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# New data on the Late Bronze Age / Early Iron Age metallurgy in Central Portugal. The contribution of Vila do Touro (Sabugal, Guarda)

## Nuevos datos sobre la metalurgia de la Edad de Bronce Final / Primera Edad del Hierro en el centro de Portugal. La contribución de Vila do Touro (Sabugal, Guarda)

**KEY WORDS:** Late Bronze Age (LBA)/ Early Iron Age (EIA), Western Iberia, X-Ray Fluorescence, Lead Isotopic Analysis, "Orientalising" metallurgy.
**PALABRAS CLAVES:** Edad del Bronce final/Primera Edad del Hierro, Iberia occidental, Fluorescencia de rayos X, Análisis isotópico del plomo, Metalurgia "orientalizante".
**GAKO-HITZAK:** Brontze Aroaren amaiera/Burdin Aroaren hasiera, mendebaldeko Iberia, X izpien fluoreszentzia, berunaren analisi isotopikoa, metalurgia "orientalizatzailea".

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### ABSTRACT

This paper focuses on the study of a group of metal artefacts recently recovered during the archaeological excavations in Vila do Touro (Central Portugal), i.e., 19 artefacts and a small metallic inclusion embedded in a pottery sherd.

The objects have been analysed by an X-Ray Fluorescence spectrometer to characterise the elemental composition of metal artefacts. A Scanning Electron Microscope with X-ray Microanalysis System and an optical microscope were used to observe and chemically characterise the metal inclusion in the pottery. The fragment of an ingot was also analysed by a multicollector Inductively coupled plasma mass spectrometer to address issues bound to the provenance of raw material. The results revealed different compositional patterns (pure copper, binary bronze, i.e., Cu+Sn, leaded bronzes, i.e., Cu+Sn+Pb, and gold), while pointing out the Ossa Morena region (Southwest of the Iberian Peninsula) as likely source of copper used to produce the ingot.

### RESUMEN

Este trabajo se centra en el estudio de un grupo de artefactos metálicos recuperados recientemente durante las excavaciones arqueológicas en Vila do Touro (Portugal Central), es decir, 19 artefactos y una pequeña inclusión metálica incrustada en las paredes de un fragmento de cerámica.

Los objetos han sido analizados mediante un espectrómetro de fluorescencia de rayos X para caracterizar la composición elemental de los artefactos metálicos. Se utilizó un microscopio electrónico de barrido con sistema de microanálisis de rayos X y un microscopio óptico para observar y caracterizar químicamente la inclusión metálica en la cerámica. También se analizó el fragmento de un lingote mediante un espectrómetro de masas de plasma acoplado inductivamente multicolector para abordar cuestiones relacionadas con la procedencia de la materia prima. Los resultados revelaron diferentes patrones de composición (cobre puro, bronce binario, es decir, Cu+Sn, bronces con plomo, es decir, Cu+Sn+Pb, y oro), al tiempo que señalaron la región de Ossa Morena (suroeste de la Península Ibérica) como probable fuente del cobre utilizado para producir el lingote.

### LABURPENA

Orain dela gutxi Vila de Touron (Portugalgo erdialdea) egindako indusketa arkeologikoetan zehar berreskuratutako tresna metalikoen multzo bat aztertzen du lan honek, hau da, 19 tresna eta zeramikazko zati baten hormen barruan sartutako inklusio metaliko txiki bat.

X izpien fluoreszentzia-espektometro baten bidez aztertu dira objektuak, tresna metalikoak zer elementuz osatuta dauden jakiteko. Zeramikan sartutako inklusio metalikoari behatzeko eta kimikoki aztertzeko, ekorketarako mikroskopio elektroniko bat (X izpien mikroanalisi-sistemarekin) eta mikroskopio optiko bat erabili dira. Lingote baten zati bat ere aztertu zen, lehengaien jatorriarekin lotutako gaiak lantzeko. Horretarako, multikolektore bati indukzio bidez akoplatutako plasma-masen espektometro bat erabili zen. Hainbat konposizio-patroi hauteman zituzten emaitzek (kobre purua; brontze binarioa, hau da, Cu+Sn; brontzeak berunarekin, hau da, Cu+Sn+Pb; eta urrea). Aldi berean, lingotea ekoizteko erabilitako kobrearen iturria Ossa Morena eskualdea (Iberiar penintsularen hego-mendebaldean) izan litekeela adierazi zuten emaitzek.

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## 1. INTRODUCTION

The Vila do Touro settlement is located in the municipality of Sabugal, in the Guarda district, Central Portugal (Fig. 1). The site sits between two high elevations, punctuated by abundant granite cliffs (Fig. 2). On one of them, known as Alto da Pena, a 13th century medieval fortification was constructed in a slightly prominent position in relation to the village, at an altitude of 831 m. (Portugal Military Chart 1: 25 000, nº 216), at a latitude of 40º 25' 04.81'' North, longitude 7º 06' 24.01'' West.

This formation constitutes a topographic accident visible from a distance, but also enjoying a wide, 360º, visual domain of the landscape, which makes it an excellent strategic point of control over the Riba Côa region, namely the valley of the Ribeira do Boi, the Côa valley and the Meseta. The hill is marked by several topographic unevenness interspersed with granite outcrops, some cyclopean, having originated distinct platforms, part of which were transformed into terraces resulting from the intervention of secular agricultural practices.

Besides the medieval fortification, never finished and today ruined, there were indications of a pre or protohistoric occupation based on the news of the discovery, at the end of the XIX or beginning of the XX century, of a bronze axe of unknown whereabouts and of which there is no description or graphic record (Correia, 1946: 284; Vilaça, 1995: 86). Hand-made pottery sherds found on the surface at the beginning of this century also indicated that older chronology (Osório, 2005: 37).

Between 2014 and 2018, and then again in 2020-2021, excavations carried out at the Alto da Pena were distributed by distinct platforms and targeted the diachrony of the occupation of the hill. The results of this intervention, part of which have already been published (Ponte *et al*., 2017; Vilaça *et al*., 2018; Tereso *et al*., 2020), confirmed the protohistoric occupation of the site at the end of the Bronze Age and the Early Iron Age, more precisely between the IX/VIII and the VII/VI centuries BC.

From this occupation, of residential nature, structures were identified in three of the eight areas investigated, which were associated with various ceramic materials of supra-regional circulation (*e.g.,* Cogotas I, Carambolo and Cogotas II types), some lithics, namely one axehead, elements of hand grindstones and weaving weights, in addition to the metallic artefacts. It is the latter that constitute the aim of this work, essentially focused in an archaeometallurgical perspective.

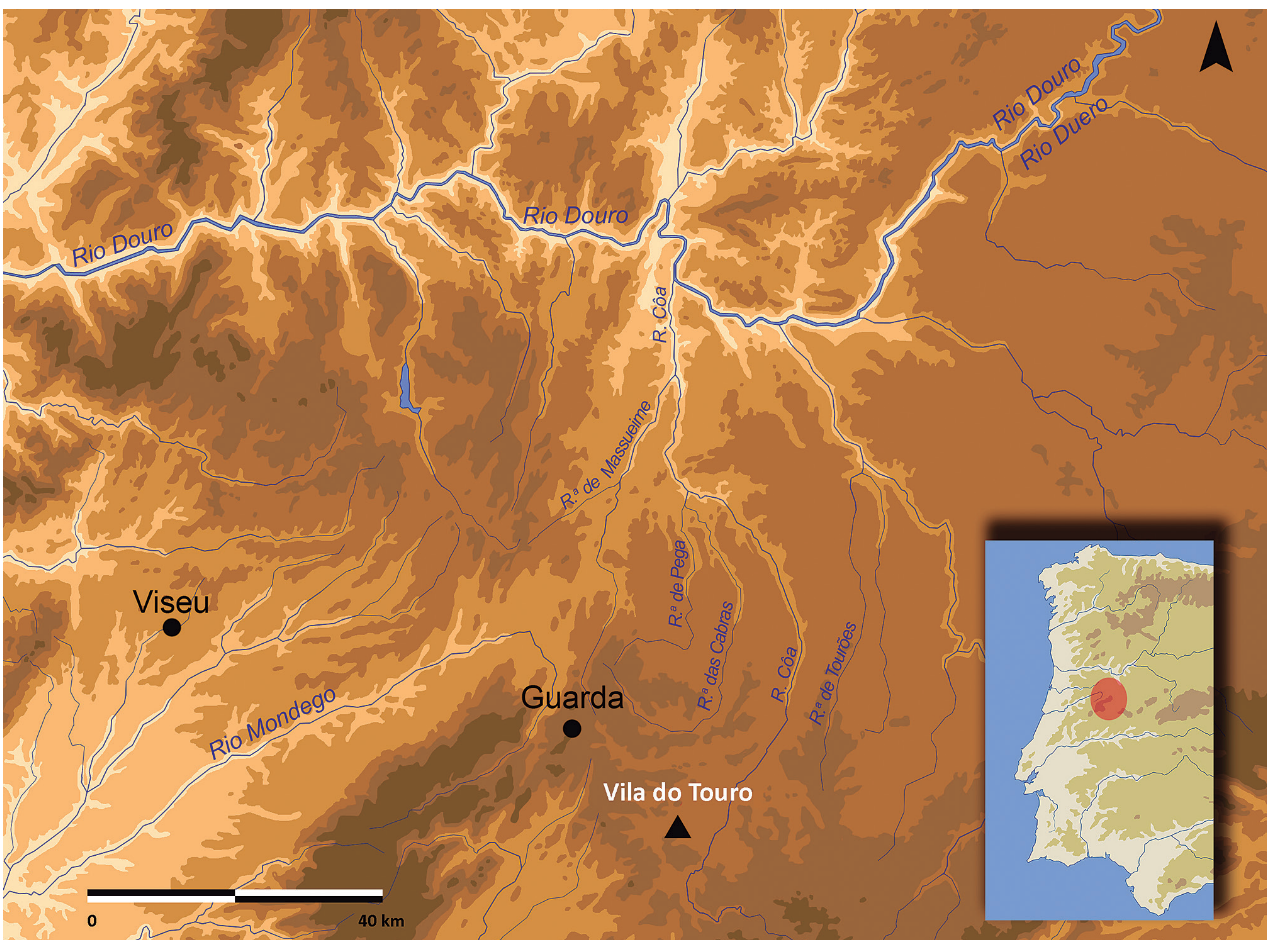


**Fig.1.** Location of Vila do Touro within the regional framework / Localización de Vila do Touro en el marco regional.


**Fig.2.** Elevation where the site is located, seen from south (A) and from west (B) / Elevación donde se encuentra el emplazamiento, visto desde el sur (A) y desde el oeste (B).

## 2. CATALOGUE OF ARTEFACTS

The 23 artefacts studied in the present paper come from the excavations carried out in areas II, III, V and VI of the site (Fig. 3). Most of them are fragmented or quite incomplete, part of them unclassifiable and, in general, characterised by a thick corrosion layer. However, some of them deserve special interest for the information they provide. Apart from VDT-19, in gold, all the others are copper-based alloys. The following catalogue does not include a pottery sherd with a tiny piece of metal embedded in it.

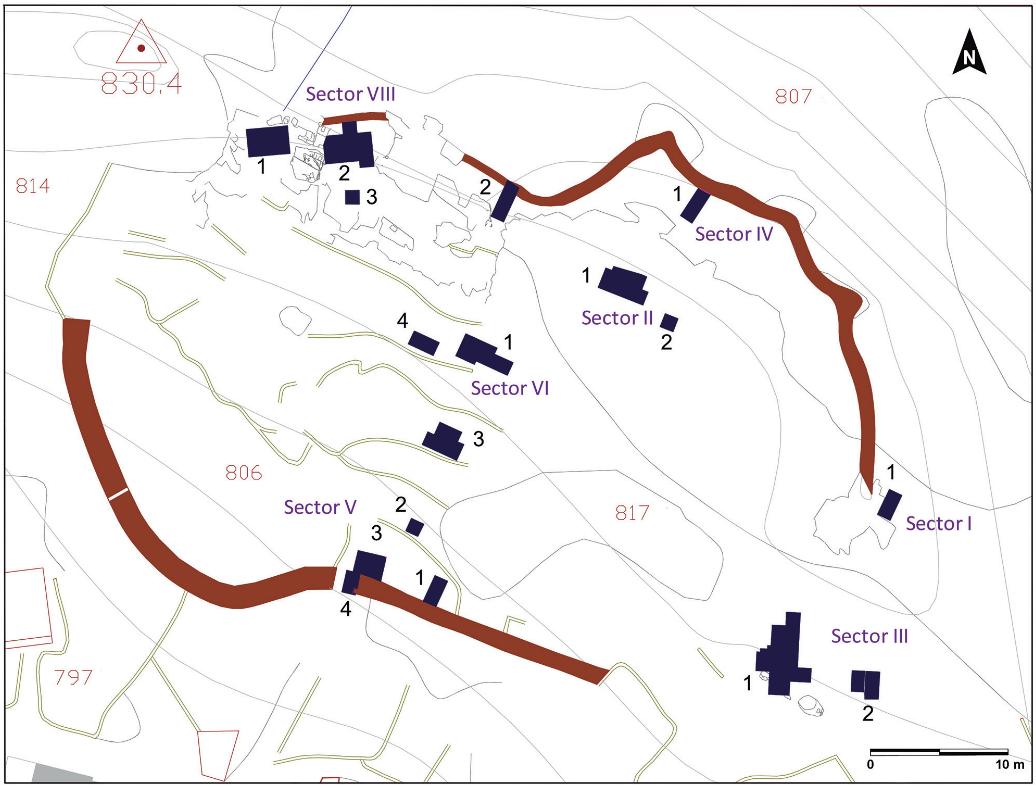


**Fig.3.** Excavated sectors / Sectores excavados

VDT-01 (inv. 2/2014) (Fig. 4, nº. 1)

Three rectilinear fragments possibly belonging to the same piece, given that they were found together. Irregular surface and sub-circular section. Length: 2a: 3.7 cm; 2b: 1.7 cm. Thickness: 0,6 cm (max.); 0,4 cm (min.). Field reference: S II E 3/4 [02].

VDT-02 (inv. 6/2014) (Fig. 4, nº. 2)

Fragment of a forged sheet with irregular shape due to corrosion, slightly wavy in the central part, possessing rivet hole. Length: 3.6 cm. Width: 2.7 cm. Thickness: 0.1 mm. Field reference: S V 2 [2].

VDT-03 (inv. 6/2015) (Fig. 4, nº. 3)

Fragment of a fibula preserving the arch, part of the spring and start of the rest; sub-quadrangular section. According to Ponte *et al*. (2017: 139) it belongs to the Bencarrón type. Length: 5.5 cm. Height: 2.5 cm. Field reference: S III L 4 [2] (cut).

VDT-04 (inv. 1/2014) (Fig. 4, nº. 4)

Slightly curved stem, with an irregular surface and sub-circular section. Fragmented at the thinner end. Length: 4.9 cm. Thickness: 0.5 cm (max.); 0.3 cm (min.). Field reference: S II D 3/4 [02].

VDT-05 (inv. 4/2014) (Fig. 4, nº. 5)

Stem fragment of irregular surface, thickened in the centre, sub-quadrangular section. Unclassifiable piece. Length: 1.9 cm. Thickness: 0.6 cm (max.); 0.4 cm (min.). Field reference: S III D 3/4.

VDT-06 (inv. 3/2014) (Fig. 4, nº. 6)

Fragment of irregular contour, twisted, of sub-circular section. Unclassifiable piece. Length: 2 cm. Thickness: 0.3 cm (max.); 0.2 cm (min.). Field reference: S II D 3/4 [3].

VDT-07 (inv. 5/2014) (Fig. 4, nº. 7)

Fibula with laminar arch of rhomboidal profile and sub-triangular section, foot and long rest, fragmented; longitudinal rib and thin horizontal and parallel incisions on on the outer face of the arch. The fibula belongs to the Alcores type. Length: 5 cm (arch); 1,8 cm (rest). Thickness: 0,1-0,2 cm. Field reference: S III G4 [5].

VDT-08 (inv. 2/2015) (Fig. 4, nº. 8)

Originally closed subcircular ring, with slightly irregular surface due to corrosion, sub-circular section. Diameter: 2 cm (ext.); 1.4 cm (int.). Thickness: 0.6 cm (max.); 0.4 cm (min.). Field reference: S II E 4 [8].

VDT-09 (inv. 5/2015) (Fig. 4, nº. 9)

Slightly curved fragment, with a regular surface and sub-quadrangular section. Length: 2.4 cm. Thickness: 0.3 cm (max.); 0.2 cm (min.). Field reference: S III D6 [03].

VDT-10 (inv. 1/2015) (Fig. 4, nº. 10)

Belt hook with stem slightly thickened in the centre and fully arched hook; sub-rectangular section. Length: 5.5 cm. Thickness: 0.5 cm (max.); 0.1 cm (min.). Field reference: S II E 4 [03].


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VDT-11 (inv. 3/2015) (Fig. 4, nº. 11)

Unclassifiable fragment of an object with a body of sub-circular section and two thin lateral pieces of similar section, but smaller in size. Length: 1.6 cm. Thickness: 0.4 cm (max.); 0.2 cm (min.). Field reference: S III D5 [5].

VDT-12 (inv. 4/2015) (Fig. 4, nº. 12)

Shapeless ingot with one side showing an irregular surface and the other slightly flattened. Length: 4.8 cm (max.). Width: 3 cm (max.). Thickness: 1.8 cm max. Weight: 70 g. Field reference: S III K4 [3].

VDT-13 (inv. 1/2017) (Fig. 4, nº. 13)

Sub-circular arch, losangular in section, with a rather long foot and folded into a short caudal appendage of conical shape; triangular rest; lacks the fibula needle and bilateral spring. It is a Ponte 24c/25 type fibula. Length: 4,6 cm. Height: 2 cm. Weight: 4 g. Field reference: S VI test pit 1 (extension).

VDT-14 (inv. 3/2016) (Fig. 4, nº. 14)

Fibula with complete arch, preserving a spring spiral and start of the rest; sub quadrangular section. The fibula appears to be rather similar to VDT-03, probably also belonging to the Bencarrón type. Weight: 5 g. Field reference: S VI test pit 1 A1 [07].

VDT-15 (inv. 6/2018) (Fig. 4, nº. 15)

Small shapeless piece of smelted metal, with an irregular surface. Length: 0.9 cm. Width: 0.6 cm (max.); 0.4 cm (min.). Thickness: 0.4 cm. Field reference: S III F4 [08].

VDT-16 (inv. 5/2018) (Fig. 4, nº. 16)

Small shapeless piece of smelted metal, with an irregular surface. Length: 1.5 cm. Width: 1.3 cm (max.); 0.8 cm (min.). Thickness: 0.5 cm (max.); 0.2 cm (min.). Field reference: S III D4 [05].

VDT-17 (inv. 1/2020) (Fig. 4, nº. 17)

Fragment of a small, socketed object with irregular edges. Rim with thickening forming a kind of collar. It has an elliptical loop, with traces of wear (or corrosion); it still retains casting burrs resulting from manufacture in a bivalve mould. Length: 2,8 cm.; (estimated) socket diameter: 2,7 cm; 1,7 cm (distal end). Thickness: 0,4 cm. Field reference: S VI, test pit 3 B7 [12].

VDT-18 (inv. 2/2020) (Fig. 4, nº. 18)

Fragment of very thin sheet with irregular contours, forged, and bent at one end; it has a small hole for the insertion of a possible rivet in the bent part and, on the flat part, traces of another rivet. Length: 2,1 cm. Width: 2.3 cm; Thickness: 1 mm. Field reference: S VI, test pit 4 [5].

VDT-19 (inv. 3/2020) (Fig. 4, nº. 19)

Small gold ring, complete, with sub-circular contour and section. Diameter: 0.5 cm. Thickness: 0.1 cm. Field reference: S VI, test pit 3 A8 [10].

In addition to the objects listed so far, four other pieces from Vila do Touro have been not analysed due to their fragile state of conservation and the impossibility of removing the layers of corrosion while guaranteeing physical integrity. These are the following objects:

VDT-20 (inv. 4/2020) (Fig. 4, nº. 20)

Fragment of curved and twisted stem, with irregular surface and sub-circular section. Unclassifiable. Length: 4.6 cm. Thickness: 0.2-0.4 cm. Field reference: S VI, test pit 4 (west cut clearance).

VDT-21 (inv. 1/2016) (Fig. 4, nº. 21)

Three fragments of rectilinear stem, with sub-rectangular section, having one of the faces slightly flattened and the other with an irregular surface. It must have belonged to the same piece. High degree of corrosion. Length: 1a: 2.7 cm; 1b: 1.7 cm; 1c: 2 cm. Width: 1a, 1b and 1c: 0.3-0.4 cm (max.); 0.2 cm (min.). Thickness: 1a, 1b and 1c: 0.1-0.2 cm. Field reference: S III D5 [12].

VDT-22 (inv. 2/2016) (Fig. 4, nº. 22)

Small laminar ring fragmented in half, with smooth surface and lenticular section. External diameter: 0.7 cm. Internal diameter: 0.5 cm. Thickness: 0.2 cm. Field reference: S III E3 [2].

VDT-23 (inv. 1/2018) (Fig. 4, nº. 23)

Thin and slightly twisted fragment, of sub-circular section. Length: 2.7 cm. Thickness: 0.2 cm (max.); < 0.1 cm (min.). Field reference: S III D5 [11].

## 3. ARTEFACT TYPOLOGY

As mentioned above, of the 23 metal artefacts under study, 1 is gold and the remaining 22 are copper-based alloys. With the only exception of that one, a small ring, the remaining materials are fragmented and/or incomplete, which explains the fact that almost one object in every three is unclassifiable. Even so, it was possible to count: 4 fibulae (VDT-03, VDT-07, VDT-13 and VDT-14), 3 rings (VDT-08, VDT-19 and VDT-22), 3 stems (VDT-01, VDT-04 and VDT-21), 2 sheets (VDT-02 and VDT-18), 1 belt hook (VDT-10), 1 ingot (VDT-12), 1 socketed object (VDT-17), the remaining 8 being unclassifiable (VDT-5, VDT-6, VDT-9, VDT-11, VDT-15, VDT-16, VDT-20 and VDT-23). The copper-based objects studied in this paper are part of a wider group of metallic artefacts recovered during the excavations carried out at Vila do Touro that also includes iron items.

Despite the rather modest number, the assemblage itself presents several interesting elements. A first aspect to be pointed out is the presence of items linked to characteristic productions of the so-called "orientalising" world, namely three of the four fibulae and the belt hook. The Alcores type fibula (Ponte 8a/I.2) (Fig. 4, nº. 7) and two of the Bencarrón type (Ponte 10b/2, cf. Ponte *et al.*, 2017: 139) (Fig. 4, nº. 3 and 14) are traditionally considered to be productions from the Lower Guadal-

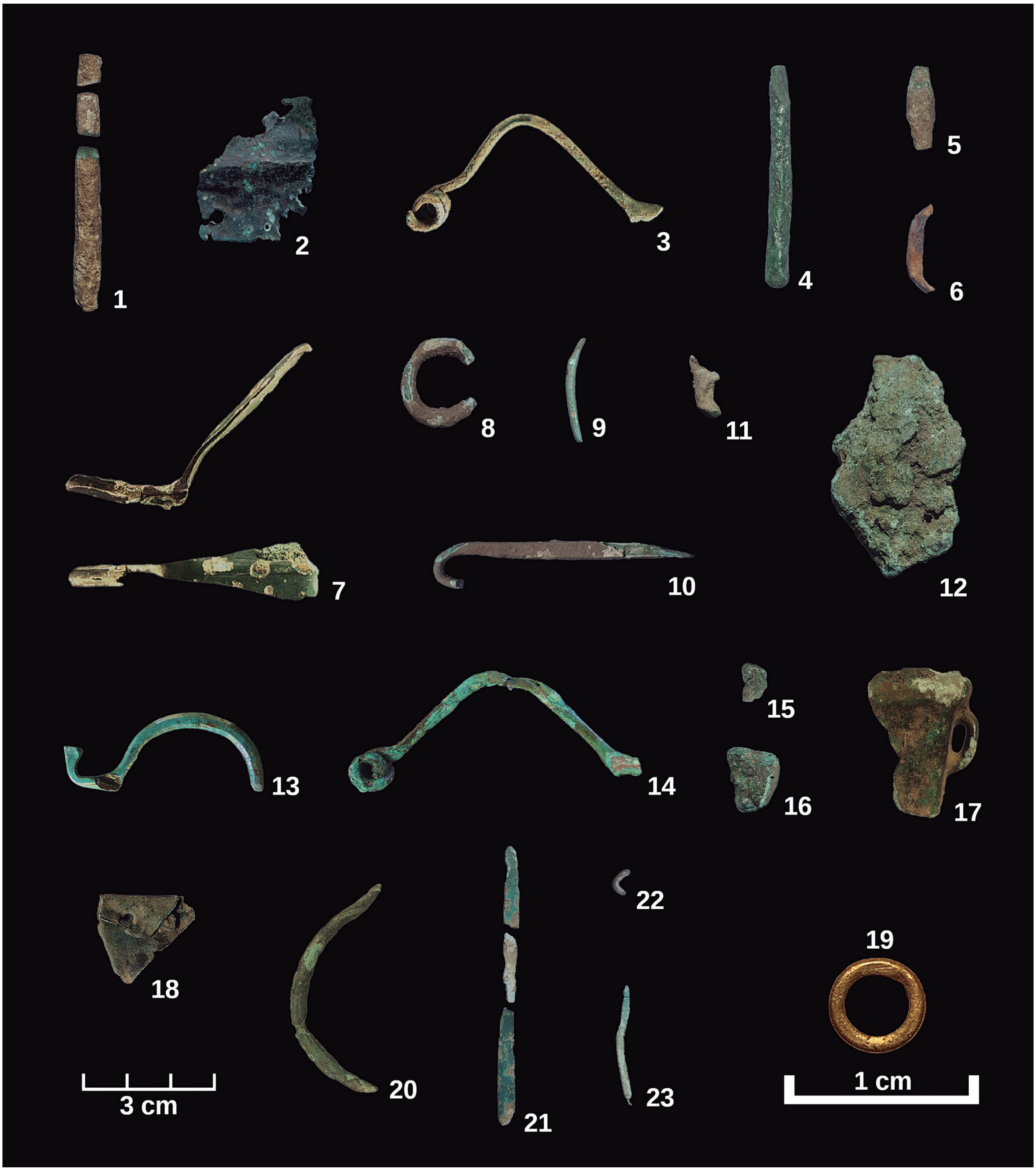


**Fig.4.** The artefacts found during the excavation of Vila do Touro / Los artefactos encontrados durante la excavación de Vila do Touro.

quivir and dated to the 8th and 7th centuries BC (Ponte, 2006: 128-135; 144-152; Ponte *et al.*, 2017: 139). At a regional level, the only parallel known to date is a fibula characterised by similar morphological and mechanical elements of the Bencarrón type found at Alegrios (Idanha-a-Nova) (Vilaça, 1995: 341). On a wider scale, and even though these are not such common types in Portuguese territory, Bencarrón and Alcores type fibulae are distributed from north to south, with examples having been found both in settlement and grave contexts. The former type is documented, for example, in the settlements of Coto da Pena (Caminha) (Silva, 2007), Fraga dos Corvos (Macedo de Cavaleiros) (Senna-Martinez *et al.*, 2012: 250), Conímbriga (Condeixa-a-Nova) (Co-


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rreia, 1993: 261), Castro dos Ratinhos (Moura) (Valério *et al*., 2010), and Quinta de Almaraz (Almada) (Valério *et al*., 2012). Alcores type fibulae also appear in Conímbriga (Correia, 1993: 261) and, in a funerary context, in Palhais (Beja) (Santos *et al*., 2017: figs. 7-1 and 4), and Esfola (Beja) (Valério *et al*., 2021).

In addition to these two types of fibulae, there is also a specimen of Ponte 24c/25 type with a short caudal appendage, types which the most ancient models date back to the 7th-early 6th century BC, possibly reaching the 5th century BC, with parallels in the Meseta area (Ponte, 2006: 233 ff.; 243). The same researcher mentions that these are *sui generis* manufactures, revealing techno-morphological affinities with LBA/EIA prototypes and with Atlantic and Mediterranean influences (Ponte, 2006: 244-245). Regionally, it is worth mentioning the existence of a Ponte 24b type fibula at the Cachouça site (Idanha-a-Nova), also occupied during the Early Iron Age (Ponte, 2006: 246; Vilaça, 2007).

As for the belt hook, the fragment found in Vila do Touro would probably be part of a much more complex artefact, i.e., a plate or "Tartessian-type" buckle with multiple hooks, components which were not found during the excavation (cf. Arruda *et al*., 2022). Complete specimens are unknown in the Beira Interior region, except for the buckle and plate from Tapada das Argolas (Fundão), but datable to a Late Iron Age (Vilaça *et al*., 2002-2003: 182-183, fig. 8-1, 2). Loose hook objects similar to the one from Vila do Touro and of equally ancient chronology, dating to the transition from the Bronze Age to the Iron Age, are known in the region, namely the two examples from the LBA settlement of Moreirinha (Idanha-a-Nova) (Vilaça, 1995: CCXXVII-9 and CCXLVI-15). Also, but in these cases with two curved ends, the hooks from Abrigo Grande das Bocas (Rio Maior) (Carreira, 1994: 85) and Castro dos Ratinhos (Berrocal-Rangel *et al*., 2010: 305). Other belt buckles are known in the south of Portuguese territory, mainly coming from funerary contexts from the Beja region. It worth remembering Tartessian-type buckle from Vinha das Caliças (Beja) (found together with two Celtic-type and three iron made buckles) (Arruda *et al*., 2016: 203, fig. 13), Palhais (Beja) (Santos *et al*., 2017: 240, fig. 10), Esfola (Beja) (Valério *et al*., 2021), and Olival do Senhor dos Mártires (Setúbal) (Gomes, 2022).

The occurrence of metallic elements of Mediterranean influence (or import) is a well-documented situation in the Beira region since the end of the 2nd millennium BC and the beginning of the following one, as can be verified by the occurrence of elements such as tweezers, multi-curved arch and double spring fibulae, iron objects and glass necklace beads, among others (Vilaça, 2008; Vilaça, 2013). The four fibulae and the belt hook now found in Vila do Touro, from Early Iron Age contexts, to which we may add the Acebuchal type fibula, or Ponte 9a/1, from Sabugal Velho (Osório, 2005: 44, Est. 19-4; Ponte, 2014: 9), demonstrate continuity regarding the use and manipulation, by local communities, of artefacts from the Mediterranean cultural sphere. Such elements should be further valued in connection with others that express the existence of these same cultural influences, as is the case of the painted pottery of Carambolo type (Vilaça *et al*., 2018). As in the LBA, also in the EIA, the penetration routes to the Beira Interior would have been the ones that crossed the Extremadura or even the ones that reached the interior from the western Atlantic coast, through the Mondego or Tagus rivers.

Among the pieces morphologically recognisable, it is also worth mentioning the presence of a fragment of a socketed artefact, possibly a small axe. Given its fragmentary state, limited to the socket, it is not possible to determine whether it had one or two loops. Socketed axes are a common type in the Iberian West, particularly in Central and Northern Portugal and Galicia (Monteagudo, 1977: 242-260). But one of the most interesting aspects of this piece is its small dimensions: the socket has a diameter estimated in only about 2.7 cm and the thickness of its walls, around 0.4 cm, reveals little robustness, allowing this specimen to be brought closer to others (Montegaudo, 1977: Taf. 122), which, not being miniatures, constitutes a different group in comparison to the more classic, more robust and heavier socketed axes found throughout Western Iberia.

Nevertheless, other alternatives should not be discarded. In fact, the Vila do Touro socketed axe does not seem to be very different from some one-looped miniatures from the LBA/EIA of Brittany (France) (Roussot-Larroque *et al*., 2004; Milcent, 2012: 148-149). On the other hand, we cannot fail to mention a bimetallic one-looped socketed chisel from Senhora da Guia de Baiões (S. Pedro do Sul), originally classified as a dagger (Silva *et al*., 1984: 83, Est. VII-3), that shows similar morphological characteristics to the socketed object from Vila do Touro.

The ingot fragment is also noteworthy. As elements related to the operational chain of the metal artefacts found, ingots are extremely rare finds in western Iberia (Montero-Ruiz *et al*., 2010-2011). Other ingots found in Portuguese territory come from hoard contexts, namely from the Viatodos (or Fonte Velha) (Barcelos) (Fortes, 1905-1908; Bottaini, 2013) and Quinta do Ervedal (Fundão) hoards (Villas-Bôas, 1947), the latter located not far away from Vila do Touro.

Finally, and in addition to the metal artefacts, we must point out to a tiny piece of metal embedded in pottery sherd, apparently after its firing, and found in the Sector V sond. 3 [3] (Fig. 5). The fragment belonged to a finely hand-made vessel, with compact paste, well-distributed small inclusions, and intensely polished surfaces. When observed under the electron microscope, the fragment of metal embedded in the ceramic consists of an extremely thin folded blade, forming a kind of small box, which was inserted from the inner surface of the container. Its interpretation is not obvious due to the fragmented state of the pottery sherd, the


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characteristics of the metal fragment and the singularity of the find. Without known direct parallels, we hypothesise that it could be the remains of some sort of metal staple or rivet used to join two parts of a fractured vessel, given its location near the fracture zone. The idea that it could correspond to the remains of an inlaid decorative element found on pottery from the Early Iron Age in Meseta, Extremadura and the south of the Peninsula does not seem to be the most compatible with the reality observed, although it cannot be rejected outright.


**Fig.5.** Metal piece embedded in the pottery sherd seen under stereoscopic microscope / Pieza de metal incrustada en la cerámica visto bajo microscopio estereoscópico.

## 4. ANALYTICAL METHODOLOGY

The composition of the Vila do Touro metal artefacts was determined with a Bruker TRACER III-SD X-ray fluorescence (XRF) spectrometer equipped with a rhodium X-ray tube and SDD X-Flash detector, with a resolution of 145 eV in the Kα line of Mn. The analyses were focused on points of the objects from which the surface corrosion layer was previously removed. The following working conditions were used: 40kV, 3 µA, Al/Ti filter (304.8 µm Al/25.4 µm Ti), 60 seconds of acquisition. Quantification was performed with reference standards with a similar composition to the materials analysed, namely BCR-691 standards (for copper-based alloys) (cf. Bottaini *et al.*, 2022), and internal standards (for the gold ring).

A Scanning Electron Microscope with X-ray Microanalysis System (SEM-EDS) was used for the analysis of the metal fragment present inside the pottery sherd. For this purpose, a HITACHI S-3700N electron microscope equipped with Bruker Xflash Silicon Drift Detector (SDD) energy dispersive X-ray spectrometer was used. Data were acquired with the following analysis conditions: 20 kV and 90 µA. The metal embedded in the pottery sherd was further observed by a Leica M205C stereo microscope. Analyses were carried out at the HERCULES Laboratory of the University of Évora (Portugal).

Lead Isotope Analysis (LIA) of the ingot was performed in the Geochronology Service at the Basque Country University (SGiker-UPV/EHU, Spain). All stable lead isotope ratios were determined on a Thermo Scientific™ Neptune XT™ double-focusing multicollector Inductively coupled plasma mass spectrometer (MC-ICPMS) with a double-pass dual cyclonic/Scott spray chamber. Sample preparation and measurements protocols including Instrumental mass fractionation and the use of reference material is described in Rodriguez *et al.* (2020).

## 5. RESULTS AND DISCUSSION

The data on the chemical composition of the analysed items are summarised in Table 1. Of the 23 metallic artefacts recovered in Vila do Touro, the results are presented for 19, one in gold and the others copper-based alloys. The specimens VDT-20, VDT-21, VDT-22 and VDT-23 were not analysed due to their fragile and oxidised state, which made it impossible to properly clean the corrosion products.

The copper-based artefacts show some heterogeneity as three distinct compositional groups can be defined. The ingot fragment (VDT-12) and the sheet (VDT-18), both made out of copper with reduced impurity contents, namely Sn, Sb, As, Fe and Ag, fit in the first one. The numerically most consistent group, composed by twelve specimens, consists of the objects manufactured in bronze binary alloy (Cu+Sn), with traces of Pb, Sb, As, Fe, Ni and Ag, which total amounts vary between 0.21% (VDT-02) and 3.31% (VDT-16). Finally, four artefacts are made using bronze alloys with lead (>3% Pb) and traces of secondary elements, i.e., Pb (<3%) Sb, As, Fe, Ni and Ag, which total concentration does not exceed 1.69%. Overall, the Pb levels remain below 2% (13 out of 19 pieces) (Fig. 6A).

In the last two groups, i.e., binary alloys and binary alloys with Pb >3%, tin levels oscillate between 8.82% and 19.44%, with a higher incidence between 12% and 14% (Fig. 6B) and an average of approximately 13%. This data suggests a reduced tendency for recycling, even though the presence of several shapeless and fragmented metal pieces, eventually used as scrap, may give, at a first glance, a different impression. The fact is that the recycling and re-melting of used pieces as raw material to produce new objects would lead to a gradual but constant decrease in the tin concentration, due to a preferential oxidation process of the tin itself during the melting. On the contrary, the Sn contents detected in Vila do Touro suggest that the craftsmen who produced these objects had a continuous and sufficient supply of tin ores for the quantity of artefacts manufactured. On the other hand, the Vila do Touro production matches the typical LBA metallurgy from the Beira region characterised by alloys with a tin percentage that


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| Type | Lab ID | Cu | Sn | Pb | Sb | As | Fe | Ni | Ag | Au |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stem** | VDT-01 | 83.36 | 16.07 | n.d. | 0.13 | 0.42 | 0.02 | n.d. | n.d. | n.d. |
| **Sheet** | VDT-02 | 85.23 | 14.51 | n.d. | N.D. | N.D. | 0.01 | 0.20 | n.d. | n.d. |
| **Bencarrón type fibula (?)** | VDT-03 | 90.24 | 9.32 | 0.07 | N.D. | N.D. | 0.31 | n.d. | n.d. | n.d. |
| **Stem** | VDT-04 | 85.75 | 13.71 | n.d. | 0.10 | 0.40 | 0.03 | n.d. | n.d. | n.d. |
| **Undetermined** | VDT-05 | 82.95 | 16.43 | n.d. | 0.11 | 0.47 | 0.04 | n.d. | n.d. | n.d. |
| **Undetermined** | VDT-06 | 79.44 | 17.80 | 2.15 | 0.09 | 0.11 | 0.41 | n.d. | n.d. | n.d. |
| **Alcores type fibula** | VDT-07 | 81.74 | 14.41 | 3.41 | 0.12 | 0.26 | 0.04 | n.d. | 0.02 | n.d. |
| **Ring** | VDT-08 | 87.52 | 11.81 | 0.15 | 0.19 | 0.21 | 0.01 | n.d. | 0.11 | n.d. |
| **Undetermined** | VDT-09 | 85.60 | 12.06 | 1.89 | 0.14 | 0.21 | 0.02 | 0.02 | 0.06 | n.d. |
| **Belt hook** | VDT-10 | 91.13 | 8.82 | 0.26 | N.D. | 0.54 | 0.05 | 0.02 | 0.18 | n.d. |
| **Undetermined** | VDT-11 | 75.10 | 12.58 | 10.63 | 0.58 | 0.87 | 0.13 | N.D. | 0.11 | N.D. |
| **Ingot** | VDT-12 | 99.89 | 0.01 | N.D. | N.D. | N.D. | 0.05 | N.D. | 0.05 | N.D. |
| **Ponte 24c/25 type fibula** | VDT-13 | 80.25 | 12.7 | 6.2 | N.D. | 0.6 | 0.05 | N.D. | 0.2 | N.D. |
| **Bencarrón type fibula (?)** | VDT-14 | 85.73 | 13.20 | 0.63 | 0.13 | 0.19 | 0.08 | N.D. | 0.04 | N.D. |
| **Undetermined** | VDT-15 | 79.12 | 19.30 | 1.14 | N.D. | 0.40 | 0.04 | N.D. | N.D. | N.D. |
| **Undetermined** | VDT-16 | 77.26 | 19.44 | 1.86 | 0.74 | 0.33 | 0.04 | 0.34 | N.D. | N.D. |
| **Socketed artefact** | VDT-17 | 81.6 | 13.47 | 4.27 | 0.23 | 0.38 | 0.02 | 0 | 0.04 | N.D. |
| **Sheet** | VDT-18 | 99.18 | 0.03 | N.D. | 0.42 | 0.3 | 0.01 | N.D. | 0.06 | N.D. |
| **Ring** | VDT-19 | 0.45 | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | 23.61 | 75.94 |

**Tabla 1:** XRF analysis results (in wt%; n.d.: not detected). / Resultados de los análisis XRF (en % en peso; n.d.: no detectado).

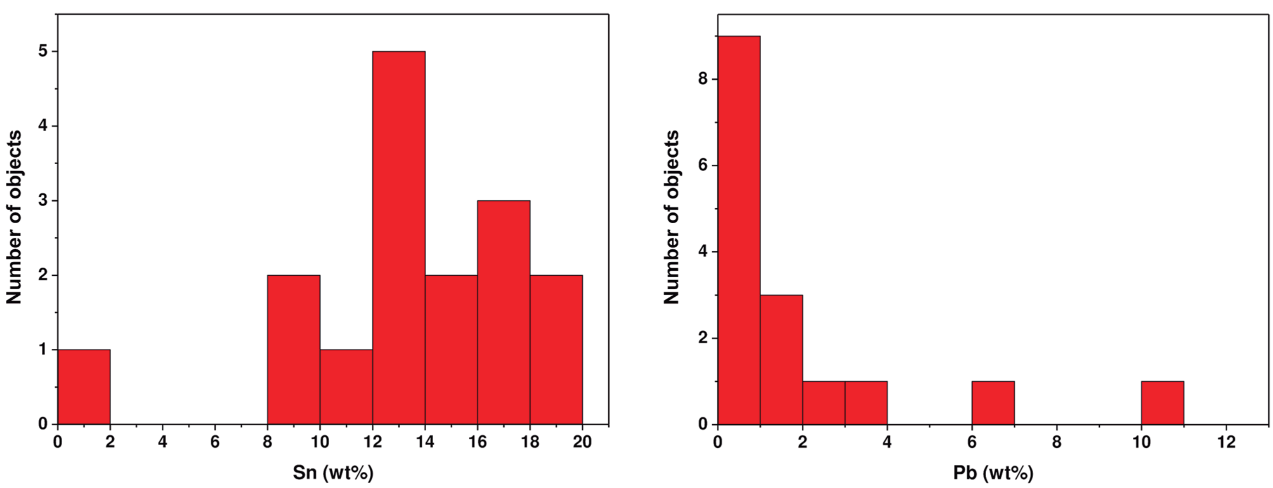


**Fig.6.** Frequency distribution histogram for Sn (A) and Pb (B), in the collection of artefacts analysed from Vila do Touro / Histograma de distribución de frecuencias para Sn (A) y Pb (B), en la colección de artefactos analizados de Vila do Touro.

usually ranges between 8 and 15% and low impurities (Vilaça, 1997; Bottaini *et al.*, 2016).

In relation to other chemical elements, iron occurs in rather small percentages. The presence of this element in concentrations above approximately 0.05% is generally interpreted as an indicator of the type of ore reduction technology used (Craddock *et al.*, 1987). In the case of the artefacts under study, Fe does not exceed the above-mentioned value in 12 of the 16 objects, which is also coherent with local LBA/EIA metallurgy in the Beira Interior. On the other hand, considering the thick layer of corrosion that surrounded the objects, a higher concentration of iron may possibly result from traces of the corrosion itself not sufficiently removed from the area where the analysis took place.

Regarding the composition of the metal fragment embedded inside the pottery sherd, the data obtained by micro-analysis through SEM-EDS show that it is composed mainly of Cu, Sn and Pb (Fig. 8). However, the superficial nature of the analysis and the impossibility of


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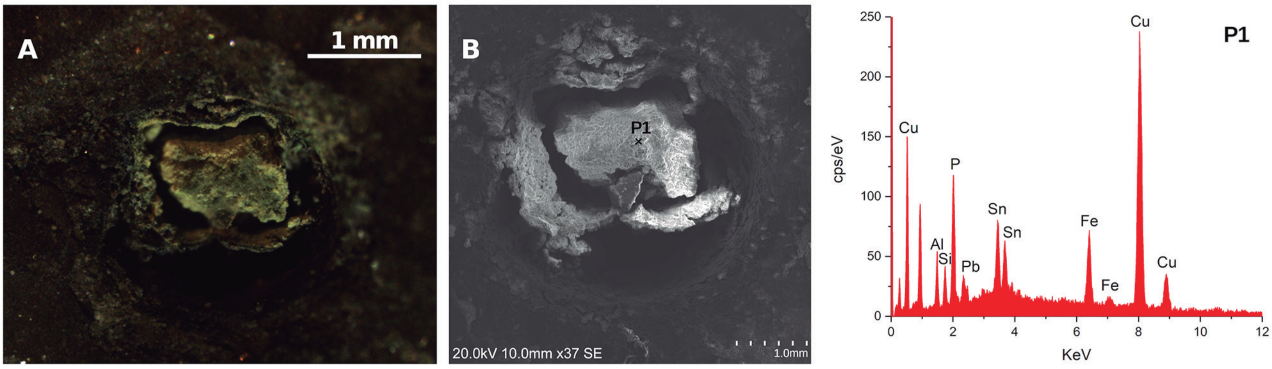


**Fig.7.** Metal fragment embedded in the pottery sherd observed by optical microscope (A) and SEM (B), with microanalysis by EDS (point 1) / Fragmento de metal incrustado en el la cerámica observado mediante microscopio óptico (A) y SEM (B), con microanálisis por EDS (punto 1).

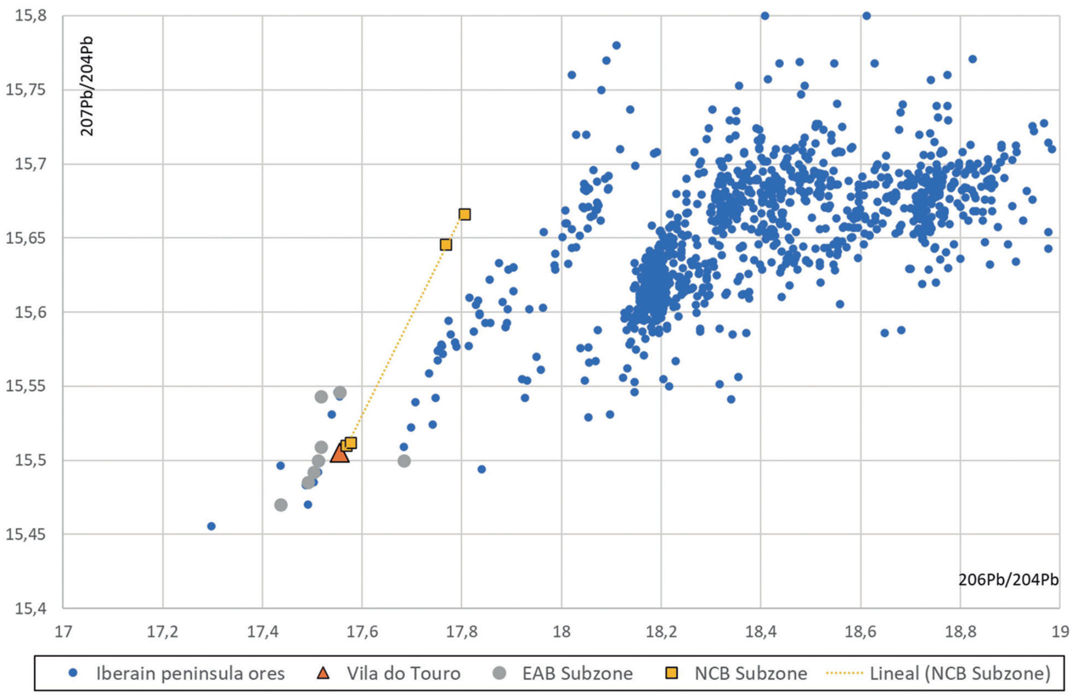


**Fig.8.** Binary diagram of Pb isotope ratios comparing the ingot from Vila do Touro to ore deposits in the Iberian Peninsula / Diagrama binario de las relaciones isotópicas del Pb comparando el lingote de Vila do Touro con yacimientos de la Península Ibérica.

removing the corrosion did not allow the concentration of each of the elements to be correctly quantified.

In general, there does not seem to be any kind of relationship between the composition of each object and its morphological and functional characteristics. The four fibulae, for example, although belonging to three different types and despite their common Mediterranean influence, reveal a divergent composition. The two Bencarrón type fibulae (VDT-03 and VDT-14) are composed of a binary bronze (Cu+Sn), in which tin levels vary between 9.32% and 13.2%, both with reduced impurities, including lead. The remaining two fibulae of the Alcores (VDT-07) and Ponte 24c/25 (VDT-13) types, are ternary bronzes, with lead values of, respectively, 3.41% and 6.16%.

The occurrence of higher amounts of Pb has traditionally been linked to the morphological and typological characteristics of the artefacts. Pb, in fact, makes the metal, in its liquid state, more fluid, which simplifies the manufacture of more elaborated artefacts. However, it is generally assumed that the maximum fluidity is reached with values around 3-4% (Rovira *et al.*, 1991: 62). Beyond this value, the addition of lead no longer produces any beneficial effect for the alloy. Quite the contrary, given the non-miscibility of lead with copper, an excessive presence of Pb leads to the formation of inclusions that end up making the alloy more fragile and brittle. The presence of higher contents of Pb, namely in an unclassifiable piece (10.63% Pb) and in the socketed artefact (4.27% Pb), reinforce the idea that in Vila do Touro the addition of lead was not an unequivocal option from the technological point of view.

In general, the data reveal a lack of homogeneity in the composition of the alloys, showing an unpredictable variability of both Sn and Pb. Consequently, it is not possible to find any possible correlation between the typology of the artefacts and its composition, thus making it difficult to deduce whether and which artefacts found at Vila do Touro were locally produced or imported.

Furthermore, the differences in terms of chemical composition do not seem to be evident even between the metals found within the different excavated sector. Sector II, for example, from which the belt buckle come from, has been radiocarbon dated to between the 9th and the 8th century BC (Vilaça *et al.*, 2018: 61; Tereso *et al.*, 2020: 261). No further radiocarbon dating is available for the rest of the excavated areas, but the typology of some other artefacts might indicate areas with a slightly different chronology. This is the case, for example, of area III, where an Alcores fibula has been found. This specific type of fibula is generally dated to the 9th-8th century BC, although its production may extend up to the 7th century BC (cf. Ponte *et al.*, 2017: 139). However, while there may be slight chronological differences between the excavated areas of the settlement, the metals from these areas show no appreciable variation in terms of chemical composition.

In a wider context, if we look at the data available for the fibulae from Portuguese LBA/EIA, we can also observe a certain lack of uniformity in terms of metal alloys. Within the Bencarrón type fibulae, for example, the specimens from Coto da Pena (Caminha) (Silva, 2007), Alegrios (Idanha-a-Nova) (Vilaça, 1997: 148) and Castro de Ratinhos (Valério *et al.*, 2010: 1813) are composed of binary bronzes. Only the specimen from Fraga dos Corvos (Macedo de Cavaleiros) shows a Pb concentration reaching a value of approximately 2% (Senna-Martínez *et al.*, 2012: 257-258). Also in binary alloys are the Alcores type fibulae, namely the one from Palhais (Valério *et al.*, 2013: 365) and the two Acebuchal type specimens, also of "orientalising" influence, found at Quinta de Almaraz (Almada) (Valério *et al.*, 2012). Finally, the two Alcores and Acebuchal type fibulae from Esfola are also made of a binary alloy very poor in elements other than Cu and Sn (Valério *et al.*, 2021).

Regarding the socketed axes, type to which VDT-17 may belong to, the analyses also depict a not very homogeneous picture, characterised by the coexistence of pieces produced both in binary (Cu+Sn) and ternary alloys (Cu+Sn+Pb). Belonging to the first group are, for example, the double-looped axes from Coles de Samuel (Soure) (Bottaini *et al.*, 2016), Freixianda (Ourém) (Gutiérrez-Neira *et al.*, 2011; Vilaça *et al.*, 2012), Casais da Pedreira (Alenquer) (Bottaini *et al.*, 2012), Candemil (Amares), and the one-looped axe from Lugar da Bouça (Vila Nova de Famalicão) (Bottaini *et al.*, 2012; Bottaini, 2013). Although less expressive in quantitative terms, the number of socketed axes made with lead-rich alloys, including the one from Vila do Touro, counts to date two other specimens, namely an axe from Castro de Fiães (Santa Maria da Feira) (2 loops, 15±2% Pb) (Bottaini *et al.*, 2012) and from Quinta do Espadanal (Castelo Branco) (1 loop, 3.7% Pb) (Bottaini *et al.*, 2017). Finally, it is also worth mentioning a stone mould found in Guidoiro Areoso (Galicia) used for casting a socketed axe and produced of ternary bronze (Figueiredo *et al.*, 2021).

The belt hook (VDT-10) also "orientalising" influence, is composed of a binary alloy, confirming a tendency already recorded in specimens from Moreirinha (Vilaça, 1995: CCXXVII, no. 9), Castro dos Ratinhos (Valério *et al.*, 2010: 1813), Palhais (Valério *et al.*, 2013: 364, fig. 3), and Esfola (Valério *et al.*, 2021).

The ingot fragment (VDT-12) is made of almost pure copper with impurities lower than 1%, similarly to other ingots from the Iberian Peninsula (Montero Ruiz *et al.*, 2010-2011: 45), i.e., analysed ingots from the Quinta do Ervedal (Fundão) (Coffyn, 1976: 20) and Viatodos (Barcelos) (Bottaini, 2013) hoards. The ingot from Vila do Touro has also undergone MC-ICPMS analysis to identify its isotopic fingerprint and infer on the provenance of metal. For this purpose, the result obtained was firstly compared with geological data from the Iberian Peninsula compiled in IBERLID (García de Madinabeitia *et al.*, 2021) and own data from the Iberian Peninsula Archaeometallurgical project (Rovira Llorens *et al.*, 2018). A first approach was published by Aragon *et al.* (2022) suggesting the south of the Iberian Peninsula and areas of the Ossa Morena zone as the best options for this ingot (Fig. 8). We can suggest a close relationship with some samples from the NCB subzone (Tornos *et al.*, 2004). The closest values are in fact those of Las Minas that form a linear distribution with the Retin samples that cross the Vila do Touro ingot. These samples are far from the ones from the North Central Belt (NCB), especially those from the Azuaga lead deposits. Other similar isotopic signatures are found in mineralizations in the Cadomian volcanic sequence, in the Évora-Aracena Belt (EAB) subzone. Although Las Minas is mainly a galena deposit, it is described in the Type 5 mineralizaton, Ba-Pb-(Cu) and some copper is present. The choice of EAB deposits is also possible because the copper ingot is in an intermediate position between the Maria Luisa and Santa Ana copper deposits. The Maria Luisa mine has been worked for Cu-Zn, consists of several lenses of massive sulphide about 100 m long and both Las Minas and Maria Luisa are of synchronous carbonate-related mineralisation in the central Ossa Morena zone (Tornos *et al.*, 2004: 966 and 977). The copper ingot from Vila de Touro reflects the general trends in this period, when various copper resources from the Ossa Morena area were exploited and traded long distance through various areas of the Iberian hinterland and Mediterranean coastal sites (Aragon *et al.*, 2022).

Regardless of the precise provenance of the raw materials used for the ingot, the key point here is that copper is not local. A similar result was recently obtained on a small stick found at a site very close to Vila do Touro, Quinta da Samaria (Fundão), which according to isotopic data would have been produced with raw material from the Aljustrel region (Southern Portugal) (Baptista *et al*., 2020). In both cases, the use of copper sources from outside the Beira is an intriguing point that deserves further investigation, even given the fact that LBA copper sources are known locally, as documented by the discovery of a palstave from the Quarta-Feira copper mine (Sabugal) (Melo *et al*., 2002).

Finally, the ring is composed of gold and silver with low amount of copper. While the presence of rings made of copper alloys is well known in Central Portugal, i.e., Castro de Argemela, where a ring and moulds for rings were found (Vilaça *et al*., 2011), or in Porto do Concelho (Mação) (Bottaini *et al*., 2017), much rarer are those in gold. As for the ring from Vila do Touro is concerned, its composition seems to indicate that it was produced with a natural gold alloy, conventionally defined as having less than 25% of silver and 1% of copper (Montero Ruiz *et al*., 1991: 10). On the other hand, the fairly high content of silver makes the metallurgical tradition of this ring closer to the production of gold artefacts from the EIA from the north-west of the Iberian Peninsula, characterised by silver values higher than 20% (Montero Ruiz *et al*., 1991: 16).

To sum up, the metal artefacts found in Vila do Touro and dated to the LBA/EIA are mostly rather pure binary bronzes, marginally with higher lead contents. Regionally, the data presented here are consistent with what is already known for metal artefacts produced at other settlements, namely at Alegrios, Castelejo, Monte do Frade, Moreirinha (Vilaça 1997), Tapada das Argolas (Vilaça *et al*., 2002-2003), Cachouca (Bottaini *et al*., 2022) and Castro de Argemela (Vilaça *et al*., 2012). Metals used at Vila do Touro, however, were produced with materials that required quite different knowledge and skills in terms of technology and material properties. In fact, the manufacture of objects made of copper, iron and gold involved operational chains that are quite distinct from each other, which also implies a quite complex organisation of labour, both in terms of mining and of production itself. If, on the one hand, the presence of an ingot fragment points to a metallurgical practice carried out locally, on the other hand, during the excavations no other element linked to the metal working chain was identified. In the absence of more solid data, what the archaeological finds show is the presence, in Vila do Touro, of metal artefacts of a distinct nature, a fact that does not occur very often in the LBA/EIA of Central Portugal.

## 6. CONCLUSIONS

Based on the data presented in this paper, which enriches the picture about the metallurgy in use in the LBA/EIA of Central Portugal, we can retain the following points:

1. The presence of metal artefacts at Vila do Touro confirms a pattern of metal distribution already known in the LBA/EIA of Central Portugal in which objects of small dimension are systematically distributed throughout all the settlements excavated in the region.
2. At the typological level, the recognisable forms are placed in the context of characteristic types of local production (i.e., socketed axe), with others well represented in more southern areas, namely the Mediterranean world (i.e., fibulae, belt hook). The finding of Mediterranean-style metal artefacts reinforces a fact already known in other regional settlements, that is the coexistence of local metal types with others whose form has an exogenous origin.
3. In technological terms, metal artefacts from Vila do Touro are mostly produced in binary alloys with low impurities, even though artefacts made of pure copper and leaded bronzes have also been found. The higher occurrence of lead in some of the artefacts analysed seems to be random, not responding to any intentional addition to improve the mechanical properties of the alloys.
4. Isotopic analysis performed on the ingot shows that copper is not local, suggesting the Ossa Morena (Southern Iberian Peninsula) as the most likely option for its origin. We do not know if the rest of the artefacts from Vila do Touro have the same isotopic fingerprint as the ingot. In any case, it is worth investigating further why LBA/EIA metalworking at Vila do Touro (and nearby Quinta da Samaria) was fed by non-local raw material when copper was also available locally.
5. If we look at the entire metal repertoire found during the excavations, it appears to be clear that people living at Vila do Touro during the LBA/EIA were used to employ artefacts made with different kinds of metal alloy, namely copper-based, iron, and gold artefacts. However, it is not clear whether this diversity was bound to some extent to the social value that the metal had among the inhabitants of Vila do Touro, nor whether the metals were locally produced or imported.

To sum up, considering the chronology of the artefacts analysed in this paper, on the one hand, and the typological and cultural affiliation of certain objects, on the other, the archaeometric characterisation of the Vila do Touro metallurgy constitutes an important contribution to a more global understanding of the metallurgical productions of Central Portugal in the transition from the Late Bronze Age to the Early Iron Age.

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