Fonteta, the typology of groups R1-3, which include mainly bowl-shaped vessels with different kinds of rims, are commonly used for both smelting and melting metals in antiquity (Tylecote 1976: 184; Mohen 1992: 121; Bayley & Rehren 2007: 48-49). Oval shaped vessels were also used at the site, as suggested by one specimen included in variant R1B. This type of crucible has been documented in several settlements of the 4th and 3rd millennia BC, as for example at Zambujal in Portugal (Müller *et al.* 2007), Valencina de la Concepción in the Seville province (Nocete *et al.* 2008), or at Cabezo Juré (Alosno) in the Huelva area (Nocete 2006). However, one specimen is also known in a context contemporary of La Fonteta. It has been found at El Cabezo de la Fuente del Murtal (Alhama de Murcia, Murcia), a site with a strong Phoenician influence in its material culture (Lomba & Cano 1996: 196). It is a fragment of a vessel with a flat base and a small portion of preserved wall, suggesting a lower thickness compared to the fragment from La Fonteta.

With respect to the other diagnostic features examined here, vessels with pouring spouts (DF1) have been found in several Iberian metallurgical sites. The most

Fig. 14: Diagram that shows the correlation between the thickness of the walls and the diameters of the vessels from La Fonteta.



ancient examples have been collected in contexts of the Early Bronze Age, such as the ones from Minferri (Juneda) in the Lleida province (López-Melción & Moya-Garra 2009), and from Rillo de Gallo in the Guadalajara area (Redondo et al. 1989). This type of vessel became more widespread during the Middle and Late Bronze Age, as shown by the numerous assemblages of crucibles found at El Argar (Siret & Siret 1890), among others.

Some fragments are also known in Late Bronze Age/ Early Iron Age contexts, as for example the one from the Portuguese site of Entre Águas 5 in Serpa (Rebelo *et al.* 2009; Valério *et al.* 2013). Nevertheless, only one fragment has been collected in a Phoenician context, namely at Morro de Mezquitilla (Algarrobo, Málaga) where a thick-walled metallurgical vessel with the start of a slagged pouring spout was found (Schubart 2006).

Concerning DF2, which includes the vessels with handles and "ears", no crucibles with similar features are known in the Iberian Peninsula so far. However, in the Bronze Age, different systems for handling the crucibles have been documented at several sites, as for example vessels with a socket handle or a socket developed base where a rod would have been inserted.

One example of this type of vessel has been collected at Cerro de la Mora (Granada), dated to the end of the 2nd millennium-beginning of the 1st millennium BC. This is a bowl-shaped vessel with a protuberance with a central squared hole as a handle (Carrasco & Pachón 2006). A variant of these socketed handle crucibles comes from a Late Bronze Age-Early Iron Age site in the Madrid province, Las Camas (Villaverde). In this case, the handle is a flared protuberance with a round section and a central squared hole (1x1 cm in size). Only a small part of the vessel is preserved and the original shape cannot be reconstructed, although the curve of the preserved fragment suggests it was a small bowl-shaped crucible with a possible diameter of 8 cm approx. (Urbina *et al.* 2007).

Concerning the fragment of crucible with a handle interpreted as a nipple-shaped appendix, its closest parallel comes from an earlier context, namely from the argaric site of El Pic de les Moreres (Crevillente, Alicante) (González-Prats 1986; Simón 1996). In addition to this fragment, and according to the description provided by Keesmann *et al.* (1989: 101-102), a vessel with a similar handle could come from the Phoenician site of Toscanos (Vélez, Málaga), although it is difficult to confirm it as no drawing or picture of the fragment was published.

Examples of metallurgical vessels with small protuberances possibly used as handles are known also outside the Iberian Peninsula, as for example the ones found in some metallurgists' tombs in the Kalinovka necropolis (Volgograd, Russia) and in the Tomb 7 of Tumulus 2 of Malaya Ternovka necropolis (Zaporizka, Ukraine), dated to the end of the 3rd/beginning of the 2nd millennium BC (Mohen 1991).

The case of some crucibles collected at Mozartstrasse (Zurich) dated to the 4th millennium BC is worth mentioning. These vessels present a tongue-shaped appendix that protrudes horizontally from the rim forming a sort of handle (Fasnacht 1991).

With regards to the last two groups of vessels DF3 and DF4, very few parallels are known.

For DF3 the only similar find comes from the Early Bronze Age site of Can Roqueta II (Sabadell, Barcelona). This is a small metallurgical cup-like vessel with a truncated cone-shaped base (Rovira-Hortalà 2006; Rovira-Hortalà *et al.* 2007).

No crucibles comparable to the ones forming DF4 have been found in the Iberian Peninsula so far. Flat bases are usually associated with bowl-shaped crucibles but closer forms like the one from La Fonteta are not common in this period. Few examples of conical walled vessels have been documented in Early Bronze Age contexts at Mozartstrasse (Zurich, Switzerland) (Fasnacht 1991: 163; Mohen 1992: 87), Fort-Harrouard en Sorel-Moussel (Eure-et-Loir, France) and in Scandinavia (Mohen 1992). In addition, cylindrical crucibles have been documented in Level VI B2 of Arslantepe (Malatya, Turkey), dated to the first quarter of the 3rd millennium BC (Hauptmann 2007: 229; Di Nocera 2010: 270) but the body vessel is straight and not slightly globular as the specimen from La Fonteta. A similar cylindrical vessel comes from a Late Cypriot context of Enkomi (Dikaios 1969: IIIa, Pl. 159, n. 20; Hauptmann *et al.* 2002: 17), although this one presents a hole at the base and has an unusually large diameter of 54 cm (Dikaios 1969: I, 259).

As a summary, the metallurgical vessels from La Fonteta show a wide and varied morphological set, in some cases with peculiar features like handles, pouring spouts and developed bases. All of them have been heated from inside, as shown by the slaggy layers adhering to their inner surface. The crucibles are hand manufactured with two kinds of fabric that have different colour and characteristics, one being tempered with organic material and the other with a mineral temper. The walls have an irregular thickness and the finish of the internal surface is usually not very fine, though few specimens show a smoother and spatulate surface.

Most of the vessels have a circular mouth and their diameters vary between 10 and 22 cm. As already mentioned, the thickness of the walls is very variable, ranging from 6 mm to 30 mm. Still, as expected, within this variability of values a positive correlation between the diameters and the vessels' walls can be observed: a greater diameter corresponds to thicker walls. Nevertheless, the increase of the diameter is lower in thick-walled vessels. In fact, as the diagram in figure 14 shows, the gradient of the regression line is more marked with respect to the one of the vessels with thin walls. The measured values of the thin-walled crucibles generate a high correlation coefficient, whereas in the other case the correlation, although still positive, is significantly lower.

Analytical study of some crucibles from La Fonteta

The large diversity of typologies of vessels documented at La Fonteta raised the question whether this variety reflects different functions of certain morphologies of crucibles within the *chaîne opératoire* carried out at the site for producing metals. A specific function can be easily pointed out for group DF1, as the presence of a pouring spout makes sense in crucibles employed for melting operations. Unfortunately, it is more complex to determine the function of the other types of vessels as their diagnostic features do not provide clear information regarding their functional use. Handles and "ears" can be used for both removing a crucible from the earth and for pouring the molten metal into a mould, and the shape, the type of base or the different rims are elements than can hardly contribute to this debate.

The nature and the chemical composition of the slagged layers adhering to the inner surface of the crucibles can provide useful information to differentiate between vessels employed in operations for melting metals from those used in processes that involve ores (Rovira-Llorens & Ambert 2002; Rovira-Llorens 2005), such as smelting and active alloying by co-smelting or by cementation. While on the melting crucibles the slag layer would be thinner, often corresponding only to a vitrification of the ceramic with some metallic remains on its surface, smelting vessels would usually show a thicker and more heterogeneous slag.

However, although the morphological characteristics of the slag layers on vessels is a diagnostic element that has to be taken into account for interpreting their function, only an exhaustive analytical study of the different compositional phases of those slags can provide conclusive data to determine the specific use of a crucible. In fact, other factors can contribute to the formation of a thicker slaggy layer, like for example a low-melting ceramic or the use of a particularly "dirty" metal. Also, the part we are examining can play an important role for the correct functional interpretation of the vessel. Crucibles are open reactors, therefore the non-equilibrium conditions of the metallurgical process carried out within them will form a slag whose chemical composition will not be homogenous on the whole surface of the vessel. The information that can be retrieved from the central part, where the main reactions occurred, is not the same as what would be extrapolated by examining the area close to the rim, which might not preserve important information on the nature of the crucible charge (Rademakers & Rehren 2014).

Regarding the assemblage from La Fonteta presented here, some fragments were selected for SEM-EDX analysis with the aim of differentiating between vessels used in the different stages for producing metals. Portable ED-XRF analyses have also been carried out on a larger number of slagged fragments in order to obtain a preliminary approximation of the nature of the metal or metal alloy produced at the site. We also wanted to check whether these results could provide further data for determining whether a positive correlation existed between the typology of the vessel and its function or choice for producing a certain metal/alloy. However, as discussed further on, in most cases the information provided by these pXRF analyses does not offer conclusive data due to the conditions of the analysis and the nature of the samples.

SEM-EDX analyses

The SEM-EDX analyses have been performed at the laboratory of the National Museum of Natural Sciences (MNCN-CSIC) in Madrid using a FEI Quanta 200 scanning electron microscope equipped with an Oxford Instruments Analytical-Inca EDX system.

Ten samples of crucibles were selected for analysis, choosing the fragments with a well-developed slag layer, and the sampling carried out is thus not fully representative of the typological variety of La Fonteta's vessels. It should also be noted that only in a few cases has it been possible to cut samples big enough to include the ceramic part of the vessels. Therefore, it has not always been possible to determine the contribution of the crucible charge to the formation of the slag by examining the difference in the chemical composition of the fabric and the slag.

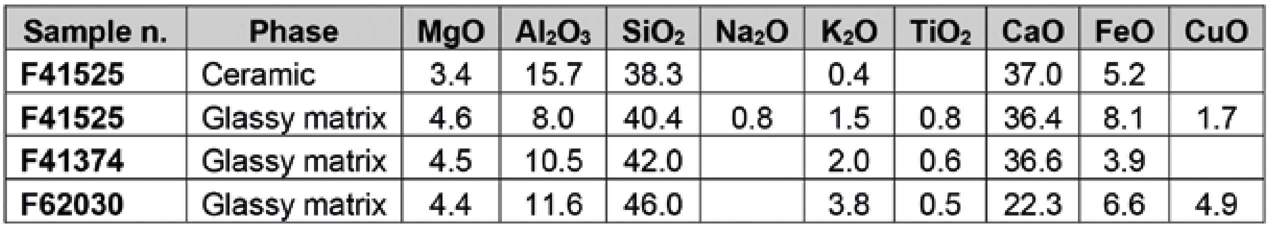
The analysed vessels show that the metallurgists from La Fonteta were producing both unalloyed copper and bronze. In particular, two fragments belong to crucibles employed in copper smelting and one in copper processing; two other samples can be associated to activities for making tin bronzes, four to leaded bronze production and one vessel was possibly used to melt/purify freshly smelted copper. However, although the metal or the alloy processed in the vessels have been identified; some difficulties emerged for determining the different methods used for producing it (see below). It also needs to be born in mind that the proportion of base metals in the slag could lead to a misinterpretation of the composition of the alloy that was processed. In most cases, the slag would show an over-representation of the oxidizing metallurgical conditions, as traces of the reactions that occurred under reduction conditions are less likely to survive on the surface of a crucible. Therefore, the interpretation we can give based on this over-representation of oxidizing episodes can be misleading, especially in the case of a crucible where the working conditions can be very variable. Specifically, elements such as iron, tin or lead would be over-represented in the crucible slag compared to copper due to their preferential oxidation (Dungworth 2000; Kearns *et al.* 2010). However, a careful analytical examination of the data can often provide useful information for offering a correct interpretation of the functional use of a crucible, as well as the general type of alloy processed.

Copper production

The main question that arises when analysing a crucible related to copper production is whether the vessel was used to smelt copper ores, to melt fresh copper metal or if it was employed in recycling operations. Unfortunately, it is not always easy to distinguish between smelting and melting crucibles. In fact, the analytical study of metallurgical vessels used in experiments for smelting ores shows how these operations can leave little residue when high quality ores were exploited (Hauptmann *et al.* 1993; Rovira-Llorens & Ambert 2002; Rehren 2003). Deposits of pure oxidic copper ores such as malachite and cuprite are quite widespread in Spain and, according to the very small quantity of slags documented in Chalcolithic and Bronze Age contexts, they were the main resource used for producing copper (Rovira-Llorens 2005).

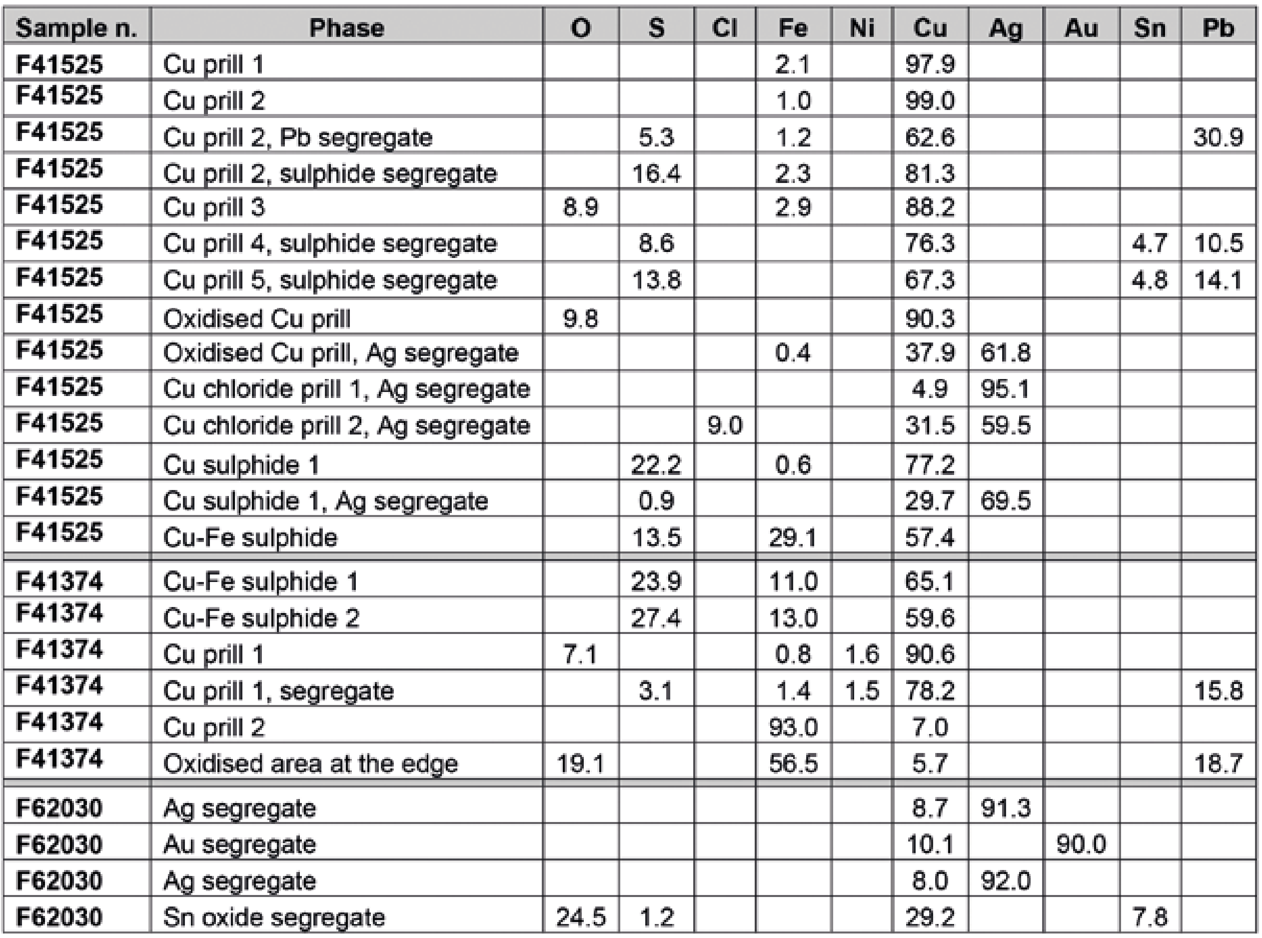
The slagged layers on the crucibles from La Fonteta are not an exception and their microstructure and chemical composition do not provide clear evidence for classifying them as clear smelting or melting crucibles. In all samples, the glassy matrix is a melilite-like material that in two cases retained some copper (Table 3). However, observing the composition of the met-

Table 3: SEM-EDX results (%wt) of the glassy matrix and the ceramic of the samples associated with copper production.



Sample n.	Phase	MgO	Al_2O_3	SiO_2	Na_2O	K_2O	TiO_2	CaO	FeO	CuO
F41525	Ceramic	3.4	15.7	38.3		0.4		37.0	5.2	
F41525	Glassy matrix	4.6	8.0	40.4	0.8	1.5	0.8	36.4	8.1	1.7
F41374	Glassy matrix	4.5	10.5	42.0		2.0	0.6	36.6	3.9	
F62030	Glassy matrix	4.4	11.6	46.0		3.8	0.5	22.3	6.6	4.9

Table 4: SEM-EDX results (%wt) of the composition of the metal prills and sulphide inclusions identified in the samples associated with copper production.



Sample n.	Phase	O	S	Cl	Fe	Ni	Cu	Ag	Au	Sn	Pb
F41525	Cu prill 1				2.1		97.9				
F41525	Cu prill 2				1.0		99.0				
F41525	Cu prill 2, Pb segregate		5.3		1.2		62.6				30.9
F41525	Cu prill 2, sulphide segregate		16.4		2.3		81.3				
F41525	Cu prill 3	8.9			2.9		88.2				
F41525	Cu prill 4, sulphide segregate		8.6				76.3			4.7	10.5
F41525	Cu prill 5, sulphide segregate		13.8				67.3			4.8	14.1
F41525	Oxidised Cu prill	9.8					90.3				
F41525	Oxidised Cu prill, Ag segregate				0.4		37.9	61.8			
F41525	Cu chloride prill 1, Ag segregate						4.9	95.1			
F41525	Cu chloride prill 2, Ag segregate			9.0			31.5	59.5			
F41525	Cu sulphide 1		22.2		0.6		77.2				
F41525	Cu sulphide 1, Ag segregate		0.9				29.7	69.5			
F41525	Cu-Fe sulphide		13.5		29.1		57.4				
F41374	Cu-Fe sulphide 1		23.9		11.0		65.1				
F41374	Cu-Fe sulphide 2		27.4		13.0		59.6				
F41374	Cu prill 1	7.1			0.8	1.6	90.6				
F41374	Cu prill 1, segregate		3.1		1.4	1.5	78.2				15.8
F41374	Cu prill 2				93.0		7.0				
F41374	Oxidised area at the edge	19.1			56.5		5.7				18.7
F62030	Ag segregate						8.7	91.3			
F62030	Au segregate						10.1		90.0		
F62030	Ag segregate						8.0	92.0			
F62030	Sn oxide segregate	24.5	1.2				29.2			7.8	

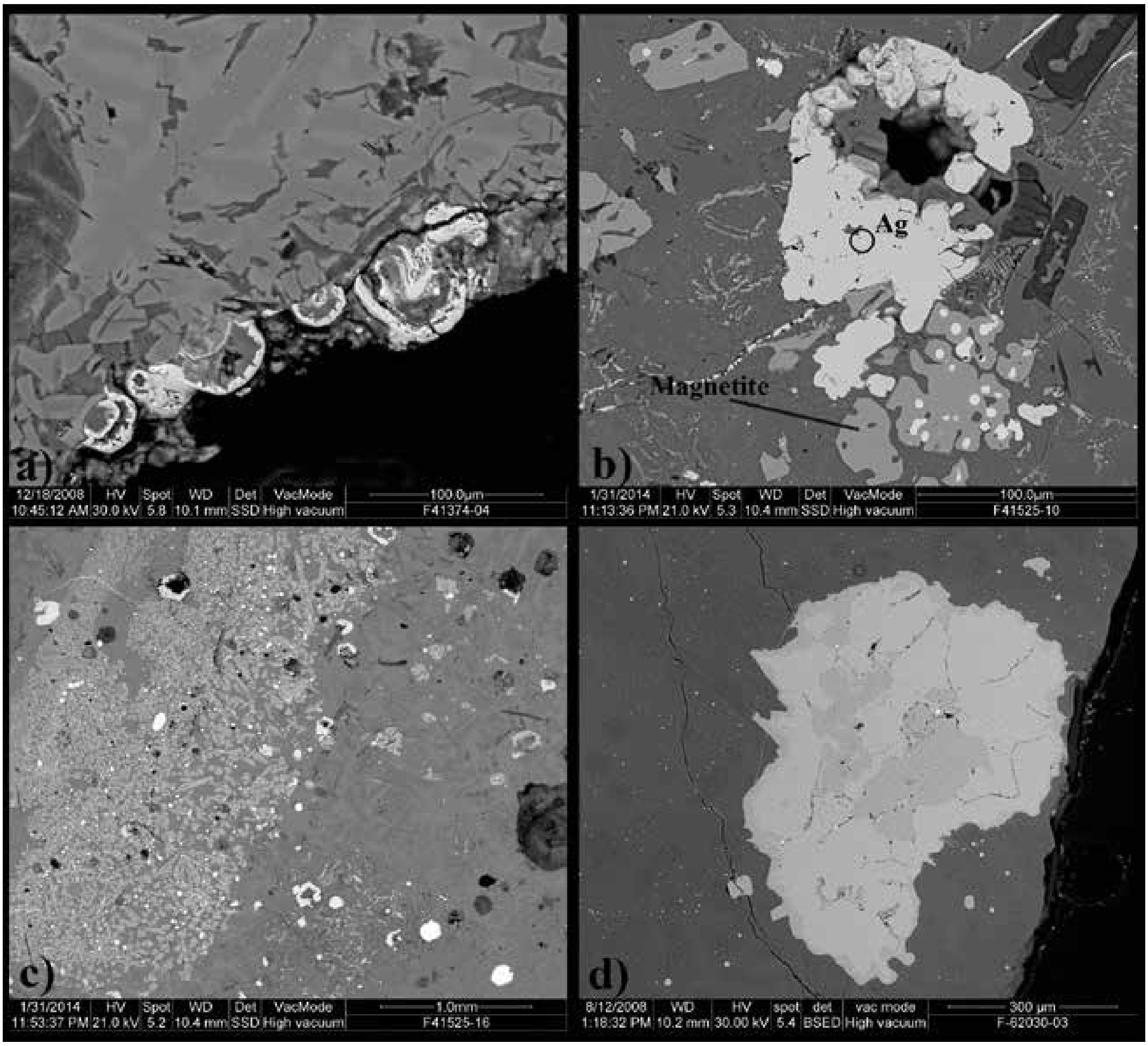


Fig. 15: SEM images of some of the phases identified in the slagged layers adhering to the crucibles used for processing copper at La Fonteta: a) F41374, botryoidal formations of iron hydroxide on the edge of the sample; b) F41525, corroded copper prill with a silver segregate in a magnetite-rich area; c) F41525, general view of the magnetite-rich area; d) F62030, oxidized copper prill with several segregates of silver and gold.

al phases and the presence of certain minerals, we can extrapolate information that allows us to offer a possible interpretation of the function of the vessel.

The first sample, **F41374** (R3B; Table 1), has a small lump of slag attached to its inner surface and some vitrified areas (Renzi 2013: 113, Fig. 7.9a). Several small prills of copper-iron sulphides are embedded in the glassy matrix. Metal prills mainly composed of copper with iron and sometimes nickel have also been analysed (Table 4). The iron present in the system produced on the edge of the sample some botryoidal formations of iron hydroxide (Fig. 15a) and an iron-rich area with some lead and copper. This iron could come either from the original ore or from the metal, but it is less likely to come from the ceramic, which is rather low in iron oxide, as shown by the analysis of other crucible fragments (Tables 3 and 5). However, there is no clear evidence for suggesting that copper smelting was carried out in this vessel (see below), but the presence of secondary sulphides, generally round-shaped, and lead particles in the copper prills points at the processing of freshly smelted copper instead of remelting of scrap metal. Both iron and lead have also been documented in some copper slags from La Fonteta (Renzi 2013, 37-43).

The other two samples (F41525 and F62030) document the smelting of silver-rich copper ores. **F41525** (DF4/R2A; Table 2) is a cup-like crucible and the slag layer adhering to its interior is 1 cm thick (Fig. 13). The microstructure and the chemical composition of this sample are highly heterogeneous. Magnetite-rich areas can be observed and there are several copper prills with a few percent of iron (Fig. 15b-c; Table 4). Some of these prills are oxidized and show silver particles within the corroded areas (Fig. 15b), while some others have inclusions of lead and lead-tin sulphides. Prills of copper sulphide and copper-iron sulphide with silver segregates have also been detected (Table 4).

Fragment **F62030** (R2B; Table 1) is entirely covered by a glassy blackish layer of slag that is 0.5 cm thick (Renzi 2013: 114, Fig. 7.10a). Several metal prills are embedded in a glassy matrix (Tables 3-4). Most of them are oxidized and have silver segregates; tin oxide, gold and lead particles have been detected as well (Fig. 15d).

However, the composition of these metallic phases, the presence of sulphides and the abundance of iron in the system do not necessarily provide evidence for ore processing; the sulphides are secondary and the iron content could come from the refining of raw copper. However, other minerals identified in the samples do offer additional data for interpreting these fragments as part of smelting crucibles. A number of barite ($BaSO_4$) and barite-celestine [$(Ba,Sr)SO_4$] inclusions have been identified (see, for example, Renzi 2013: 38-39, 76, Fig. 5.14). These minerals are widely documented as impurities in ores and they are often observed recrystallized in both ferrous and non-ferrous slags from La Fonteta. Furthermore, the presence of silver, gold, tin and lead particles in the copper indicates the use of complex ores.

The exploitation of silver-bearing complex ores at La Fonteta to produce copper is also confirmed by the analysis of another slag (F31225; Renzi 2013: 38-39). This fragment, as suggested by its flat bottom that shows a vitrified and bloated ceramic material, could also have been part of a slaggy layer detached from a crucible. Its chemical composition is similar to the ones examined here; corroded copper prills with silver particles and several copper-iron sulphides with lead, lead-bismuth and tin segregates have been analysed. Inclusions of recrystallized barite laths are also present, confirming that this mineral was a common impurity of the ores used at La Fonteta.

Moreover, the presence of Cu-Pb cupellation debris at the site provides interesting data to suggest that the exploitation of these silver-bearing ores could have been related to activities for extracting silver. As proposed elsewhere, the smelting of these ores could have been the first step of the process for obtaining a silver-rich copper lump that would have been subsequently de-silvered (Renzi *et al.* 2007; Renzi *et al.* 2009: 2594; Renzi 2013: 64-70).

The production of bronze

Concerning the vessels related to bronze making, with this analytical study we intended to determine what kind of alloying process was carried out at La Fonteta, whether it was active alloying or whether they were just recycling scrap metal. Active alloying can be done by using freshly smelted metals, by co-smelting copper and tin ores or by cementation of copper/copper-lead with cassiterite. On the other hand, re-melting of scrap metal was performed by simply reusing bronze objects and sometimes also by adding a fresh tin source to the melt. However, as mentioned in the previous section, often the slags do not provide enough evidence to identify what kind of process for making bronze was being carried out.

None of the analysed fragments of vessels from La Fonteta can be clearly related to a co-smelting process, although this method is documented at the site by some bronze slags (Renzi 2013, 43-45). The methods identified so far for bronze production are cementation and the alloying of metals but, again, the evidence for recognizing the use of cementation *versus* metals is not always clear. Only two samples (F21122 and F50165) show strong evidence for the use of cassiterite to produce bronze by cementation, in one case to make leaded bronze and in the other one to produce tin bronze.

F21122 (unclassified) is part of the body of a crucible even though, due to the lack of rim and other diagnostic features, it is not possible to include it in one of the

Table 5: SEM-EDX results (%wt) of the glassy matrix and the ceramic of the samples associated with tin bronze and leaded bronze production.

Sample n.	Phase	MgO	Al_2O_3	SiO_2	P_2O_5	Na_2O	K_2O	TiO_2	CaO	MnO	FeO	CuO	SnO_2	PbO
F21121	Ceramic	1.3	24.0	59.6			4.1	0.8	6.6		3.6			
F50165	Ceramic	4.0	14.7	54.0		1.2	4.3	1.1	15.7		5.0			
F41529	Ceramic	2.8	11.3	41.8			1.6	1.0	35.5		4.3			1.7
F21121	Glassy matrix	2.7	10.5	38.1		0.7	3.5	0.5	19.5		18.0	5.2	2.7	3.8
F21122	Glassy matrix		5.9	23.4			0.9		6.6		1.6	1.9		59.7
F31130	Glassy matrix	3.6	14.6	43.9			1.1	0.5	32.5		3.1	1.1		
F31204	Glassy matrix	1.1	10.6	76.6			1.9		4.6		0.7	1.0		3.5
F41529	Glassy matrix	4.6	6.3	41.6			1.6		19.0		2.5	8.3	5.1	28.8
F41577	Glassy matrix	7.3	9.4	39.3			3.0	1.3	41.2		2.8			
F50165	Glassy matrix	2.4	11.7	34.6	3.4		4.1	3.6	17.7	2.0	17.4		3.0	

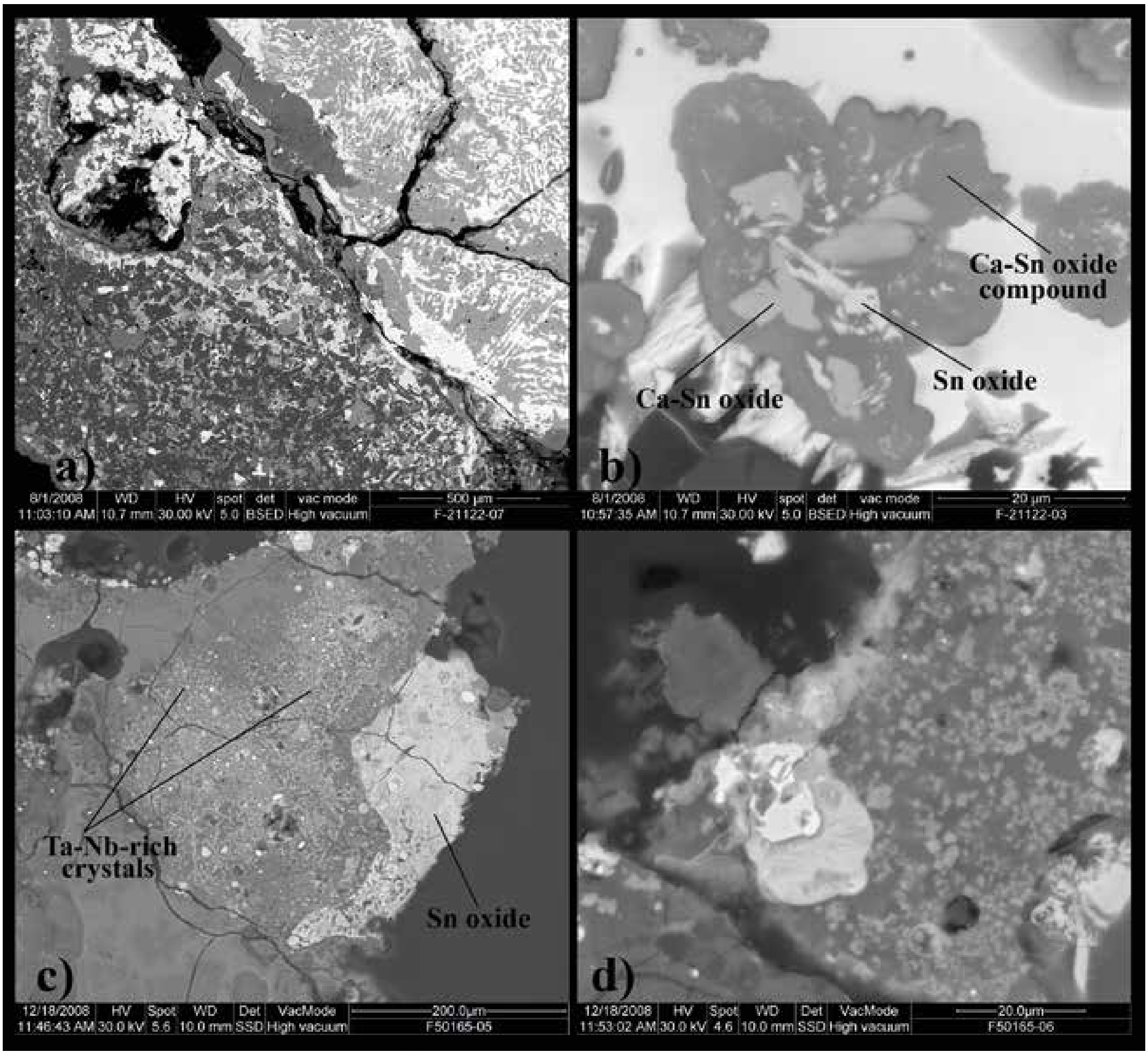
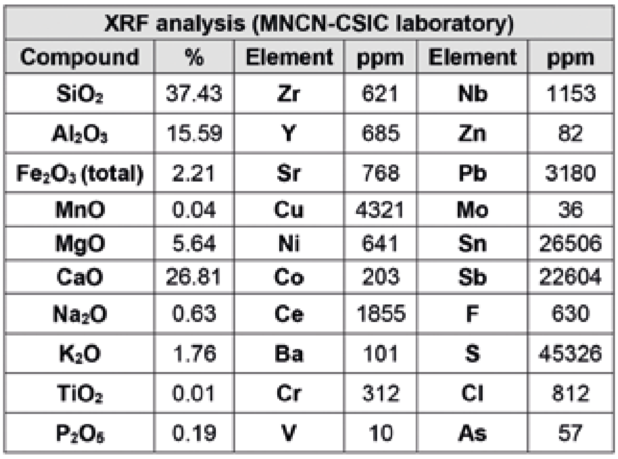


Fig. 16: SEM images of some of the phases identified in samples F21122 and F50165: a) F21122, large copper-lead metallic area adhering to the slag; b) F21122, detail of a grain of calcium and tin oxides compounds with a core of tin oxide; c) F50165, region formed by Ta/Nb-rich square crystals; d) F50165, detail of the previous area.

groups of vessels identified at La Fonteta. It presents a 1 cm-thick layer of slag that covers the whole inner surface of the fragment (Renzi 2013: 125, Fig. 7.26).

The matrix of the slag is a lead-rich glass with formations of melilite-like crystals (Table 5). Copper grains are embedded in the glassy matrix and a large copper-lead metallic area, with approximately 30% Pb, can be observed (Fig. 16a). Also, compounds of calcium and tin oxides have been detected indicating that tin metal or cassiterite was involved in the metallurgical operation carried out in this vessel. Some of these grains still preserve a nucleus of tin oxide (Fig. 16b), showing how they form by reacting first with the calcium oxide and then with the silica and other components present in the system. However, no bronze or tin inclusions have been detected. This portion of the slag shows that highly oxidizing conditions occurred within the vessel producing the reaction of the tin/cassiterite with the clay and the fuel ash to form complex Ca-Sn oxide compounds instead of forming bronze. So far, we can assume that this vessel was used to produce a leaded bronze by mixing a Cu-Pb alloy with a tin source, but we do not have enough evidence for suggesting the use of either metallic tin or cassiterite. Nevertheless, the XRF and XRD analyses of a fragment of this slag provide interesting data that indicate that tin ores had been employed in this process. The XRF analysis performed prior to the XRD examination – both carried out at the laboratory of the National Museum of Natural Sciences (MNCN-CSIC) in Madrid – shows an unusual high presence of niobium (approx. 0.1% Nb; Table 6).

On the SEM we could not observe any niobium-rich phases and we were wondering where this high con-



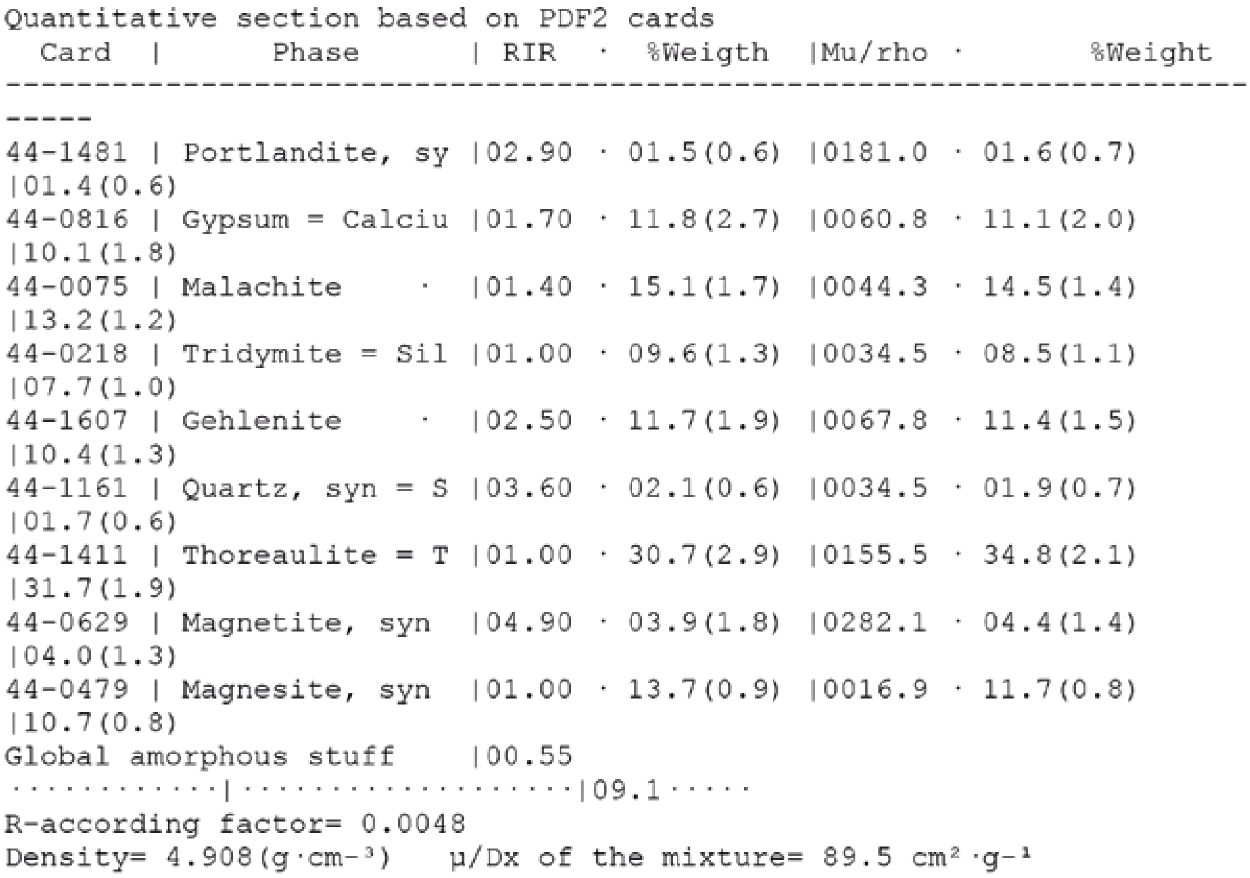
XRF analysis (MNCN-CSIC laboratory)					
Compound	**%**	**Element**	**ppm**	**Element**	**ppm**
SiO_2	37.43	Zr	621	Nb	1153
Al_2O_3	15.59	Y	685	Zn	82
Fe_2O_3 (total)	2.21	Sr	768	Pb	3180
MnO	0.04	Cu	4321	Mo	36
MgO	5.64	Ni	641	Sn	26506
CaO	26.81	Co	203	Sb	22604
Na_2O	0.63	Ce	1855	F	630
K_2O	1.76	Ba	101	S	45326
TiO_2	0.01	Cr	312	Cl	812
P_2O_5	0.19	V	10	As	57

Table 6: XRF results of a fragment of vessel F21122.

tent could come from. It had to be geological as this element during the metallurgical process would be lost in the slag and would not go into the metal. A hint was given by the XRD analysis that – apart from common components of slags such as gehlenite, tridymite, magnetite and quartz – identified the presence of thoreaulite ($Sn(Nb,Ta)_2)O_7$ (Table 7). This mineral, in which both tantalum and niobium are present, is quite rare but can be found in granitic pegmatites, rocks that are documented in several areas of Spain (Sánchez-Muñoz & García-Guinea 1992: 455-463) and are often associated with tin ores (Uher *et al.* 2007). Unfortunately, the XRF spectrometer could not measure the tantalum content in the slag due to the lack of a suitable CRM. However, the minerals of the foordite-thoreaulite series ($Sn^{2}+Nb_2O_6$-$Sn^{2}+Ta_2O_6$) present a wide compositional variability of Ta/(Ta+Nb), with lead and antimony as common substitutive elements (Uher *et al.* 2007). Interestingly, a noticeable content of antimony (2.3% Sb) has also been detected by XRF in this sample (Table 6).

The other sample that provided relevant data on the use of tin ore is the crucible fragment **F50165** (R3A; Table 1). It has a 0.5 cm-thick slag layer that covers the whole fragment and reaches the rim where it turns into a thin vitrification (Fig. 6a). The slag has an iron-rich glassy matrix, with some manganese, and shows a heterogeneous microstructure. There are several metallic areas, often partially oxidized, and most of the metal prills analysed are composed of copper, iron and tin, with very variable contents of these elements, and some others are only made of iron and tin. Only in one case a tin-rich bronze prill has been observed (Table 8). This high content of iron in the metallic phases explains the enrichment of this element detected in the matrix of the slag with respect to the composition of

Table 7: XRD analysis of the fragment of vessel F21122 analyzed by XRF.



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Quantitative section based on PDF2 cards
  Card  |       Phase       | RIR  · %Weigth  |Mu/rho ·       %Weight
----------------------------------------------------------------------
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44-1481 | Portlandite, sy |02.90 · 01.5(0.6) |0181.0 · 01.6(0.7)
|01.4(0.6)
44-0816 | Gypsum = Calciu |01.70 · 11.8(2.7) |0060.8 · 11.1(2.0)
|10.1(1.8)
44-0075 | Malachite     · |01.40 · 15.1(1.7) |0044.3 · 14.5(1.4)
|13.2(1.2)
44-0218 | Tridymite = Sil |01.00 · 09.6(1.3) |0034.5 · 08.5(1.1)
|07.7(1.0)
44-1607 | Gehlenite     · |02.50 · 11.7(1.9) |0067.8 · 11.4(1.5)
|10.4(1.3)
44-1161 | Quartz, syn = S |03.60 · 02.1(0.6) |0034.5 · 01.9(0.7)
|01.7(0.6)
44-1411 | Thoreaulite = T |01.00 · 30.7(2.9) |0155.5 · 34.8(2.1)
|31.7(1.9)
44-0629 | Magnetite, syn  |04.90 · 03.9(1.8) |0282.1 · 04.4(1.4)
|04.0(1.3)
44-0479 | Magnesite, syn  |01.00 · 13.7(0.9) |0016.9 · 11.7(0.8)
|10.7(0.8)
Global amorphous stuff    |00.55
············|···················|09.1·····
R-according factor= 0.0048
Density= 4.908(g·cm-³)   µ/Dx of the mixture= 89.5 cm²·g-¹
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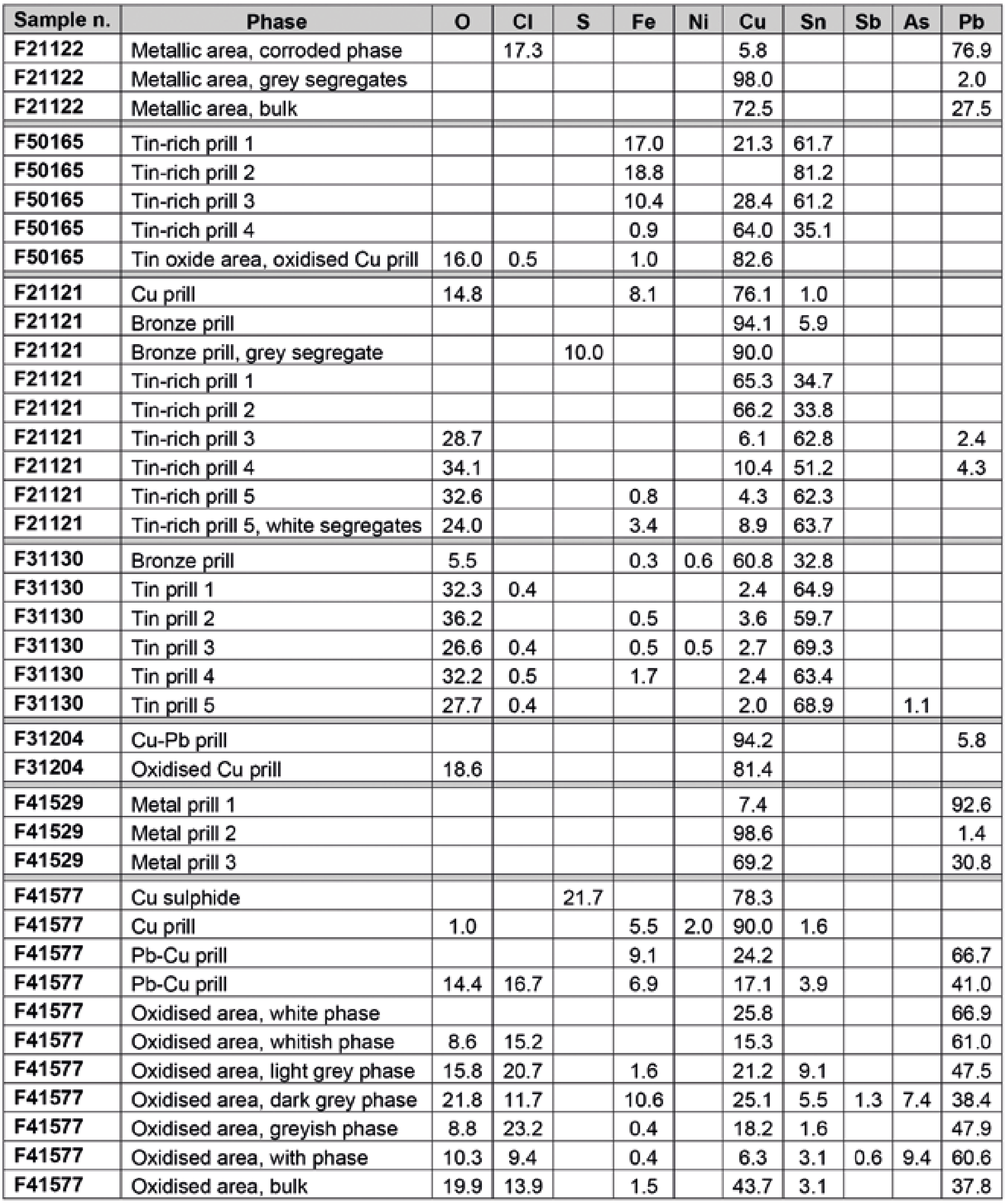


Sample n.	Phase	O	Cl	S	Fe	Ni	Cu	Sn	Sb	As	Pb
F21122	Metallic area, corroded phase		17.3				5.8				76.9
F21122	Metallic area, grey segregates						98.0				2.0
F21122	Metallic area, bulk						72.5				27.5
F50165	Tin-rich prill 1				17.0		21.3	61.7			
F50165	Tin-rich prill 2				18.8			81.2			
F50165	Tin-rich prill 3				10.4		28.4	61.2			
F50165	Tin-rich prill 4				0.9		64.0	35.1			
F50165	Tin oxide area, oxidised Cu prill	16.0	0.5		1.0		82.6				
F21121	Cu prill	14.8			8.1		76.1	1.0			
F21121	Bronze prill						94.1	5.9			
F21121	Bronze prill, grey segregate			10.0			90.0				
F21121	Tin-rich prill 1						65.3	34.7			
F21121	Tin-rich prill 2						66.2	33.8			
F21121	Tin-rich prill 3	28.7					6.1	62.8			2.4
F21121	Tin-rich prill 4	34.1					10.4	51.2			4.3
F21121	Tin-rich prill 5	32.6			0.8		4.3	62.3			
F21121	Tin-rich prill 5, white segregates	24.0			3.4		8.9	63.7			
F31130	Bronze prill	5.5			0.3	0.6	60.8	32.8			
F31130	Tin prill 1	32.3	0.4				2.4	64.9			
F31130	Tin prill 2	36.2			0.5		3.6	59.7			
F31130	Tin prill 3	26.6	0.4		0.5	0.5	2.7	69.3			
F31130	Tin prill 4	32.2	0.5		1.7		2.4	63.4			
F31130	Tin prill 5	27.7	0.4				2.0	68.9		1.1	
F31204	Cu-Pb prill						94.2				5.8
F31204	Oxidised Cu prill	18.6					81.4				
F41529	Metal prill 1						7.4				92.6
F41529	Metal prill 2						98.6				1.4
F41529	Metal prill 3						69.2				30.8
F41577	Cu sulphide			21.7			78.3				
F41577	Cu prill	1.0			5.5	2.0	90.0	1.6			
F41577	Pb-Cu prill				9.1		24.2				66.7
F41577	Pb-Cu prill	14.4	16.7		6.9		17.1	3.9			41.0
F41577	Oxidised area, white phase						25.8				66.9
F41577	Oxidised area, whitish phase	8.6	15.2				15.3				61.0
F41577	Oxidised area, light grey phase	15.8	20.7		1.6		21.2	9.1			47.5
F41577	Oxidised area, dark grey phase	21.8	11.7		10.6		25.1	5.5	1.3	7.4	38.4
F41577	Oxidised area, greyish phase	8.8	23.2		0.4		18.2	1.6			47.9
F41577	Oxidised area, with phase	10.3	9.4		0.4		6.3	3.1	0.6	9.4	60.6
F41577	Oxidised area, bulk	19.9	13.9		1.5		43.7	3.1			37.8

Table 8: SEM-EDX results (% wt) of the composition of the metal prills and sulphide inclusions identified in the samples associated with tin bronze and leaded bronze production, and in the sample with the possible dross layer.

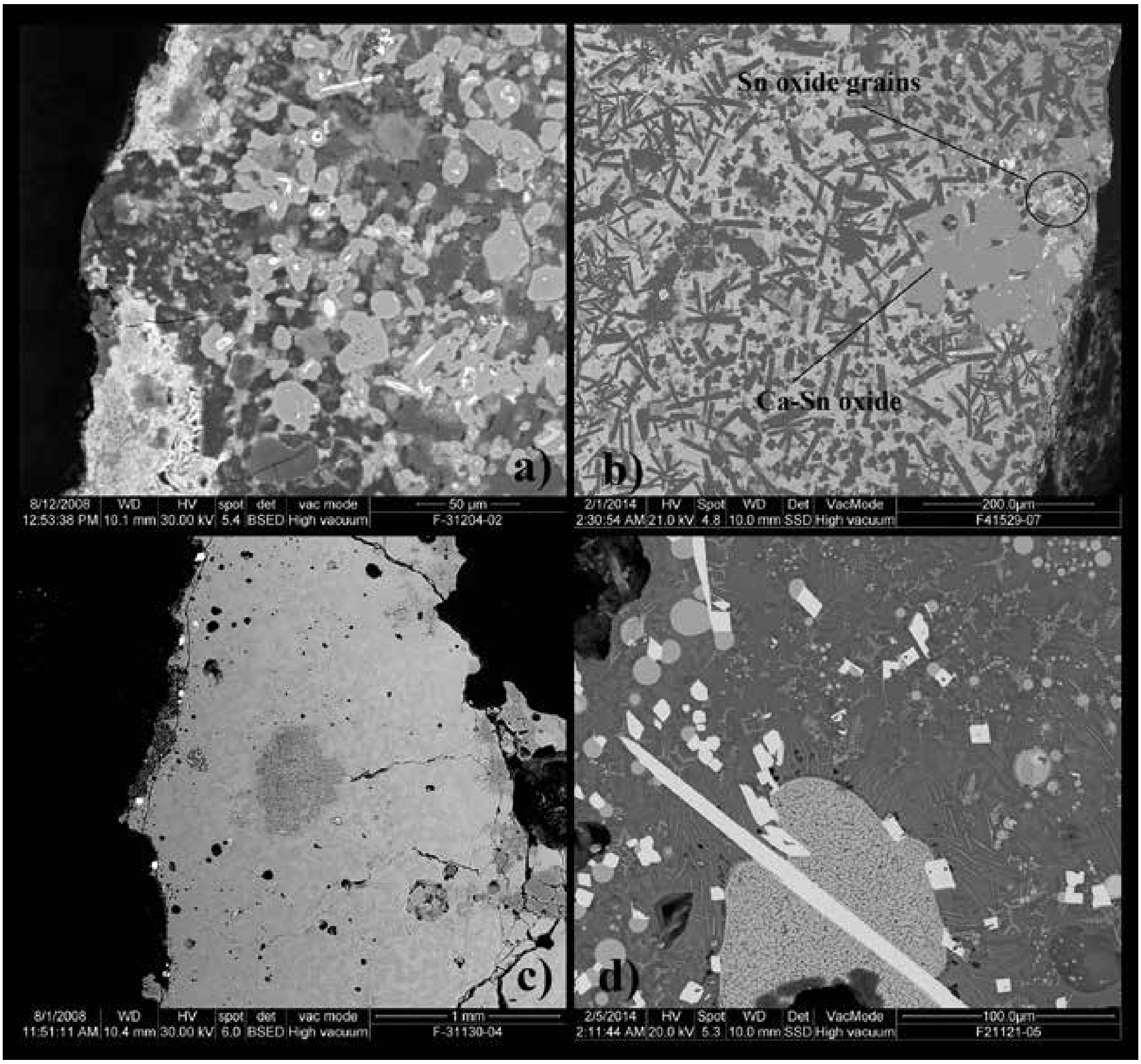
the ceramic (Table 5). In addition, a region formed by small square crystals has been observed (Fig. 16c-d). These crystals have a complex composition and present high contents of calcium and titanium with niobium and tantalum, and in one case with some tin (Table 9). They formed through the reaction of the tantalum and niobium with the calcium oxide, the silica and the other elements from the surrounding melt but, as in the previous case, the origin of the niobium and tantalum contents is certainly geological. It is especially interesting to note that next to this area of Ta/Nb-rich crystals there is another area mainly composed

Sample n.	Phase	MgO	Al_2O_3	SiO_2	K_2O	TiO_2	CaO	MnO	FeO	CuO	SnO_2	Nb_2O_5	Ta_2O_5
F50165	Tin oxide area, bulk	1.7		2.4			2.8		7.5	3.8	81.8		
F50165	Square crystals	1.8	3.5	16.4	0.8	20.6	30.4	0.4	3.1			10.4	12.5
F50165	Square crystals	1.3	2.9	14.9	0.7	19.6	28.0		3.7		2.0	9.7	17.2
F50165	Square crystals	30.0	5.7	19.7		16.7	39.1		3.8			5.7	6.3

Table 9: SEM-EDX results (%wt) of the composition of the square crystals rich in Ta-Nb oxide identified in sample F50165.

of tin oxide (Table 9). It could be argued that, again, the presence of these elements can be related to the use of cassiterite associate to minerals of the foordite-thoreaulite series. Nevertheless, the sharp separation that can be observed between the area with the small crystals and the tin-oxide region would not occur in foordite-thoreaulite where the three heavy elements could not separate so cleanly (see Fig. 16c). Therefore, we suggest that the mineral associated to the cassiterite used for producing tin bronze in this vessel was an iron-rich columbite-tantalite (aka “coltan”) that, as the minerals of the foordite-thoreaulite series, also occurs in pegmatitic rocks but is far more common. Columbite-tantalite minerals can often be found associated to tin ores, especially in alluvial deposits[2]. For example, in the Iberian Peninsula, associ-

Fig. 17: SEM images of some of the phases identified in the slagged layers adhering to the crucibles used to make tin bronze and lead bronze at La Fonteta: a) F31204, area with a concentration of grains of calcium-tin oxide compounds and lead-rich corrosion areas; b) F41529, small area with round-shaped tin oxide crystals; c) F31130, tin-rich prills concentrated at the edge of the slagged layer; d) F21121, region of the slag with idiomorphic crystals of tin oxide, cuprite dendrites and delafossite needles.



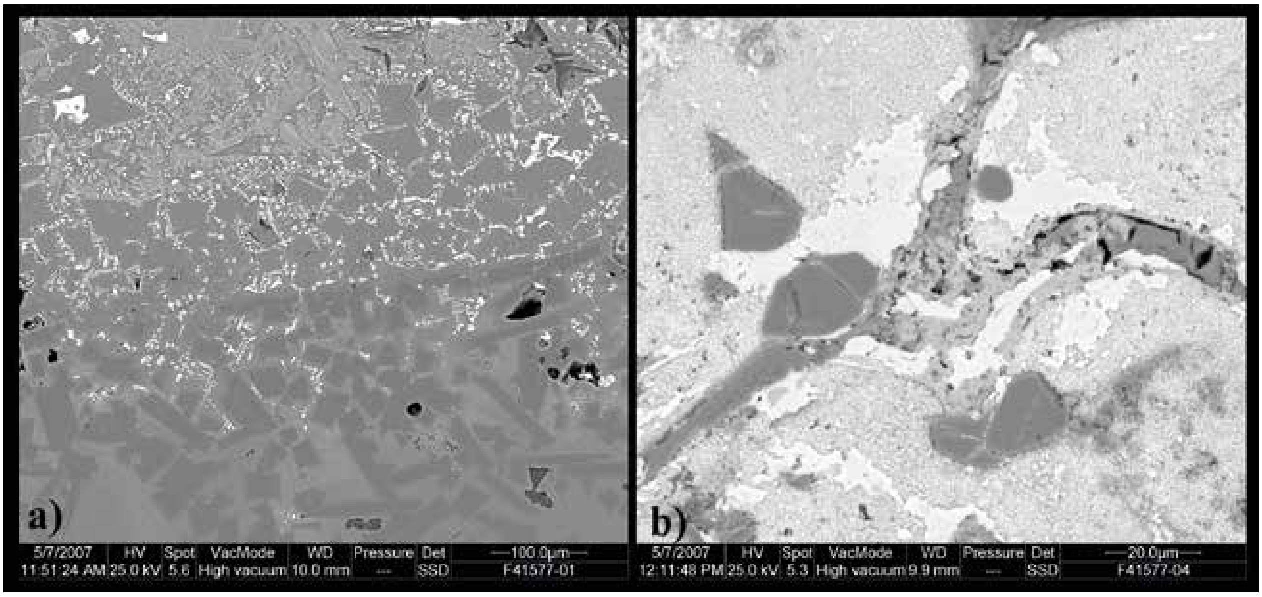


Fig. 18: SEM images of some of the phases identified in sample F41577: a) magnetite-rich area; b) detail of the corroded metallic area.

ations of cassiterite with coltan are documented in many deposits of the Iberian Hercynian Massif, as shown by the analytical study of several samples of tin ores collected from different deposits in Spain, from Galicia to Extremadura (Murciego *et al.* 1997), and in northern and central Portugal (Neiva 1996; Martins *et al.* 2011). Hence, the columbite-tantalite would be the source of the niobium and tantalum present in these samples, as well as of the manganese that frequently accompanies these minerals. In case of slag F21122, the compound identified by XRD as thoreaulite could be a mineral newly formed in the slag from the reaction and recrystallization of the coltan minerals and would not necessarily reflect the type of tin ore used for producing bronze at La Fonteta. However, independently of the type of ore exploited, these slags are providing strong evidence for the use of the cementation process to produce both tin bronze and leaded bronze at the site.

Two other samples (F31204 and F41529) analysed can be related to the use of cementation for producing in both cases leaded bronzes. Fragment **F31204** (DF4; Table 2) presents clear evidence of double use (Fig. 2b). It is part of a flat base and the original vessel has a thin metal-rich layer visible in its section. This first base was completely covered with a new clay layer in order to reproduce the original shape of the crucible. The thickness of the new clay layer is 1.5 cm, similarly to the original one, and shows a 0.5 cm thick slag adhering to its inner surface. The same fabric of the beige type was used for manufacturing both ceramic layers.

The microstructure of this sample is heterogeneous and there are several metal prills embedded in the glassy matrix (Table 5). In the whole sample, numerous grains of calcium-tin oxide compounds have been observed, and in many cases a core of tin oxide is still visible (Fig. 17a). Most of the metal prills analysed are unalloyed copper or copper-lead alloys; no tin or bronze prills have been detected (Table 8). This sample indicates that a highly oxidizing episode occurred in the crucible and hindered the formation of bronze; all the tin in this area reacted with the calcium and the other elements of the system to form Ca-Sn oxide compounds but it did not alloy with the copper. Nevertheless, despite the lack of bronze formations, these compounds are indicating that a tin source was involved in the metallurgical process, although it cannot be determined whether tin ore or tin metal was being used. It can be also argued that those compounds could form due to the burning out of tin from existing bronze during a re-melting process. Yet, the high heterogeneity and the thickness of the slag layer on the vessel are more compatible with active alloy operations, possibly cementation of a copper-lead alloy or a fresh smelted lead-rich copper with cassiterite. At La Fonteta most of the copper prills identified in slags show lead particles suggesting the use of lead-bearing ores but also intentional alloys of copper-lead have been documented (Renzi 2013: 64-68, 155-158). However, in both cases, the result would have been a ternary bronze.

The other sample related to the making of leaded bronze, **F41529** (DF2/R2B; Table 2), is part of a vessel's body but has a marked curve that seems to be the start of a handle. The lower part of the fragment shows a thin grey-greenish layer of slag. The glassy matrix of this sample has an extraordinary high lead content (40% PbO; Table 5), with some copper and tin as well. Formations of melilite-like crystals and, in one area of the sample, grains of Ca-Sn oxide compounds can be observed but no tin or bronze prills have been detected. All the metallic phases identified are composed of lead and copper-lead (Table 8). Nevertheless, both the presence of Ca-Sn oxide compounds and the noticeable content of tin dissolved in the glassy matrix (Table 5) indicate that a tin source was added to the copper-lead alloy, probably to produce a ternary bronze. Whether this source was tin or tin ores is difficult to say. The roundish shape of the tin oxide crystals identified in a peripheral area of the sample suggests they could be residual cassiterite grains (Fig. 17b). In this case, we could assume that they were making bronze by cementation but this evidence might not be sufficient, especially if we consider the reduced dimensions of the slagged area and that only the area of the vessel close to the handle is preserved. What can be safely suggested here is that a leaded bronze was being processed.

Two of the last three samples, F31130 and F21121, show the production of bronze by mixing tin and copper metals, while the third one documents (F41577) a different process that will be discussed below.

F31130 (unclassified) is a fragment of a vessel's body with no recognizable diagnostic features. It is covered with a thin slag layer that has a glassy appearance with some greenish spots (Renzi 2013, 120, Fig. 7.31). The microstructure of the sample is homogeneous and the glassy matrix has a melilite-like composition with some copper (Table 5). There are numerous small copper globules embedded in the matrix. Some tin prills with low copper contents and other impurities have also been identified (Table 8), mainly concentrated at the edge of the slagged layer (Fig. 17c). No tin oxide crystals or Ca-Sn oxide compounds have been detected, indicating that the working conditions in this vessel were sufficiently reducing to allow the tin and the copper present in the system to form bronze. This could be due to the conversion of the cassiterite into tin and its reaction with the copper, but both the homogeneity of the sample and the characteristics of the slagged layer adhering to the vessel, point to the mixing of metals rather than the use of cassiterite for producing bronze. A process involving ores would probably produce a more heterogeneous and thicker layer of slag, as observed in the other samples analysed.

F21121 (R1A; Table 1) is fully covered with a thin vitrified slaggy layer (Fig. 4a). The glassy matrix of the slag contains some copper, lead and tin (Table 5), and formations of melilite-like crystals can be observed. There are several bronze and copper prills embedded in the matrix, in some cases with lead segregates and Sn-Pb sulphide inclusions. One prill has a noticeable iron content (approx. 8% Fe), some others are tin-rich (with more than 30% Sn) or almost entirely composed of tin (Table 8). In one region of the slag, there is a concentration of idiomorphic crystals of tin oxide. The formation of cuprite dendrites and delafossite needles in the same area (Fig. 17d) also indicates that oxidizing episodes happened during the metallurgical process carried out in this vessel. Furthermore, both the iron-content of some prills, in particular the ones higher in copper, and the delafossite suggest the use of an iron-rich metal. This is confirmed by the composition of the glassy matrix that shows much higher iron content compared to the ceramic (Table 5). The copper used to produce bronze in this vessel was most likely a non-refined copper, with lead impurities. Also, the variable composition of the bronze prills, some of them with high tin, is evidence that it was an active alloying process and not recycling of scrap metal. Whether this process was carried out by using fresh metals or by cementing the copper with cassiterite is not clear, although the microstructural characteristics of the slag and its limited thickness could point to the production of bronze by mixing fresh copper and tin metals.

The last sample has a different microstructure and chemical composition compared to the ones discussed above. Fragment **F41577** is part of a flat base (DF4; Table 2), entirely covered by an irregular slaggy layer (Renzi 2013: 121, Fig. 7.24b). Little slag formed and its matrix, as in the previous samples, is a glassy material with melilite-like formations with no lead, copper or tin contribution. The sample is rich in magnetite (Fig. 18a) and shows a big metallic area that is largely corroded in the lower part of the sample (Fig. 18b), adhering to the inner surface of the crucible. This oxidized area is composed of copper and lead with tin and iron; some regions show arsenic and antimony as well. No tin prills or crystals of tin oxide have been detected to suggest the production of bronze, but some tin is present in a few of the metallic phases of the slag. At first the detection of copper, lead and tin suggested that this was another vessel used to produce a ternary bronze. However, as we already mentioned above, it has to be borne in mind that the proportions of metals or oxides detected in a crucible can be considerably different from the ones characterizing the original melt (Dungworth 2000; Kearns *et al.* 2010).

In this sample, the presence of a large oxidized metal area, as well as the abundance of magnetite crystals, document a lack of reducing conditions. Although such oxidizing episodes have been observed in other slags associated to the production of bronze, here the special enrichment in certain elements, such as tin and lead, on a wide portion of the sample could easily occur in a metallurgical process for purifying copper by fire-refining. The heterogeneous composition of the metal and its high iron content suggest that this vessel had been employed for processing a freshly smelted copper that had iron, lead and tin as impurities. The presence of these elements has been already detected in some copper slags from La Fonteta. Therefore, the slag formed on this vessel would not be the result of a process for producing bronze but could correspond to a dross layer formed during the selective oxidation of the impurities contained in the copper, either intentionally during fire-refining or inadvertently by melting under insufficient charcoal cover. The more oxidizing conditions on the surface of the melt would have produced a concentration of magnetite crystals on top of this dross layer.

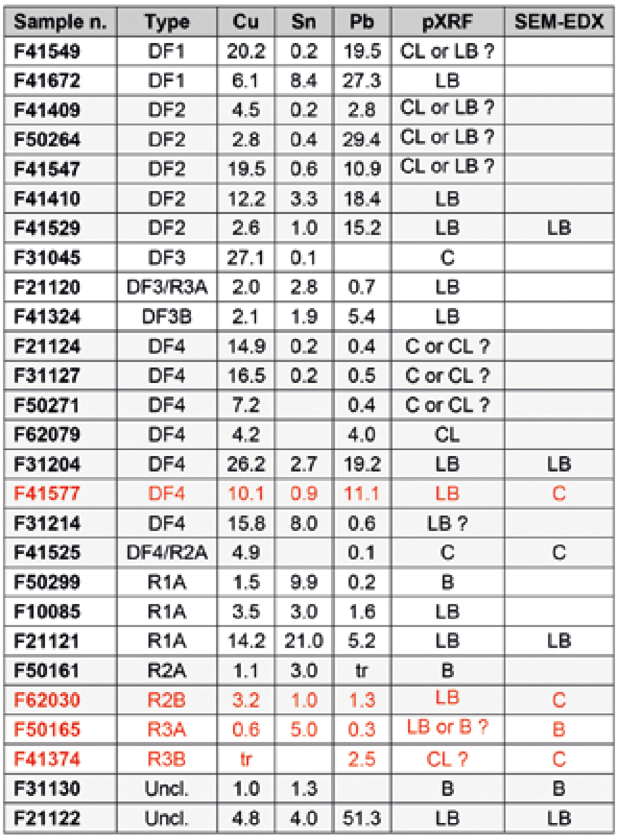
pXRF analyses

The SEM-EDX analysis of the crucible fragments from La Fonteta provided interesting information on the type of metallurgical activities carried out at the site and the variety of metals processed. However, as mentioned before, the sampling could not cover the whole typological diversity of the vessels; therefore, the data available for determining a possible correlation between the typology of the crucibles and a specific metal were insufficient. We decided then to analyse a wider set of slagged fragments employing portable ED-XRF in order to achieve a preliminary approach to the composition of the metal processed.

The pXRF analyses had been carried out by Dr I. Montero-Ruiz and Dr S. Rovira-Llorens using a portable spectrometer Metorex X-Met 920MP of the National Archaeological Museum (MAN) in Madrid. This device was equipped with a primary radioactive source of gamma rays Am-241 with an intensity of 20 mCi, a Si(Li) detector cooled with liquid nitrogen, with a resolution of 170eV at Mn K-alpha line. This spectrometer allows only the detection of the elements with an atomic number higher than 20 (Calcium).[3]

Around thirty fragments of slagged vessels were examined but, unfortunately, in most cases it had not been possible to cut a sample and the analyses had to be performed on the original corroded surface of the crucible fragments. The results obtained are summarized in Table 10, but they have to be considered as merely qualitative, since oxidized and corroded metallurgical remains do not reflect the real composition of the original material processed in these vessels (Dungworth 2000; Kearns *et al.* 2010).

For example, concerning the two fragments that could be part of the same crucible (F21124 and F31127), that have been already mentioned before; the pXRF results seem to confirm the matching suggested by the macroscopic examination. In fact, their composition is practically the same (Table 10), although the type of alloy produced cannot be safely stated, as explained below. Unfortunately, in several cases the information provided by the pXRF analysis can be misleading, as shown by some of the SEM-EDX analyses. Samples F62030 and F41577 offer a good example of this mismatch between the results obtained by pXRF and by SEM-EDX of the chemical compositions of the metals processed in these vessels. According to the SEM-EDX, these samples were used for processing copper but the pXRF detected noticeable amounts of lead and tin in relation to the proportion of copper, suggesting they could have been used for working leaded bronze. The impurities of the copper processed in the vessels produced an enrichment on the corroded surface of the crucible slag in certain elements, in particular lead and tin, on the corroded surface of the crucible slag, showing a bulk composition that strongly differs from the original one.



Sample n.	Type	Cu	Sn	Pb	pXRF	SEM-EDX
F41549	DF1	20.2	0.2	19.5	CL or LB ?	
F41672	DF1	6.1	8.4	27.3	LB	
F41409	DF2	4.5	0.2	2.8	CL or LB ?	
F50264	DF2	2.8	0.4	29.4	CL or LB ?	
F41547	DF2	19.5	0.6	10.9	CL or LB ?	
F41410	DF2	12.2	3.3	18.4	LB	
F41529	DF2	2.6	1.0	15.2	LB	LB
F31045	DF3	27.1	0.1		C	
F21120	DF3/R3A	2.0	2.8	0.7	LB	
F41324	DF3B	2.1	1.9	5.4	LB	
F21124	DF4	14.9	0.2	0.4	C or CL ?	
F31127	DF4	16.5	0.2	0.5	C or CL ?	
F50271	DF4	7.2		0.4	C or CL ?	
F62079	DF4	4.2		4.0	CL	
F31204	DF4	26.2	2.7	19.2	LB	LB
F41577	DF4	10.1	0.9	11.1	LB	C
F31214	DF4	15.8	8.0	0.6	LB ?	
F41525	DF4/R2A	4.9		0.1	C	C
F50299	R1A	1.5	9.9	0.2	B	
F10085	R1A	3.5	3.0	1.6	LB	
F21121	R1A	14.2	21.0	5.2	LB	LB
F50161	R2A	1.1	3.0	tr	B	
F62030	R2B	3.2	1.0	1.3	LB	C
F50165	R3A	0.6	5.0	0.3	LB or B ?	B
F41374	R3B	tr		2.5	CL ?	C
F31130	Uncl.	1.0	1.3		B	B
F21122	Uncl.	4.8	4.0	51.3	LB	LB

Table 10: pXRF results of the main elements detected on some slagged fragments of vessels from La Fonteta (%wt; tr: traces) and the type of alloy produced versus the information provided by the SEM-EDX analyses. C: copper; CL: copper-lead alloy; B: tin bronze; LB: leaded bronze.

A similar case occurred with sample F41734 where the pXRF measured a noticeable lead content in the slag, while in the SEM we could only observe copper prills with small lead segregates as impurities. Also for F50165, the pXRF analysis detected some lead while in the SEM-EDX only tin and copper were found.

The situation that emerges from this analytical study is much in accordance with what other scholars have evidenced in the recent past with respect to XRF analyses of slagged layers on crucibles and moulds (Dungworth 2000; Kearns *et al.* 2010; Martinón-Torres & Rehren 2014). The study carried out by Dungworth (2000) on a fragment of crucible from Mucking (Essex) with an adhering metal prill already showed how the ED-XRF analysis can give an overall result with a proportion of elements that does not match the one of the original batch. Measurements were taken on two areas of the surface of the crucible and on the polished metal prill adhering to it. The proportions of the alloying elements – in the case of this study copper, zinc, lead and tin – changed dramatically in the three analysed areas, showing an underestimation of the copper content and strong enrichments of zinc, tin and lead in the crucible and in the transition area compared to their contents in the metal (Dungworth 2000: 84). Several factors contribute to the final composition of a crucible slag. Temperatures reached during the process, redox conditions within the vessel and the physico-chemical properties of the different elements present in the metal are important aspects that have to be borne in mind when interpreting the composition of a slagged vessel. During the metallurgical operation, both high temperatures and oxidizing conditions boost the volatility of metals and their reaction with the crucible fabric, forming a layer of vitrification or slag that would show different ranges of base metal contents. Tin, lead and zinc can be more easily oxidized compared to copper and, due to the strong affinity of zinc and lead oxides for silica, these elements are more likely to be found concentrated in the slagged ceramic (Dungworth 2000: 84-85).

Similar results have been achieved by Kearns *et al.* (2010) in their study on casting experiments conducted with a range of known-composition alloys and on the XRF analysis of the contamination in the moulds used for casting those alloys. Copper traces were detected in all the moulds while the zinc, and to a lesser extent the lead, have been found concentrated in high levels on the moulds' surfaces, despite their low content in the original alloy. More interestingly, tin showed a different behaviour. In the moulds employed for bronze casting, tin contamination is very low, and in some cases, could hardly be detected. On the other hand, the tin contents in the moulds used for casting leaded bronze were much higher. This might be due to the capacity of lead oxide to enhance the oxidation of other base metals, forming stable compounds with them. In addition, lead oxide would easily form a glass phase when reacting with the ceramic, boosting the retention of tin oxide (Kearns *et al.* 2010: 55-56), as shown in some of the slagged layers on the crucibles from La Fonteta.

Therefore, XRF analysis should always be combined with other techniques that allow a better characterization of the different phases of the slag for a more accurate interpretation of the relation between the bulk composition of the crucible slag and of the original melt processed in the vessel. As shown in this paper, SEM-EDX analyses provide useful data for a further understanding of the behaviour of metals and their oxides during the metallurgical process.

However, we have to bear in mind that both methods offer only partial information on what was happening in the given crucibles. The XRF offers a qualitative bulk composition of the surface of the slag that can dramatically differ from that of the metal originally processed. On the other hand, even though the SEM-EDX allows the analysis and simultaneous observation of the distribution of the elements in the slag and of the complex reactions that can take place during the metallurgical process, the information obtained will mostly depend on which portion of the slag or crucible we are looking at. It has already been mentioned how different the chemical composition of the slag can be depending on whether we analyse the central part or the rim area of a crucible (Rademakers & Rehren 2014).

The examination of this type of metallurgical waste is complex and influenced by several factors, as mentioned above. Thus, the data should be interpreted in a critical way, and the information obtained should be considered as only indicative and not as a solid proof of the processes that were being carried out in these vessels. However, the presence of tin-rich metallic phases (>30 wt% Sn) is a very strong indication of active alloying, either using tin metal or cementation. Furthermore, the identification of slag areas rich in niobium and tantalum can be taken as a strong evidence for the use of cementation, as it is highly unlikely that these two elements would go into the metal phase during tin smelting.

Conclusions

Despite the non-fully conclusive results provided by the analyses performed on the crucibles from La Fonteta, we can safely state that both the SEM-EDX and the pXRF data highlight the large variety of composition of metals produced at the site. Unalloyed copper, tin bronze, leaded bronze and copper-lead alloys were all processed, in accordance with the information provided by the analysis of the slags and metal artefacts from La Fonteta (Renzi 2013: 64-65, 155-158).

Above all, these results show how no direct relation could be established between the typology of vessels and their use for producing a certain metal. At La Fonteta, the choice of a particular vessel seems to correspond to other criteria rather than the type of metal that was going to be processed in it. Similarly, the fragments of crucibles whose use could be associated to a specific metallurgical process provide no evidence to suggest a positive correlation between the morphology of the vessels and their function in the metallurgical *chaîne opératoire*. This topic received so far little attention in the study of Iberian metallurgical vessels and the number of comparative studies available is very scarce, in particular due to the lack of large and varied sets of crucibles such as the one found at La Fonteta.

As mentioned earlier, a further indication of the type of metallurgical process carried out in a certain vessel can be given by a macroscopic examination of its visual features, such as the thickness and the heterogeneity *vs.* homogeneity of the slagged layers. In the samples presented here, the formation of thick layers of slag can be related to the use of the crucibles in processes that involved ores processing, namely copper smelting or cementation for producing bronze. On the other hand, thin and glassy layers of slags can be associated with alloying processes by mixing metals, or simple re-melting of existing alloy or metal. However, even if we consider that this criterion could be valid for differentiating between vessels used in operations that involve ores and metals, respectively, no correspondence can be found between the typology and the function of the vessels. The same occurs if we look at the thickness of the crucibles' walls or at the type of fabric used.

In any case, some interesting data can be extrapolated from the analyses carried out on the La Fonteta crucibles. The fragments of vessels used for copper smelting document the exploitation of complex ores, possibly oxidic ores originated from the weathered layers of copper sulphide deposits, as suggested by the presence of several sulphide prills in the analysed crucible slags.

Regarding the production of tin bronzes and leaded bronzes, the samples examined by SEM-EDX document that active alloying was carried out. The two methods identified are cementation of copper and copper-lead alloys with cassiterite, and the mixing of tin and copper metals. Crucibles employed for co-smelting operations have not been clearly identified, although the use of this method for bronze production at La Fonteta has been documented by the analyses of some slags (Renzi 2013: 43-45).

Interestingly, in the Iberian Peninsula the use of the cementation process for making bronze is not known in earlier periods. The crucibles from La Fonteta, together with the slags from Gusendo de los Oteros (León) (Rovira-Llorens 2007: 29-30) and Carmona (Sevilla) (Renzi *et al.* 2007), provide the oldest evidence known so far from the Iberian Peninsula, dated to the early 8th century BC.

The mixing of tin and copper metals for obtaining bronze has not been documented at any other earlier settlement either. Only one bronze slag coming from the Phoenician levels of Carmona (Sevilla) has been related to the use of this process (Rovira-Llorens 2007: 30-33). The evidence available so far indicates that during the whole Bronze Age, co-smelting has been the only method used for making bronze in the Iberian Peninsula. Although further investigations are needed, it seems that these new techniques for alloying copper and tin appeared in the transition period between the Late Bronze Age and the Iron Age, when new eastern Mediterranean groups, such as the Phoenicians, settled in Iberia.

Apart from the smelting of copper ores and the production of fresh bronze, the presence of pouring spouts on some vessels suggests that melting and casting operations were also carried out at La Fonteta. This is further confirmed by the finds of a few melting drops (Renzi 2013: 50-51) and of several mould fragments, generally made of sandstone and mainly related to the production of ingot-axes (Renzi 2010; 2013: 133-143). In addition to this evidence for the manufacturing of copper-based objects, a large number of undetermined metallic items was found fragmented in the workshop area of the settlement, suggesting that scrap metal could have been another source for the production of alloys. However, no metallurgical waste has been clearly related to this practice so far.

To sum up, it is interesting to note how the use of different raw materials for producing copper and copper alloys coexisted at La Fonteta: copper ores, tin ores and tin metal, copper ingots (Renzi 2013: 146-149) and scrap metals, processed in a variety of techniques including cementation, mixing metals for alloying, and simple re-melting. The same variety can be observed in the composition of the alloys used and in the typology of the vessels used for processing these metals.

These peculiar characteristics of the metallurgy of La Fonteta are a novelty in the general outlook on Iberian metal production, but they seem to be possible common features for Phoenician settlements at the beginning of the 1st millennium BC. Unfortunately, there are no other analytical studies of large sets of contemporary metallurgical debris available up to date, but the diversity of finds at other Phoenician settlements – such as Abdera (Adra) in the Almeria province (Carpintero 2009), Cerro del Villar (Rovira-Hortalà 2005) or La Rebanadilla in Malaga (Sánchez *et al.* 2011) – points to the same direction. Both the variety of the metallurgical methods and of the crucible forms used at La Fonteta seems to be a reflection of different cultural and technological traditions that coexisted at the site. This should not be surprising if we think that the label "Phoenician" most likely included groups of different provenance and ethnicity that undertook joint trade journeys along the Mediterranean Sea and finally settled on strategic areas of the western Mediterranean coastline.

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Notes

1 For general information on the settlement, see for example González-Prats 2011.

2 Thilo Rehren, personal communication. We would like to acknowledge and thank him for his suggestions in identifying the minerals associated with the cassiterite used in this vessel as columbite-tantalite instead of foordite-thoreaulite.

3 According to the characteristics of the spectrometer, the detection limits established for the main elements generally present in non-ferrous alloys are as follow: Fe (K-alfa) <0.01%; Ni (K-alfa) <0.01%; Cu (K-alfa) <0.01%; Zn (K-alfa) <0.1%; As (K-alfa) 0.01%; As (K-beta) <0.1%; Au (L-alfa) 0.1%; Pb (L-beta) <0.01%; Bi (L-beta) <0.01%; Ag (K-alfa) <0.001%; Sn (K-beta) <0.01%; Sb (K-alfa) 0.001%.

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