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Reviewed Article:

Throwing Punic Amphorae: An Archaeological and Experimental Approach to the use of the Potter's Wheel in southern Iberia during the Iron Age

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The transport of food products in amphorae was a basic pillar for the maritime-oriented economies and sustenance supplies of the Phoenician and Punic communities of first

millennium BC southern Iberia. Over the last few decades, numerous investigations have been carried out aimed at identifying the manufacturing sites of these amphorae, at defining both their typological and chronological aspects, the features of their fabrics, and focusing on the relationship of certain types with specific contents (De Frutos and Muñoz, 1994; 1996; Muñoz and De Frutos, 2006; Sáez Romero, 2008). Little attention has been paid to other important issues, including the production process of such containers, the operational sequence, and the technology used to produce them in large quantities since at least the 6th century BC This contribution aims to systematize the information on the parts of potter's wheels found in the south of the Iberian Peninsula (See Figure 1) and based on this data, to raise new hypotheses about the type of wheel used to produce amphorae in the 5th century BC. Using 3D digital models and replicas of these potter's wheels, we also reflect on their turning potential, dimensions, and ways of using them. This is a stepping stone for the identification of models which were potentially in use in the workshops of the Bay of Cadiz (Punic Gadir) at the time (See Figure 2), and how local artisans produced the T-11213 amphorae, a key type for the regional salted fish seaborne trade.

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The Ergasteria Project - Scope and initial developments

For almost two decades, our research priorities for the case of Gadir and other Phoenician-Punic cities in the south of the Iberian Peninsula have focused on the archaeological characterization of ceramic workshops and their products, both from a chronological and a typological point of view, with the aim of creating a solid historical foundation for interpreting the significance of these activities and their role in the colonial system and in the later Classical and Hellenistic urban network. In the case of the Bay of Cadiz, since the 1980s, work has focused on the analysis of the numerous kilns, amphorae, and wasters found in a very specific area of the bay (and in turn, the role of pottery production in the local and regional maritime economy). Many excavations have been published, discussing in detail the technological origins of the kilns, the typological evolution of the amphorae (See Figure 3), and their relationship with the fish-processing sector, which until then had been known only through Greek and Roman literary references. These investigations have resulted in a vast dataset of great importance that allows raising new questions in order to deepen the understanding of technological aspects and artisanal practices that have not been considered until now, but that may provide critical insights to further refine the historical narrative.

For this purpose, as part of various projects, we have worked over the last few years on the archaeometric characterisation of the local fabrics and "clay recipes" used by Punic potters for the manufacture of amphorae (Bernal et al., 2016; Fantuzzi et al., 2020). At present, as part of the project *Ergasteria. Arqueología experimental y virtual para el estudio de los procesos de producción anfórica y su comercialización en la Protohistoria* (Proyectos I+D+i FEDER Andalucía 2014-2020, US-1266376; https://ergasteriaproject.com/), new initiatives are being developed to analyse the whole production sequence of Punic amphorae from an experimental perspective, all the way from the extraction of the raw materials (clays, tempers) to their commercialisation through maritime routes. The project combines material and digital research, reproducing in both formats the experiments of tool making, turning, construction and loading of the kilns for the firing, etc., in order to compare results and evaluate possible biases in both formats.

The main goal of the project is to shed light, from a technological perspective, on the features of the processes and to reproduce them as accurately as possible, taking into account the available archaeological evidence and the results of the material and digital tests, analysing (quantifying) the investment of time, effort, and human and material resources used in the construction of a kiln, a potter's wheel, or an amphora. Other aspects of the manufacture of transport containers are also part of the aims of the project. These include connectivity between the amphora workshops, the areas where their food contents were manufactured, and the city's port infrastructures. Particular attention has been paid to the stamps impressed on the amphorae, both from an iconographic and functional perspective (what they were for and what connections existed with the local craftsmen and elites; Zamora et al. 2021; Sáez Romero et al. 2021) and experimentally, reproducing the dies in metal, wood, and pottery and making impressions on vessels made with local clays processed according to the "recipes" of that period. The case study selected is the Punic city of Gadir, one of the main commercial port emporia of the western Mediterranean, with the focus in this case on the workshops and amphorae of the 5th century BC, given the large amount of archaeological data available for this period and that it is a phase of great historical significance for the city and the region.

Clay sources, recipes and archaeometric approaches

As summarized in Appendix 1, for more than two decades, extensive work has been carried out on the chronological and typological classification of artefacts (kilns, wasters, etc.) and Punic pottery (like amphorae). There has also been a focus on the historical significance of these elements in the context of the evolution of Gadir and the so-called Strait of Gibraltar region. Less attention has been paid to other approaches to these aspects, leaving aside the technological and ethno-archaeological analysis and the archaeometric characterisation of the products, structures, artisanal equipment, and the operational sequences. As part of the recent Ergasteria Project and other related initiatives (such as the Corinth Punic Amphora Building Project), further research is in progress with the aim of providing new data through science-based and experimental approaches. The focus is primarily on pottery production dating from the 6th to 3rd centuries BC, with particular emphasis on the study of amphorae and workshops of the 5th century BC

One of the fields in which significant progress has been achieved is the identification and archaeometric analysis of local ceramic fabrics and the sources of raw materials (See Figure 4). Given that a large data set had been published and that a large number of excavations had been carried out on Punic pottery workshops, both aspects might be obvious research priorities, but unfortunately, until the last five years these topics had not been the subject of specific in-depth research (Domínguez et al., 2004; Cau 2007). In several of the excavated kiln sites, pits had been identified as quarries for the mining of clay, and also refused, melted, or even unfired sherds had been recorded, as well as other structures apparently related to the processing of the clays. However, up to now, this group of findings has received little attention if compared to the kilns. Therefore, the Ergasteria Project aims at thoroughly defining the operational sequence related to the extraction and processing of the clay resources that were used in these workshops, identifying the materials used as tempers, defining the 'recipes' of the fabrics used to produce amphorae, and the use given to the structures identified as quarries and settling pits.

Recently, laboratory analyses (Fantuzzi et al., 2020) have been combined with a survey and testing of suspected Punic clay mining areas, giving priority to sampling near the location of previously excavated kilns and/or waste dumps (with particular emphasis on the sites of Torre Alta, Villa Maruja – Janer, and Camposoto - Cerro de la Batería). The clays have been processed and examined for their qualities (plasticity, drying shrinkage, etc.). The tempers naturally present in each of the various geological formations have been sampled, and their suitability as a raw material for the manufacture of amphorae analysed. The review of numerous stratigraphic sections in the vicinity of the workshops, in addition to the experimental study of the clay samples (used to make both briquettes for archaeometric analysis and also some vases on the wheel), revealed that the local geological diversity is greater than had generally been assumed. Most of the deposits that had been identified as potential sources of clay do not have the appropriate conditions for their systematic exploitation and use in the production of ceramics (see Fantuzzi et al. 2020). In some cases, we have confirmed that the Punic potters had an in-depth knowledge of this local geology and were able to identify the most suitable areas for the exploitation of the most appropriate veins and outcrops, placing the kilns themselves on top of these clay deposits. These include the site of Maruja - Janer (See Figure 5). This is an ongoing line of research that will soon contribute innovative improvements both from a strictly archaeometric perspective, making the "recipes" even more precise by comparing the raw materials and the finished products. Also, it will provide an indispensable material base for the manufacture of replicas with local fabrics similar to the Punic ones and for checking such important aspects as the shrinkage coefficients during the initial drying process and after firing.

The potter’s wheel in Iberia - An overview of the archaeological evidence

Any approach to the study of the introduction of the potter's wheel in the south of the Iberian Peninsula should take into consideration the role of the Phoenicians in the transmission of a technology that, until then, was unknown in the region. This know-how could only be acquired through direct training and regular contact between craftsperson and apprentice, since there is little chance of acquiring this knowledge merely by observing the pottery vessels (Berg, 2015; cf. Gagné, 2014; Gorogianni et al., 2016). It is therefore worth considering the similarities between the oldest potter's wheels found in the south of the Iberian Peninsula and those known in the Near East and the Levant in order to identify the prototype/s that was/were brought to the area examined in this contribution.

The stone base of a Phoenician potter's wheel identified at the necropolis of Cortijo de Montañez (Rodríguez de Berlanga, 1903, p. 118, lám. XXXIV) is, until now, the oldest example found in the area under analysis. Another possible base of a different type was found in the Teatro Cómico excavations in Cadiz but must be interpreted with caution as its function is not clear and the context has not been completely published yet. However, the former can very likely be dated in the 7th or 6th centuries BC (Delgado, 2011) and corresponds to the type known as Canaanite-Israelite (or Type Ia), which consists of two small stone blocks (socketed and pivot-stone). It is a popular type of potter's wheel in Egypt, the Ancient Near East, and the Levant since the Late Bronze Age, with some small variants which do not significantly modify their functioning (Yadin, 1957, pp. 41-44, figure 19; Wood, 1990, figs. 1.4, 1.5, 1.9, 2.1; Powell, 1995; Pelta, 1996, figure 3c; Duistermaat 2007, p.146, figs. V.8, 11). The archaeological evidence for the study of potter's wheels in the so-called Punic area of the Iberian Peninsula is, unfortunately, scarce, and not always conclusive. Examples of these tools are not particularly abundant, and the identification of their specific functionality has not always been widely accepted, as we will examine in the next sections.

Archaeological evidence on potter’s wheels in the Punic area of Iberia

A much-discussed example of equipment is the socketed slab found in the excavations of Cancho Roano, which was first interpreted as a door hinge (Celestino, 1991; cf. Meseguer and García, 1995). Gran-Aymerich proposed, for the first time, that items of this type may be potter's wheels, with convincing arguments that have been broadly accepted by other researchers (Gran-Aymerich, 1991; Gran-Aymerich and Gran-Aymerich, 1991; cf. Jiménez Ávila 2013, pp.188-193; Soares et al., 2013), including the authors of this paper.

A first review of this evidence of Iberian Iron Age pottery technology has been carried out over the last few years (Jiménez Ávila, 2013; Soares et al., 2013). The findings were divided by

Jiménez Ávila into three types: stone blocks with a cylindrical shape with a central conical pivot (A) or with a central socket (B) and bronze pivots similar to the first type (C). The picture is more complex from a typological point of view, with at least two variants of the longer established type of Near Eastern/Levantine tradition and also diverse designs of the pivot-shaped metal parts. The latter, at least according to information published for other areas of the Mediterranean, seems to be an innovation typical of the Iberian Peninsula that was in use at least from the 5th to the 1st centuries BC, coexisting with the use of stone potter's wheels of Levantine tradition (See Figure 6 and Table 1).

Sites	Types				References
	Ia	Ib	IIa	IIb	
Azougada (Moura, Portugal)	?				Lima 1988, p.59; Soares et al. 2013, p.1144
Cabeço Redondo (Moura, Portugal)		X	X		Soares et al. 2013
Cancho Roano (Badajoz, Spain)		X			Gran-Aymerich 1991; Celestino 1991
La Mata (Badajoz, Spain)		X			Rodríguez and Ortíz 2004
Cortijo de Montañez (Málaga, Spain)	X				Aubet et al. 1995; Jiménez Ávila 2013
Gallineras (San Fernando, Spain)			?	?	Unpublished
Teatro Cómico (Cádiz, Spain)	?	?			Gener Basallote et al. 2014
Casa del Hondo (Valencia, Spain)			X		Meseguer and García 1995; Jiménez 2013
Comarca de Mérida (Badajoz, Spain)	X				Jiménez Ávila 2013
Cerro de las Cabezas (Valdepeñas, Spain)	X	X			Fernández Maroto 2013
Las Cogotas (Cardeñosa, Spain)			X		Cabré 1930
Baetulo (Badalona, Spain)				X	Serra Rafols 1942
Palomar de Oliete (Teruel, Spain)			X		Vicente Redón 1981; Celestino 1991
Foz-Calanda (Teruel, Spain)		?	?		Gorgues y Benavente 2007
Conimbriga (Coimbra, Portugal)		?	?		Alarcão 1973

TABLE 1: LIST OF THE FINDS OF PRE-ROMAN OR EARLY ROMAN POTTER'S WHEELS IN THE IBERIAN PENINSULA. THE SYMBOL "?" IS USED WHEN DEALING WITH FRAGMENTED PIECES OR WITH DOUBTFUL TYPOLOGICAL CLASSIFICATION (TYPES ACCORDING TO THE ONES DESCRIBED IN FIGURE 6).

These findings constitute a very heterogeneous dataset. Its interpretation is not easy due to the way they have been identified. Firstly, we must highlight those examples that were found during non-archaeological activities. The potter's wheel published by J. Jiménez Ávila, for instance, was collected somewhere in the *Vegas Altas* of the Guadiana River, and its precise provenance is unknown (Jiménez Ávila 2013). The two metal pivots published by Meseguer and García (1995), also interpreted as door hinges, were in the hands of an inhabitant of Ayora (Albacete), with no connection to a specific archaeological site.

There are also potter's wheel parts that have been identified during archaeological surveys, namely in Alpera (Albacete; see Meseguer and García 1995) and at the Azougada hillfort (Moura, Portugal; see Lima, 1988, p.59; Soares et al., 2013, p.1144). The description of the latter, without any photograph or drawing attached, is not informative, so we cannot add any further comment. Like those mentioned above, the former was interpreted as a door hinge, following the hypothesis of S. Celestino (1991).

Thirdly, emphasis should be put on the identification of potter's wheels in catalogues or inventories of archaeological sites, which also lack a clear context. For instance, the two items found at Cabeço Redondo (Sobral da Adiça, Moura), identified during the review of the materials from the site and stored at the Moura Museum after the destruction of the site occurred in 1990. They were not initially interpreted as such, but the publication of these items (one base in diorite and one pivot in bronze) reveals that in the site may have existed, possibly in the 5th century BC, a ceramic atelier which would explain, in the opinion of the authors of the study, the increase in the number of amphorae made with local clays during the final phase of the building (Soares et al., 2013, p.1152).

Rodríguez de Berlanga (1903, p.118, pl. XXXIV) first published the second potter’s wheel base in a photograph belonging to the catalogue of the Loring Collection, among the "Roman materials" from Cortijo de Montañez (Málaga), a Phoenician funerary ground. The item is currently on display at the Museum of Málaga. Although the photo was reproduced in the publication of the monograph of this site, the stone base apparently went unnoticed or at least did not raise the interest of the authors (Aubet et al*.,* 1995, p.237; Jiménez Ávila 2013, 193, Figure 4). The materials with which it was associated would, hypothetically, allow dating it back to the early 6th century BC (Aubet et al., 1995, p.234). In addition, the area where it was found also makes it possible to relate the find with the important Phoenician pottery workshops of the 7th and 6th centuries located nearby at Cerro del Villar, near the mouth of the River Guadalhorce (Delgado, 2011). Similarly, out of context, the base found at Gallineras (San Fernando, Cádiz) can also be linked to a ceramic production area located in the south of the Bay of Cádiz which operated, roughly, between the 5th and the 1st centuries BC We will discuss this item further on.

The fourth group includes potter's wheel parts identified in a stratigraphic context. In the case of Cancho Roano, a site where a socketed block of diorite was found near the entrance to a courtyard, the find was interpreted by S. Celestino (1991) as a door hinge that would have been related to the access to that area. However, the piece itself is part of a set of materials that suggest the performance of artisanal activities within or nearby the building (Almagro-Gorbea, 1990, p.101; Gran-Aymerich, 1991). The wear and tear of the base, with 360º rotation chafing marks, is not consistent with the type of use proposed by Celestino (cf. Fernández Maroto, 2013, p.309ss.). As in the case of Cabeço Redondo (see above), it is associated with the intensification of the production of amphorae made with local clays, also during the 5th century BC

In the same area and in the same chronological range, the data provided by the excavations conducted in the building at La Mata del Campanario also suggest a production dimension. Although the authors present the four items identified as "door hinges or potter's wheelbases" (Rodríguez Díaz and Ortiz, 2004, pp.277-278), published evidence indicates that the second interpretation is the most convenient, since none of them were found near the doors of the building.

In the area of Valdepeñas (Ciudad Real), the oppidum of Cerro de las Cabezas has also been considered a pottery production site whose development began in the 5th century BC, along with its urban growth. As the case of Palomar de Oliete (Teruel), two parts of the same potter's wheel-bearing, socketed base, and pivot-slab (both in stone, type Ib), were identified in a single archaeological context, i.e., a bastion-warehouse in the southern area of the site (items 3 and 4) dating to the 3rd century BC according to radiocarbon dating results. Two other parts of potter's wheels (items 1 and 2) are also part of the set found at Cerro de las Cabezas. The first was discovered next to the wall in a secondary context, possibly disturbed by a surface run-off, while the second was associated with the wall of a sanctuary and belonged to the abandonment phase of the 3rd century BC It was not used as construction material (Fernández Maroto, 2013).

Further north of the area of Albacete - Ciudad Real, the surroundings of Teruel have provided archaeological evidence of far-reaching typological and chronological interest. On the one hand, a stone base and a bronze pivot were found in the Iberian settlement of Palomar de Oliete (Celestino, 1991, p.264, figure 2), while several fragments of stone bases with carved sockets of conical shape were documented in the late Iberian pottery workshop of Foz-Calanda (Gorgues and Benavente, 2007; Gorgues, 2013), which dates back to between the 3rd and 1st centuries BC On the Meseta, in the Vettonian territory, which is now the province of Ávila, a bronze pivot very similar to the one found in Moura was recorded in the settlement of Las Cogotas (Cabré, 1930), where there is also additional evidence to suggest significant ceramic production activity which extended at least between the 4th and the 3rd centuries BC (Padilla, 2011; Padilla *et al.*, 2013).

As can be observed throughout this summary of the available archaeological evidence on potter's wheel in the Iron Age Iberian Peninsula, the picture is quite heterogeneous. The dataset is geographically and chronologically scattered, and it has not always been possible to establish a clear stratigraphic context for every item. Moreover, as Jiménez Ávila (2013, pp.194-195) has already pointed out, our knowledge about these items and the related operational sequences is still scarce and raises many questions. One of the main pending questions is to refine the chronology of each type/variant and to define if the metal pivot was an Iberian innovation.

It seems that Type I continued in use, at least in certain areas of the interior of the Iberian Peninsula, from the beginning of the Phoenician presence (surely from the 7th century BC) until the 3rd century BC, while the Ib variant apparently includes the more evolved forms, which can be dated from the 5th to the 3rd centuries BC With regard to Type II, this was already in use in the 5th century in the southwest (Guadiana and, perhaps Gadir) and seems to have also been used during the 4th to 3rd centuries BC in the northwest and eastern Meseta (Ávila, Albacete, Teruel). In the current state of research, the surprising lack of findings in the main Punic and Iberian pottery production areas does not allow us to speculate on possible origins, development, and spreading routes of these technological innovations. In any case, before addressing these important issues, it would be worth drawing attention to the data from the Bay of Cadiz, which, as we have said, is the focal point of this contribution.

The typology and usage of the potter's wheel in Gadir: a preliminary hypothesis

As in the examples of the Iberian Peninsula discussed above, the available information, both quantitatively and qualitatively, is not very abundant for the Bay of Cadiz dating to the Phoenician-Punic period. Only two examples of apparently different chronologies can be considered, according to the published data. The first of these is a possible Archaic stone base identified in the excavations of the Teatro Cómico in Cadiz (Gener Basallote et al., 2014). The second, found in Gallineras (San Fernando), lacks a stratigraphic context but can be dated in a later phase considering its typological features.

The excavations in the Teatro Cómico area identified and partially unearthed several Phoenician houses or domestic units. Among these, Domestic Unit 2 stands out, where an area ("Estancia 2") was identified as used as a kitchen up to c. 800/780 BC and which was then re-defined to give a new use to the room. According to the interpretation of the excavators, the materials found in this area suggest that it was a domestic artisanal workshop, where tasks such as the manufacture of ceramic containers were performed. A circular structure of 78 cm in diameter, with a hole in the centre and that was integrated in a carefully paved floor, was identified, dating to the Period II of the sequence (820/800 - 760/750 BC). A quadrangular worked quartzite block, which showed evident wear and tear due to rotation, and whose dimensions are the same as those of the aforementioned hole in the centre of the structure, was interpreted, without any additional support, as a 'low potter's wheel' base (Gener Basallote et al., 2014, pp.32-33, figure 19). In any case, until the full context is published, and the function of the bone punches and the containers filled with a reddish substance documented in the vicinity can be clarified, we should be cautious about the role of this worked stone (as we cannot rule out for now that it might have been linked to other craft activities such as the production of purple dye).

At the opposite end of the insular area of the ancient territory of Gadir, in an area in which many Punic and Roman kiln sites were established, there is a second example that, despite its lack of a specific stratigraphic context, can be clearly interpreted as part of a potter's wheel. This is a base fragment identified at Gallineras (San Fernando, Cádiz); the Punic materials found in this workshop suggest that it was in use from the 5th to the 1st century BC (Sáez Romero et al., 2000, p.169; pp.171-172; Sáez Romero, 2008, pp.466-471). About one-third of the stone base, including the central socket, is preserved (See Figure 7). The chafing marks caused by the rotation of the pivot and the wheel head can be easily identified in the upper section of the socket and confirm its use, probably combined with a bronze pivot similar to those located in Moura, Las Cogotas, Palomar de Oliete or in the Albacete area. Our hypothesis, given that the upper area of the slab is also carefully smoothed, is that it is part of a 'low potter's wheel' of Levantine tradition (Figs. 8-9), although we cannot exclude the idea that the wheel head could have been originally placed on a longer metal pivot (like those found at Baetulo) or on a broad wooden shaft that would be attached to both the metal pivot and the wooden wheel head. The lack of context does not allow us to analyse the item associated with a set of materials or with a specific production area, but in any case, this is a very important piece of evidence since it is the only example known for the moment in this key port and artisanal hub.

The study of these examples makes it possible to define some aspects that may be considered to assess the evolution of the potter's wheel models identified in the Iberian Peninsula (see Table 1). The older ones had two stone -fixation and rotation- components, without any fitting marks on the active part or other features that would provide information on how a wheel head was attached to it (see Berg 2015, p.19, Figure 3). As already mentioned, Type Ia of potter's wheel-bearings is a group well-known in the Near East, Egypt, and the Levant since the 2nd millennium BC. It was probably predominant and perhaps exclusive in the areas colonised by the Phoenicians and among the "Orientalized" Iberian communities during the 8th-6th centuries BC (Yadin 1957, pp.41-44, figure 19; Wood 1990; Powell 1995; Jiménez Ávila 2013).

Considering other cases that have not been considered here, such as Teruel region and Las Cogotas (Celestino, 1991, pp.267-268; Jiménez Ávila 2013, pp.194-195), it is possible to assume that the later potter's wheels incorporated an innovation: the integration of a bronze pivot that would help to reduce friction and, consequently, increase rotation speed. In addition, these bronze pivots or shafts allowed the wooden wheel head to be fixed to the structure with more consistency and stability, giving the rotary movement greater regularity and certainly allowing the fitting of wheels with larger diameter and weight. Such wheels could be operated by assistants and, consequently, acquire a higher speed, which would be determinant for the manufacture of some ceramic types. This is an evolution of the previous Levantine-style type, but its origin is uncertain. It is perhaps significant that the known examples are concentrated in the South and Southwest Meseta. The identification of such an artefact in the Cabeço Redondo (Moura) makes it possible to attribute to them a chronology roughly centred on the 5th century BC or later, which would also apply to the examples found in Albacete (Meseguer and García, 1995; Soares et al., 2013) and to the stone base identified in Cancho Roano.

The potter's wheel parts unearthed at the Cerro de las Cabezas (Valdepeñas) show that the oldest type would have evolved and were still in use in the 4th and 3rd centuries BC, at least among the Iberian communities of the Southeast (Fernández Maroto, 2013). Given, on the other hand, the chronology of the examples discovered in the Middle Guadiana Valley, it seems likely that the *Vegas Altas* find (Jiménez Ávila 2013) could be equally a late Classical or Hellenistic piece. Notwithstanding, it cannot be excluded that could be dated to the 6th century BC, as it is quite similar to the one found at Cortijo de Montañez.

It is evident that there was a more systematic use of the potter's wheel technology to manufacture ceramic containers in inland areas since the 5th century BC, both in urban contexts and in 'unique buildings' such as Cancho Roano, La Mata, or Cabeço Redondo. However, the production seems to be on a small scale, since there is no more than one wheel in any of the sites where these objects could be related to stratigraphic sequences.

In the case of Gadir, it is surprising that only the stone base found at Gallineras allows, so far, an approach to the type of potter's wheels used in the Punic or late Punic workshops, despite the large number of excavated sites and the massive scale achieved by this sector between the 5th and 1st centuries BC. The only known example fits well the typology of the examples found in Moura and the Middle Guadiana area in 5th century BC contexts. This leads to the consideration that it is likely that innovations of this type may have spread to the interior of Iberia through the main fluvial valleys of the Southwest from Gadir, with rapid and significant consequences to the production of amphorae and other ceramics in Turdetania and its peripheral regions (a synthesis on Late Iron Age amphora production in García and Sáez, 2021).

It is also important to emphasize that these data are just a starting point for examining the use of these turning devices in southern Iberia, and also to establish comparisons with the evolution of the potter's wheel in other key technological spheres of the ancient Mediterranean. Greek iconography, and particularly drawings on Corinthian, Black-figure and Red-figure pottery, provides valuable information to refine the interpretation of the western finds. Although economic activities were not among the most recurrent topics of Attic ceramics, a few examples of snapshots of potters and workshops are known. Particularly, some of these illustrations, dating from the 7th-5th centuries BC, provide interesting data for the study of the usage methods and typological features (See Figure 11). Some of them show that two individuals (master and assistant) were operating the potter's wheel and potting to produce large containers. Experimental work carried out a few decades ago to test the

Levantine-style wheel-bearings (using heads with different diameters, ranging from 40 to 60 cm) demonstrated that one artisan would have worked on the wheel while the other maintained the rotation of the wheel head (Amiran and Shenhav, 1984; Edwards and Jacobs 1986), but also that only a master could have operated the wheel successfully (Powell, 1995; see the comparison of results in Duistermaat, 2007, pp.147-150). The rotations achieved, c. 15-20 rpm (Edwards and Jacobs 1986) and 60 rpm (Amiran and Shenhav, 1984) with assistant, and 60-120 rpm without the aid of a second person (Powell 1995) is a significant fact which deserves some reflection since the effectiveness seems to increase proportionally in relation to the weight of the wheel head, as well as the lubricant substances used (Powell, 1995, p.318).

How were the Punic amphorae thrown in Gadir?

During the 5th century BC, the amphorae made in local pottery workshops were essentially variants of the T-11213 type (See Figure 3), defined by J. Ramon Torres (1995), which is generally considered as the most important transport container for the famous salted tuna fish of Gadir. It is a type that has been the subject of quite a few specific investigations, and that has widely been recorded in excavated and published examples of kiln sites, such as Camposoto, a workshop equipped with several groups of kilns that were active throughout the 5th century BC. (Ramon Torres et al., 2007). These amphorae had evolved from T-10121 and T-10221 of the 6th century BC, and by the end of that century they had the typological layout that would be characteristic of the following hundred years: a biconical body, with a slightly rounded bottom edge ending in a uniform surface or with a small button-shaped toe, and an upper cone divided into two sections, a central truncated cone and an upper area with a curved wall and a triangular rim; the handles, which were generally large, were placed on the upper part of the body, close to the inflection that marked the transition from the body to the 'shoulders'. Although this basic design did not change substantially during the 5th century BC, the secondary features certainly changed: rims were thinner and longer at the end of the century, and the profile of the body, which gradually became more stylised and more elongated, grew from 80-85 cm in length to 95-100 cm at the end of the century. The diameter of the mouth remained stable (around 12-14 cm), while that of the central area of the body decreased slightly, from 44-46 cm to 40 cm. The numerous workshops located in the insular area of the Bay of Cadiz produced considerable quantities of this type of container, systematically repeating its specifications and proportions (and apparently also the techniques), as can be seen both in the refuse dumps of the pottery workshops (Ramon Torres et al., 2007) and in consumption contexts, such as the Punic Amphora Building at Corinth (Sáez Romero et al., 2020). A comprehensive examination of hundreds of examples, recorded at Camposoto and in many other kiln sites and fish salting facilities, suggests that the production was highly standardised (See Figure 10) and was carried out by craftsmen belonging to a single 'artisanal school', which resulted in very homogeneous production methods and techniques in Gadir, in terms of quality, design, and metrics (capacity standards were also stable throughout most of the 5th century BC, at around 50-53 litres, following a pattern of Levantine roots).

The details concerning the study of the manufacturing processes of the Phoenician and Punic amphorae, as mentioned above, have received little attention to date and only a few experiments on the production of transport containers have been carried out focusing on specific types of Carthaginian amphorae (Annis et al., 1995). Recent and ongoing research on the pottery workshops of Gadir and its role in local demography and economy has led us to develop a specific line on this matter, considering the T-11213 as the first case study given their huge potential as a tool for the study of maritime trade in the 5th century BC on a local but also Mediterranean scale. Several years ago, we established collaboration with master potters such as Pedro Ramírez (Cerámicas Ramírez, Conil de la Frontera, Cádiz), who helped us to produce some 1:1 scale replicas of this type and other significant series of the city's Punic and Late Punic repertoire (T-12111, T-8211, T-9111, etc.). Even though these replicas have been produced using commercial clays and electric potter's wheels (See Figure 11), the experience has been very useful for understanding the archaeological findings, for identifying markers of the production processes and the tools employed by the Punic craftsmen, as well as for making some initial calculations of the quantities of clay, water, and time required for the manufacture of each vessel.

As we already pointed out in the introductory section, one of the priority objectives of the Ergasteria Project is specifically to take a step forward in the analysis of the operation sequence and the production methods on the basis of an experimental approach. Consequently, this specific research on the potter's wheels and amphorae has been developed with the aim of reproducing the process in the most historically accurate way. The final aim is, therefore, to produce replicas of the types of potter's wheels that we assume were probably used in Gadir's workshops during the 5th century BC and to turn on them more T-11213 amphorae, using when possible the local clays and 'recipes' that have already studied through archaeometric analyses. As a first step in the research process, this experiment has been carried out in digital mode, considering the available information on local wheels and amphorae and modelling 3D replicas to test the viability of the material experiments, the amount of raw materials required, etc.

Digital experiments: spinning on the screen

Within the group of potter's wheels recorded in the south of the Iberian Peninsula for the pre-Roman period, we have focused, as has already been mentioned, on the case of Gadir (the Bay of Cadiz). Based on the parallels discussed in previous sections, and in particular, the items dating to between the 5th and 3rd centuries BC, digital experimentation has been carried out using the only reference available at present, the base or "dormant part" documented at Gallineras (San Fernando, Cádiz). There, a fragment of a stone base that preserved little more than a quarter of the original piece was found, including part of the surface that was in contact with the wheel head and part of the socket for the stand of the wheel. Despite the poor state of preservation of the item, it has been possible to develop a digital model of the base by combining this with data collected in other contemporary locations such as Moura, Cancho Roano or La Mata, and with the information indirectly provided by the interpretation of the production process of the amphorae (see below).

This theoretical model of the item has been created on the basis of 2D drawings and the reconstruction of the size and ideal morphology of this potter's wheelbase (See Figure 7). Both to generate the model and to create the textures of the object we have used the software Blender 2.91 (open source). This software has allowed the performance of different tests with the piece. It will also be the digital environment in which the next virtual experiments will be developed, aimed at recreating other peninsular potter's wheels and to test different options for the morphology of the metallic piece that enabled the rotation (with a variable vertical size). These digital tests will be vital for refining the hypotheses on the functional viability of each variant before proceeding with its material reconstruction.

After developing the replica of the piece from Gallineras, the next step was to recreate the rest of the components that were part of the potter's wheel. In order to achieve this, we based our designs on the similarities observed with other potter's wheels documented in the Iberian Peninsula and the Levant, all of them classified within the two main typological groups already discussed, and on previous proposals for the recreation of the wheel heads (which both in the West and in the Levant used to be made of wood and therefore have not survived in the archaeological record). As described above, the first of the typological clusters includes potter's wheels that were formed by a stone "dormant" base that had a socket on which another stone pivot piece was fixed and rotated (Jiménez Ávila, 2013; Fernández Maroto, 2013). On the other hand, the second group of potter's wheels also included a stone base with a socket, but a metal piece was fitted to serve as a pivot for the wheel head, as was the case for the bronze items found in the province of Albacete (Meseguer and García, 1995), Las Cogotas (Cabré, 1930; Celestino, 1991, p.266, figure 3), Palomar de Oliete (Celestino, 1991, p.265, figure 2) or in Moura (Soares et al., 2013), and the much later ones documented at Baetulo (Serra Rafols, 1942).

Due to its morphology, the fragment found at Gallineras would belong to the second of these typological groups, closely resembling the socketed slab found at the Cabeço Redondo site in Moura (with a depression surrounding the rotation area, showing friction scuff marks, which would possibly help to secure and stabilise the metal pivot). Considering that the Gallineras potter's wheel must have originally had a metal piece as a pivot, it was also recreated, taking as a model one of the bronze items found in the Albacete area (whose section had greater similarities with the pivot socket of the Gallineras base). Initially, we made a 3D model of the

Albacete piece and adapted it to the diameter and profile of the hollow of the Gallineras stone base (See Figure 12).

For the creation of the wheel head there are not such precise references as in the case of the other two parts. The most plausible option is that in Punic times these components would have been made of wood, as it would be easy to adjust the pins of the metal piece, and it would also be possible to replace it more easily as it was a material that was abundant around the pottery workshops of the area. The effort to make it spin would be reduced as it is a rough surface and can resist humidity and impacts quite well. The union of the metal piece and the wheel would involve the carving of holes in the latter to allow the insertion of the metal pins, and probably the use of resin or other adhesives to contribute to giving more consistency to the set (resin was also used, for example, to coat the inside of the amphorae, and must have been easy to obtain in the pine forests of the area in which the kiln sites were located). As for their shape, we have considered the morphology of wheel heads made of other less perishable materials such as stone or clay, well known from the Ancient Egyptian Empire or the Minoan-Mycenaean period (Pérez, 2017). Regarding the size, we have considered both the maximum diameter of a T-11213 amphora (circa 46 cm) and the main metric standards of the period, such as the royal Egyptian cubit, the Phoenician cubit, or the Biblical cubit (all of them between 49 and 52 cm). Considering these metric standards and the need for the wheel to be truly functional during the turning process (leaving enough space for the master or the assistant to provide power for rotation), we considered that the minimum diameter should be around 58 cm. It is likely, however, that in order to achieve a higher kinetic energy and a longer turning time, the wheel would have been much larger in diameter (and weight).

The result of the three-dimensional modelling of our hypothesis is a potter's wheel that consists of two dynamic parts (wheel head and metal pivot) and one passive base (stone socketed slab). The first two may be easily replaced in the event of breakage or severe mechanical stress and deterioration (See Figure 7). Regarding its eventual usage or operational mode, through this digital test we have observed some features that would be linked to making the rotation of the wheel-head work easier.

On the one hand, the socket where the metal pivot was placed shows significant wear and tear only in its upper section and on the external slot, whereas it is rough and becomes wider on the rest of the inside of the socket. This suggests that the entire socket joint was not exposed to contact with the metal pivot, and by reducing part of the friction area, the effort and energy required to rotate the wheel head would also be reduced. On the other hand, the rim of the slot shows a regular and significantly cracked surface, which could be related to the slight horizontal oscillations of the metal pivot and the wheel head itself, but also to the use of some kind of lubricant that would also facilitate the rotation of both parts (See Figures 8-9). Regarding the use of lubricating substances, it is possible that the remaining space in the bottom section of the socket would be filled with them, although it has not been possible to determine whether these would be plant-based fats (perhaps oily products) or animal fats.

The creation of these 3D objects, besides allowing us to conduct tests on these first digital experiments, has also made it possible to advance (thanks to the printing of the items in polymer) towards the creation of a full-scale material reproduction of the main variants of potter's wheels considered. This 3D printing is, therefore, only a first step leading to a second phase in which we will be able to test parts of fully functional potter's wheels produced using only original materials (stone, bronze, wood) on a 1:1 scale. We hope to complete soon the production phase of the parts (including wheels of various diameters), and in the near future to carry out tests to measure rotation speeds, individual and assisted operating capacity, and to undertake the experimental production of amphorae and other ceramics (continuing the pioneering line initially explored by Amiran and Shenhav, 1984; Powell, 1995).

A theoretical approach to the operational sequence: producing an amphora

The manufacture of a T-11213 type container was (and still is today) a challenging process that demands a significant investment in raw materials (clay and water) and time, and requires great skill and know-how, given the volume of the parts to be produced and the series of steps to be completed. The average weight of an empty T-11213 varies in the range of 12-14 kg, while 1 litre of dry local clay (marls, previously sieved or decanted to achieve an optimum state for turning) weighs around 1450-1600 g. The shrinkage due to initial drying and during firing is estimated to be around 20-30%, so several litres (kilograms) of water were added to the mixture during kneading and turning. Therefore, for a fired amphora weighing about 13 kg (6-6.5 litres of clay), about 8.7-9 litres of dry processed clay and a minimum of 2.2-3 litres of water would have been used (excluding the final process of external coating, and the use of slip to glue the main parts). Access to fresh water in the area needed to be by means of wells (none from the 5th century BC has been identified so far), or brought from the city itself, more than 10 km away, or from rivers located on the continental shore (also quite a few kilometres away). It would therefore be a limited resource, so spending several litres per amphora must have been a carefully calculated investment.

Regarding the clay, we must consider that both the marls and the local "red sands" usually have many non-desired inclusions that must be eliminated by a previous sieving or decantation. Thus, for example, about 4.25 litres of clay from the Villa Maruja - Janer area produce a minimum of 1.1 litres of waste (pebbles, sand, organic material, etc.) after processing. Therefore, in general, these are clay veins that require a long time to process the material to reach an adequate state, so that obtaining enough clay to produce 40-50 amphorae (which is what we calculate would fit in a large kiln of the time) would have meant a significant effort in terms of time for extraction and decanting/processing.

The macro and microscopic examination of the examples studied both in the Bay of Cadiz and in Corinth and other sites, as well as the aforementioned experimental production of replicas, allowed us to conclude that the amphorae of this type were made from three main parts or pieces turned separately, which were then joined on the wheel before the handles were attached (See Figure 10, above right). From previously kneaded clay balls, probably with a standardised volume and weight, the first step in the manufacture of the amphorae was the turning of the lower part (See Figure 10.1 and 13a). This section, with a conical profile and curved walls, was made after turning a cylinder whose upper part closed smoothly, creating a plain or prominent surface on the wall with a slight button-shaped protuberance (See Figure 13b). Inside, the closing process produced some characteristic imperfections (See Figure 13c), which are systematically present in the thousands of examples examined to date. These irregularities make it possible to be sure that the lower parts of the amphorae were turned by closing their upper ends and placed on a wooden disc, which would allow removing them from the wheel once the process had been completed and making way for the manufacture of other parts (central and upper sections; Figure 10.3-4).

The drying process of the lower part of the amphora may have involved placing it on ceramic cylinders or supports at an advanced stage. These supports are frequently found in local workshops such as Camposoto and may also have been used to place the vessels inside the kilns to be fired. The lower cone, placed vertically with the open part facing upwards, would have ventilated and dried in a more homogeneous and rapid manner, although this would have caused the upper part to open and crack, making these pieces unusable. To avoid these situations, it must have been frequent to use ropes or strips of vegetal fibres to wrap the upper part of these cones to prevent them from opening while they did not have the appropriate consistency to continue with the production process of the amphora (See Figure 10.2). Traces of the use of these ropes have been documented, thanks to defects in the final smoothing and coating of some examples, both on T-11213 manufactured during the 5th century BC in workshops of the Bay of Cadiz (See Figure 14a) and on T-11210 containers of the same period and later T-12111 manufactured in workshops on the coast of Malaga (See Figure 14b-c). This suggests that it must have been a very frequent practice on a regional scale throughout the Punic period, at least until the 3rd – 2nd centuries BC

For the moment, it is not possible to determine if the Punic potters mass-produced each of the parts of the amphorae, following a repetitive metric pattern to ensure that they all may fit together indifferently. Also, the number of amphorae potentially made by a master per day cannot be estimated with the available information. Based on the results of the production of replicas and depending on the capacity of the ancient workshops to decant and knead clay (operations probably carried out by assistants, like spinning the wheel), it seems possible that in optimal climatic conditions between 7 and 10 amphorae could be made per day. It is obvious that the lower parts would have required a longer drying time and greater consistency of the walls, a fact that therefore implies that these would have been the parts turned in the first step. Roofed areas would consequently be needed to allow the parts of the amphorae to dry, with adequate ventilation and equipped with shelves for the temporary storage of the parts and the finished containers, avoiding direct contact with sunlight (in the area, despite the proximity of the seaside, temperatures of between 30º-40ºC are frequent in summer). Perhaps this function could have been carried out by simple, open wooden structures covered with vegetal elements and mud, a type of construction that is quick, technically unsophisticated, and effective for providing shaded areas for storage and to work on the wheel during the work season (and whose ephemeral architecture would explain the fact that no remains of buildings have been recorded in the surroundings of the kilns).

In any case, the process of joining the parts of the amphora would begin once the lower sections had a certain degree of consistency, while still being sufficiently wet to facilitate the fitting and to avoid causing any disturbances during the final drying process that would lead to dangerous cracks or fissures during firing. The lower parts would probably be placed on the wheel (See Figure 10.5), resting on bobbin-shaped stands (See Figure 15a) or perhaps using other popular vessels such as basins (*lebrillos*), whose greater diameter and depth (See Figure 15b) would provide more stability during the process of joining the parts. In any case, supports or basins would be centred and fixed on the wheel with clay, guaranteeing the stability of the vessel and the correct rotation on the axis. By turning upside down the pieces attached to the wooden discs, the central one would be placed on the lower section, on whose rim slurry clay would probably have been added and small incisions would have been made to increase adherence. The joints, however, appear to be predominantly lateral, as the diameter of the parts would not normally be identical. As the parts were still in a semi-wet state which could be resurfaced, with the help of hands or tools, the Punic potters would have turned over and made pressure on the junction area ensuring the cohesion of the area, eliminating the traces of ropes left by the previous process and finally shaping the transition between the two cones (the direction would inevitably have been upwards, probably causing a slight increase in the maximum diameter in the area and also in the length of the central part). Once this operation was completed, this area of the maximum diameter of the future amphora would be wrapped with ropes once again, leaving marks on the outside surface which are the ones that we have been able to identify among the available archaeological finds (See Figure 14).

The next stage would likely be immediate, placing the upper part over the central section, completing the entire body of the container (See Figure 10.6). To perform this step, depending on the height of the potter and the position of the wheel with respect to the floor, a bench or auxiliary support may have been needed to introduce the arm through the mouth of the amphora. In any case, as in the previous operation, with the aid of an assistant turning the wheel, the two pieces would have been joined (perhaps glued together with barbotine, adjusting the diameters of both and therefore with lateral or lateral-vertical connection), applying considerable pressure over the joining area and shaping the upper part of the amphora, thus fixing the maximum length of the container. The attachment would have been carried out using the hands, possibly with only the help of the fingers, or perhaps using tools on the outside to produce a more homogenous surface (See Figure 16a). Even so, in most amphorae examined up to date, this bonding area is easily identifiable as striated areas or turning grooves of varying thickness are often grouped along it (See Figure 16b), and in some cases there are also slight differences in the direction of the walls. The use of ceramic smoothing blades and other tools (also ceramic dies, polished stones, etc.) is well attested at workshops such as Torre Alta in contexts that date back to the 3rd and 2nd centuries BC, where several examples of tools of this type have been found (See Figure 16c). It is possible that these same basic utensils, whether made of pottery, wood, or bone, could have been used by the potters of the 5th century BC, although none of the excavated workshops have provided any information on this matter so far.

Probably before removing the strings tied together on the central section of the amphora, the handles would then be attached (See Figure 10.7). For this purpose, clay coils of around 15-20 cm in length and 3-4 cm in thickness would have been previously produced, perhaps systematically shaped by other subaltern craftsmen of the workshop (in fact, as it is a simpler operation, we cannot exclude that the placing of the handles was not carried out by the same master who produced the body sections). The fitting process would begin with the attachment of the upper part, which normally rests on the carinated wall which defined the transition between the back and the rim, by applying pressure from the outside on the wall of the container and also pressing from the inside to produce a fingerprint of variable depth (which could be made by placing all or part of the hand inside the amphora; Figure 17a-b). On the outer surface, as the available archaeological data suggest, no incisions or other previous preparation would have been made to improve the grip of the handle, at least in the majority of the cases (See Figure 18.1). The typical "ear-shaped" Punic handles would then be created by rounding off the coil, repeating the previous operation in order to attach the lower end to the body of the amphora (See Figure 17c). Finally, an external smoothing of the joints would be carried out, attempting to prevent air pockets and fissures which could threaten the integrity of the handles during drying and firing (See Figure 17d), making the upper area and the handles stronger for later use (perhaps related to the need to join the containers with ropes during sea transport to ensure the stability of the load). The numerous examples studied at Corinth (See Figure 18.2-7), Camposoto, or Villa Maruja - Janer allow noting that this was a systematic procedure, practiced in all the workshops active at the time in the Bay of Cadiz, with slight variations in the result (different depth of the fingerprints, absence of fingerprints in one of the two joints, etc.). The attachment of the handles could have been performed on the wheel, although it was not required, so it was probably conducted once the containers (and their supports) were placed and aligned in the area intended for drying prior to firing.

Finally, after placing the handles, a general inspection of the exterior surfaces would have been made, removing the cordage to facilitate the homogeneous drying of the amphora and smoothing out any irregularities. It is relatively common to find unintentional marks such as rope impressions, scrapes or shallow scratches or sticky spots and burrs, so this final check should only be aimed at removing any imperfections that might compromise the structural integrity and proper usage of the container after firing. The final step, at least for the majority of the amphorae, would have been the coating of the outer surface with a quite liquid slip, normally of the same colour of the fabric or slightly more yellowish white, with a variable consistency depending on the workshop and the date. It does not seem, based on the available evidence, that there was a "universal recipe" followed by all the groups of potters working during the 5th century BC. In any case, clays with the same shrinkage factors as those used for the rest of the container would have been chosen, preventing the slip from cracking and becoming easily detached. The slips would be very liquid, probably applied with a soaked cloth, tow brushes, or other tools that were not particularly carefully designed or specialised, of which no archaeological evidence has been found so far. This exterior coating would have protected the amphora from environmental hazards (weather, chemicals, etc.) by closing the tiny pores on that side, but the water tightness on the inside would have been ensured only by applying a coating of pitch and beeswax, a process which would very probably have been carried out not in the pottery workshops but in the fish salting facilities.

Keywords ceramics
container / vessel

Country Spain

Appendix 1.

Pottery production in Gadir, a key Punic port hub

Since the foundation of the Phoenician colonies in the western Mediterranean/ Atlantic seaboard from the late 9th to the 7th century BC, these mainly coastal settlements became the key hubs that connected the local economic circuits with the main trade routes and economic powers of the various Mediterranean cultural spheres. The exploitation of the resources which were most in demand by both the Greeks and the Phoenicians (mainly raw materials, primarily metals) was carried out in the interior of Iberia and then drained through numerous fluvial routes to the colonies established within the indigenous riverine settlements and, thereafter, to the port hubs on the coast. Through these, the raw materials were transported to the Mediterranean routes, and at the same time a principal a variety of imports were redistributed to the interior markets.

During the 6th century BC, far-reaching changes in the socioeconomic structures of local societies, alongside improved technological development, and the crisis experienced by the

Phoenician colonies (due to multiple factors) led to a complete reorganisation of the network of settlements. It also resulted in significant role changes in the new economic systems or circuits, and in the type of commercial dialogue established between the cities of the Iberian hinterland and the Punic cities located on the coast. The Phoenician sites, following a trend which was already underway in some enclaves on the coast of Malaga, perhaps since the end of the 7th century BC, reduced their number but acquired fully urban characteristics. They also defined their territories and developed production and port facilities to reinforce the traditional role they had played as intermediaries between the "Mediterranean world" and the communities and resources of Iberia. However, at the same time, their growing population and the end of the colonial system had a relevant role in strengthening and defining collective identities, as well as in the formation of complex relations with a certain degree of political and commercial rivalry. Consequently, new artisanal activities mainly aimed at large-scale food production were developed from the late 6th century BC.

Consequently, the production of surpluses of wine, oil, and other 'trendy' foodstuffs such as salted fish, which had previously been secondary economic factors when compared to the extraction and redistribution of metals and other raw materials, would now be at the heart of the economic systems of Punic port cities such as Malaka (present-day Malaga), and particularly Gadir (in the Bay of Cadiz), which throughout the 5th century BC became the predominant hub from a commercial and maritime point of view (See Figure 1). The relationship with the inland communities and their resources continued to be a very important factor, but the new Mediterranean setting, with the emergence of new culinary practices and the extension of consumption patterns that had hitherto been restricted to certain minorities (both in the Phoenician-Punic and the Greek or Etruscan worlds) resulted in a period of great prosperity for the Punics of Iberia based on the export to distant markets (both culturally and geographically) of food products transported in amphorae.

Amphora production and the local economy

For all these Punic coastal cities, and most notably for Gadir and Malaka, one of the factors of this economic success achieved during the 6th and 5th centuries BC certainly was the export of salted fish. This large-scale industrial activity mobilised considerable financial, human, and material resources for the entire production. This would have included fishing, salt extraction, manufacture of ceramic containers, fuel for the kilns, cork or wooden stoppers for the amphorae, ropes, tools, construction of the workshops, transport to the port, etc. The marketing process including construction, furnishing and maintenance of ships, port taxes, infrastructure for loading and storage, cult activity and offerings at maritime sanctuaries, etc. would have expanded the impact. Therefore, the production of pottery, and particularly of transport amphorae, grew throughout the 6th century from a secondary sector to a flourishing business. It became essential not only for the food supply of the Punic cities but also as a key feature of their maritime trading enterprises and a core ingredient in a sophisticated sequence of food production processes.

At the same time, other activities equally related to the extraction, processing, and marketing cycle of salted fish also evolved to become local economic engines, rising from a limited volume of production to large-scale numbers for the time and the region. As a result, the landscape and the way it was exploited underwent a profound transformation, both on land and on the coast, where a large number of evaporation saltpans would have been created in the already abundant greyish marshes that surrounded the island area and the mouths of the Rivers Guadalete and Iro. These salt flats, as well as shipyards and other critical facilities involved in this transformation (or "industrialisation") of the city and its territory, are archaeologically difficult to trace, and there is little evidence of them so far. In the same way, other activities linked to the production of salted fish and amphorae are also largely unknown or can only be traced through indirect indicators: for example, the use of ropes for the manufacture of amphorae, and probably also for ships and the transport of the containers, suggests that a business focused on supplying the fish-processing sector with ropes and basket-ware, made of esparto grass or other fibres, must have flourished. Similarly, some analyses of the contents of Punic amphorae from Gadir (Pecci and Georgi 2019) suggest that to waterproof them before use they were coated with a mixture of pitch and beeswax, thereby indicating two other extractive activities which must have flourished at the time, given that thousands of amphorae were coated every year in the bay and that large quantities of pitch were also needed to seal the surfaces of the ships. Fishing, salting, ceramic production, and naval activity must have had a great economic and social impact in the city, originating its own circuit which, in the case of the pottery workshops, must have contributed to a crisis in the availability of some basic resources (such as wood used as fuel for the kilns and to make tools and auxiliary buildings). This can be inferred indirectly from the fact that the debris from the processing of tuna fish began to be systematically used as fuel throughout the 5th century BC (which gives an idea of the massive scale the local production and the complexity of the economic cycle generated with regard to tuna processing). Other towns in the region with access to similar fishing resources, such as Lixus, Malaka, Seks, and other smaller settlements, would have replicated local variants of such a business, participating on a different scale in the lucrative trade of salted fish both within the region and to Greek, Carthaginian, or Etruscan "markets" via long-distance routes.

Kiln sites in Punic Gadir

The transformations detailed here occurred during the 6th century BC, and had a very significant impact in the case of the Bay of Cadiz, whose settlements were already an important Phoenician hub in the preceding century from both a demographic and an economic point of view. Towards the middle of the 6th century BC, the insular city seems to have been re-founded and reinvented based on its advantageous location at the gates of the

Atlantic, with very favourable port conditions, prestigious maritime sanctuaries, and a territory suitable for the development of activities such as the exploitation of sea salt by evaporation or the mass production of ceramics (See Figure 2). Fishing and the redistribution of commodities from the Mediterranean Sea routes were, since then, two of its economic pillars. The town and its citizens were even more focused than before on manufacturing and trade, disputing with Malaka and other towns on the Mediterranean side of southern Iberia the leading role as regional power and most thriving economy. In particular, the city's strategic position in relation to the migratory routes of the bluefin tuna (Thunnus thynnus) and probably the development of very effective fishing methods such as the almadraba (tuna net-traps) enabled the salted fish from Gadir to become very famous all over the Mediterranean markets, and particularly among the Greeks, whose elites requested these exotic tuna fillets in cities such as Athens or Corinth both as a culinary delicacy and as a marker of their privileged status. The success of these products, packaged in T-11213 type amphorae and distributed via maritime routes, produced immense profits for the city and its oligarchs and, through these commercial connections, accelerated the process of opening to the rising Greek cultural and material influence. The stability of the system seems to have collapsed between the late 5th and the early 4th century BC due to the confluence of several factors, mostly external, among which the role of Carthage and its allies was probably one of the most decisive (in particular, the competition with the Sicilian salted fish).

During the 5th century BC, several dozen pottery workshops were active in the insular area of the Bay of Cadiz, exploiting the abundant clay sources available in the area and located not far from the fish salting facilities to which they supplied transport containers. The many excavations carried out in present-day San Fernando since the 1980s, and the research carried out over the last two decades have revealed the presence of many workshops that were active in the 5th century BC, each of which probably equipped with several kilns of different sizes. Recent quantitative theoretical approaches based on the development of 3D models of kilns and amphorae have concluded that the largest kilns (circular in shape, with a maximum diameter of around 3 m) would have been used mainly for the firing of amphorae of the T-11213 type, each of which could produce a maximum of 40-60 containers in a single firing (See Figure 3). Over several months and under favourable climatic conditions, each workshop could potentially have produced almost a thousand amphorae, in the case of being equipped with two large kilns and a corresponding capacity for wheel-throwing and processing the clays.

Unfortunately, in none of the examples excavated to date, not even in the best-preserved ones such as Camposoto or Calle Real, where some of the kilns still had their holed floors, it has been possible to find the buildings or areas dedicated to the wheel turning, decorating the vases, or decanting and processing of the clays. In any case, they must have been quite simple (made of wood and/or mudbricks) and located around the kilns, as is suggested by the finding of clay mining pits (used after they were abandoned as dumps for refused ceramics and food waste). In general, it must have been a rural landscape, with workshops situated in open spaces among the typical vegetation of the area (pines, wild olive trees, etc.) and connected by basic land roads which would link the production areas with the marshes (salt flats), the salty streams which would provide access to the sea and the bay, the sandy bar on the Atlantic coast where the salting workshops would have been located, and towards the insular city itself, which was located about 10 km to the north. During the months favourable to tuna fishing and ceramic production (primarily between April and September), this whole sector of the island probably became a swarm, with a frenetic artisanal and fishing activity that fed the ships of Gadir's fleet. The manufacture of amphorae was a strategic resource of the city that encouraged the development of other artisanal activities, such as the production of equipment (including the potter's wheels themselves, but also brushes, dies, etc.), the management of local wood resources (fuel, ships, etc.), land and sea transportation.

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Sources for images

Fig 1. Map showing the distribution of the sites of finds of pre-Roman or early Roman potter's wheels in the Iberian Peninsula (map by R. Belizón. Image source: ESRI Satellite https://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapS...{z}/{y}/{x}) Maps created using QGIS 3.16. Geographic Information System. Open Source Geospatial Foundation Projec [https://qgis.org.]).

Fig 2. Map of the bay of Cadiz showing the main places and sites mentioned in the text (map by R. Belizón. Image source: ESRI Satellite https://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapS...{z}/{y}/{x}) Maps created using QGIS 3.16. Geographic Information System. Open Source Geospatial Foundation Projec [https://qgis.org.]).

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FIG 1. MAP SHOWING THE DISTRIBUTION OF THE SITES OF FINDS OF PRE-ROMAN OR EARLY ROMAN POTTER'S WHEELS IN THE IBERIAN PENINSULA (MAP BY R. BELIZÓN. IMAGE SOURCE: ESRI SATELLITE HTTPS://SERVER.ARCGISONLINE.COM/...) MAPS CREATED USING QGIS 3.16. GEOGRAPHIC INFORMATION SYSTEM. OPEN SOURCE GEOSPATIAL FOUNDATION PROJEC [HTTPS://QGIS.ORG.]).

FIG 2. MAP OF THE BAY OF CADIZ SHOWING THE MAIN PLACES AND SITES MENTIONED IN THE TEXT (MAP BY R. BELIZÓN. IMAGE SOURCE: ESRI SATELLITE HTTPS://SERVER.ARCGISONLINE.COM/...) MAPS CREATED USING QGIS 3.16. GEOGRAPHIC INFORMATION SYSTEM. OPEN SOURCE GEOSPATIAL FOUNDATION PROJEC [HTTPS://QGIS.ORG.]).

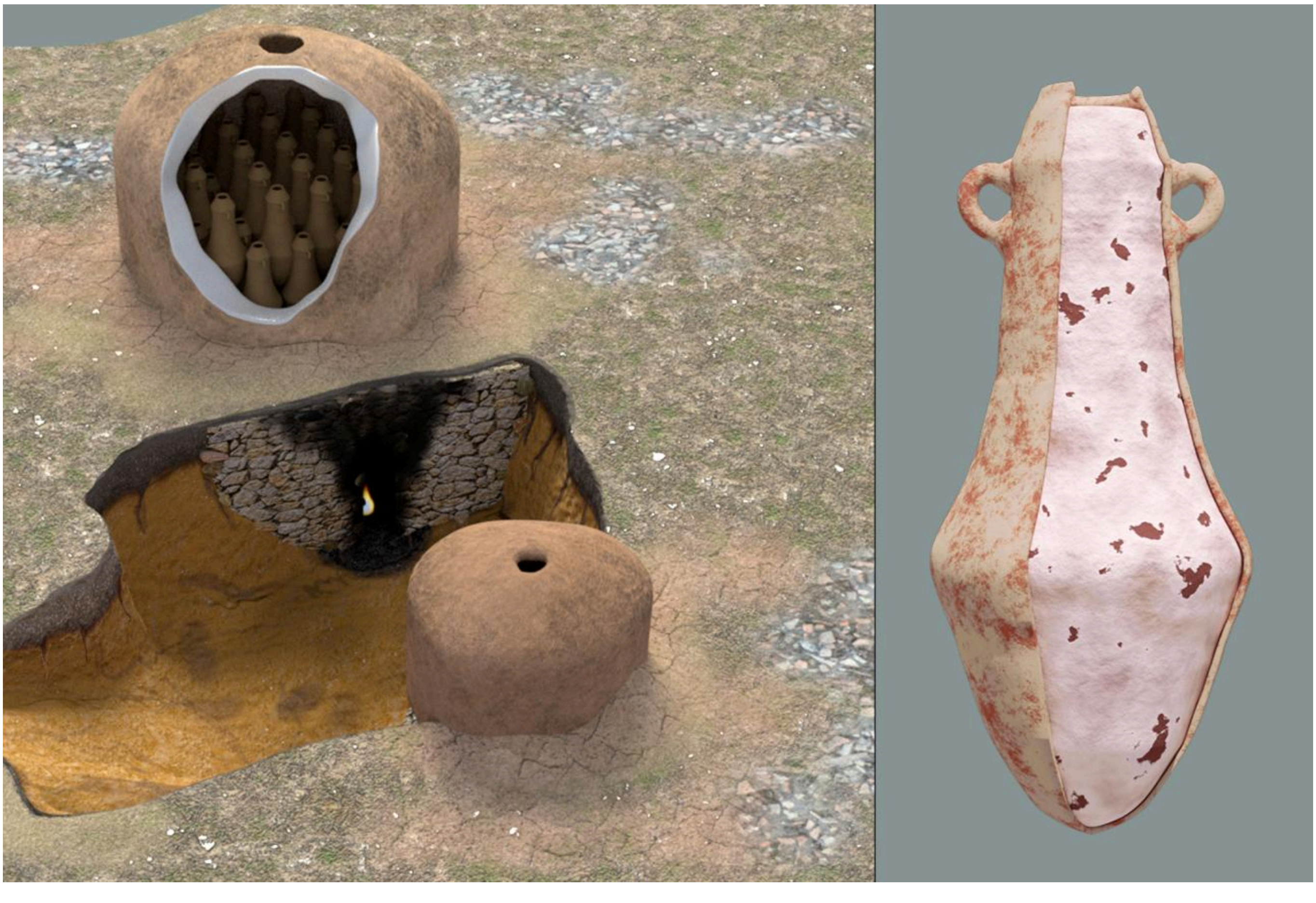

FIG 3. 3D MODEL OF 5TH CENTURY BC POTTERY KILNS 1 AND 5 EXCAVATED AT CAMPOSOTO WORKSHOP, SHOWING HOW THE AMPHORAE WERE FIRED IN THE BIGGER KILNS (LEFT), AND COMPLETE T-11213 AMPHORA WITH INDICATION OF ITS MAXIMUM CAPACITY, FULL OF SALTED FISH (RIGHT). 3D MODELS BY R. BELIZÓN

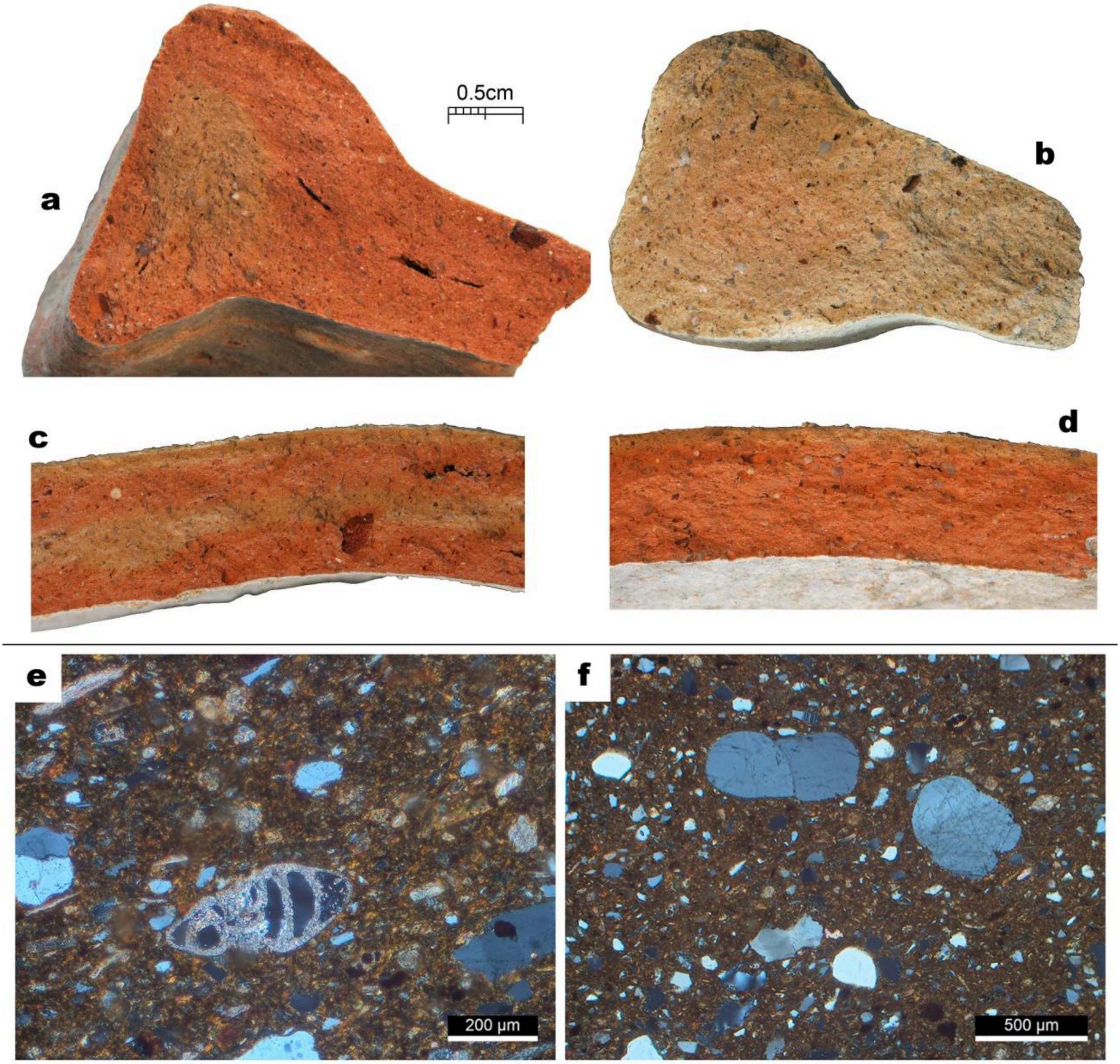

FIG 4. MICROPHOTOGRAPHS (E-F) AND MACROSCOPIC FEATURES (A-D, SCALE 2:1) OF THE FABRICS OF THE T-11213 AMPHORAE PRODUCED IN THE POTTERY WORKSHOPS OF GADIR. PHOTOS BY A. SÁEZ, AND E-F AFTER FANTUZZI ET AL. 2020, FIG. 4

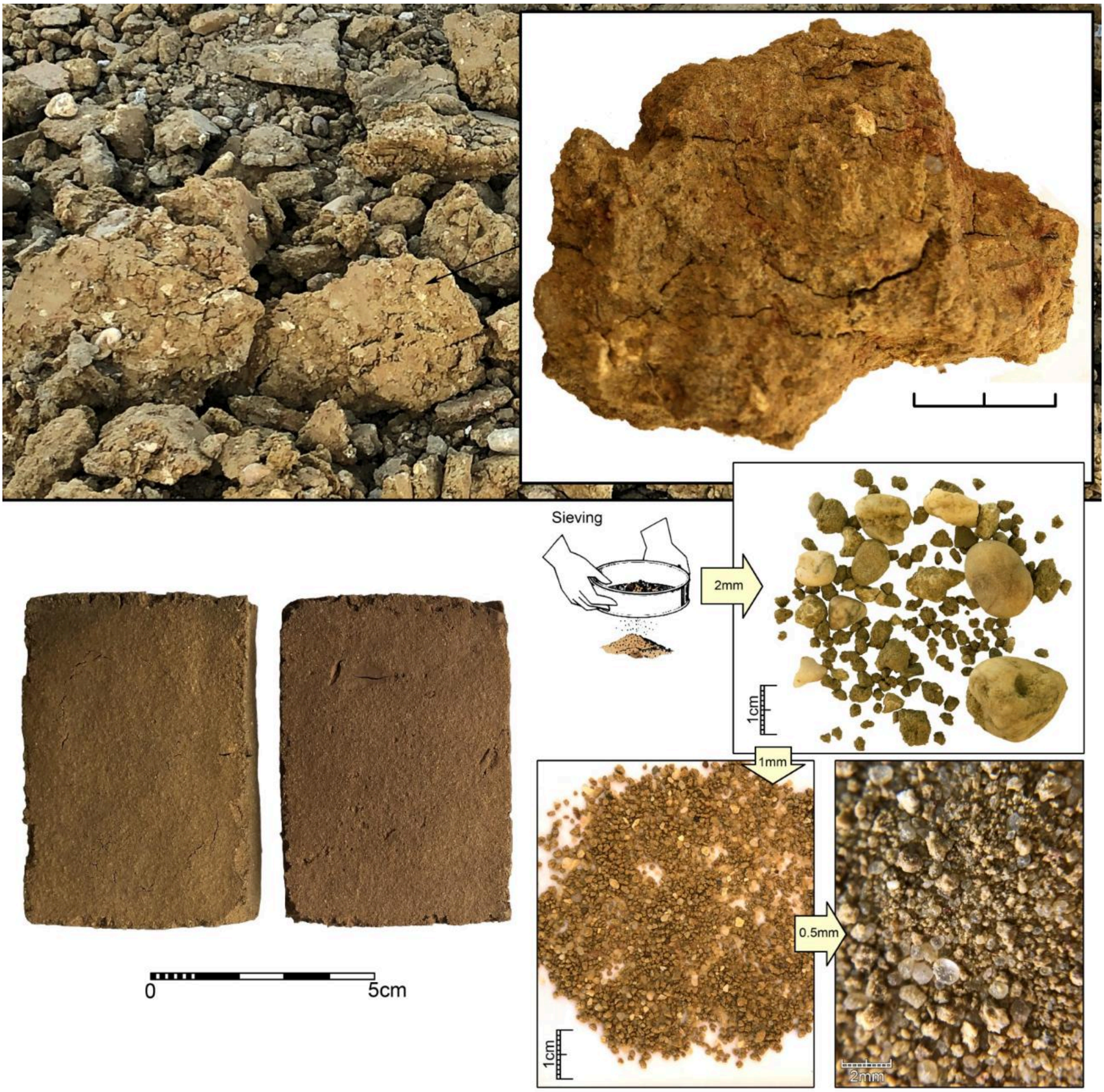

FIG 5. RAW CLAY SAMPLED IN THE VICINITY OF THE PUNIC KILN SITES OF VILLA MARUJA (SAN FERNANDO), SMALL PEBBLES AND QUARTZ SAND ELIMINATED AFTER DRY-SIEVING THE CRUSHED CLAY, AND SMALL BRIQUETTES USED TO TEST THE CONSISTENCY, QUALITY AND SHRINKAGE FACTOR OF THE LOCAL CLAYS THAT WERE USED TO PRODUCE THE T-11213 VESSELS. PHOTOS BY A. SÁEZ

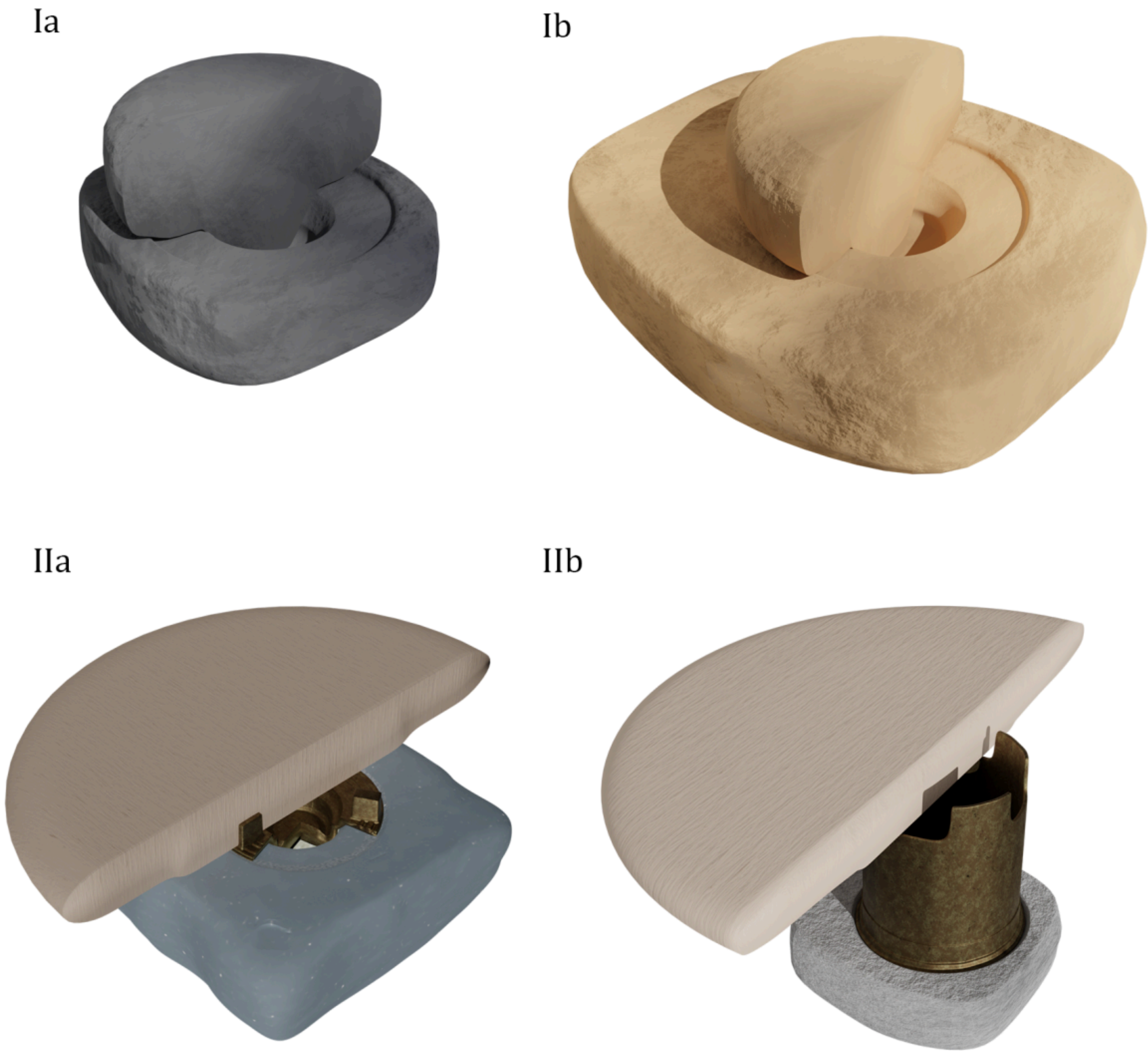

FIG 6. TYPOLOGICAL APPROACH TO THE POTTER'S WHEELS OF THE LEVANTINE TRADITION OF THE IRON AGE IN THE IBERIAN PENINSULA. TYPE IA: EXAMPLES WITH THE TWO PARTS MADE OF STONE AND OF THE SAME SIZE (APPROXIMATELY); TYPE IB: EXAMPLES WITH BOTH PARTS MADE OF STONE, BUT THE LOWER PART IS LARGER THAN THE ROTATING ONE; TYPE IIA: EXAMPLES WITH A STONE BASE AND A METAL PIVOT, WITH A FLAT TOP; TYPE IIB: EXAMPLES WITH A STONE BASE AND A METAL PIVOT, WHOSE CYLINDER IS PROJECTED AS THE AXIS OF THE POTTER'S WHEEL. 3D MODELS BY R. BELIZÓN

FIG 7. STONE SOCKETED BASE FOUND AT GALLINERAS. 2D DRAWING BY A. M. SÁEZ AND 3D DIGITAL MODEL BY R. BELIZÓN

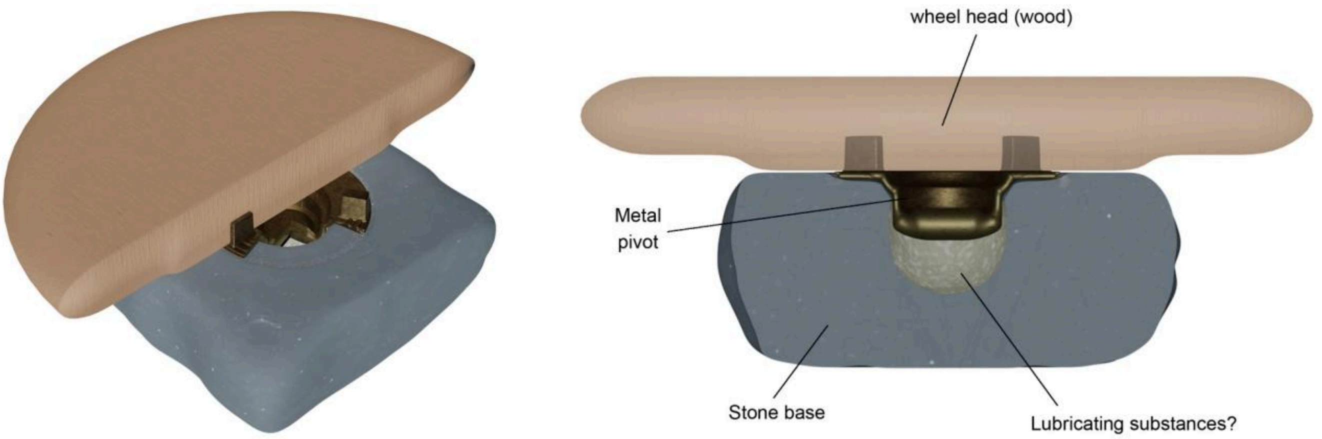

FIG 8. RECONSTRUCTION (SECTIONS) OF THE EXAMPLE FOUND AT GALLINERAS (SAN FERNANDO, CÁDIZ). 3D MODEL BY R. BELIZÓN

FIG 9. HYPOTHESIS ON THE POSSIBLE USAGE OF THE EXAMPLE FOUND AT GALLINERAS. 3D MODEL BY R. BELIZÓN

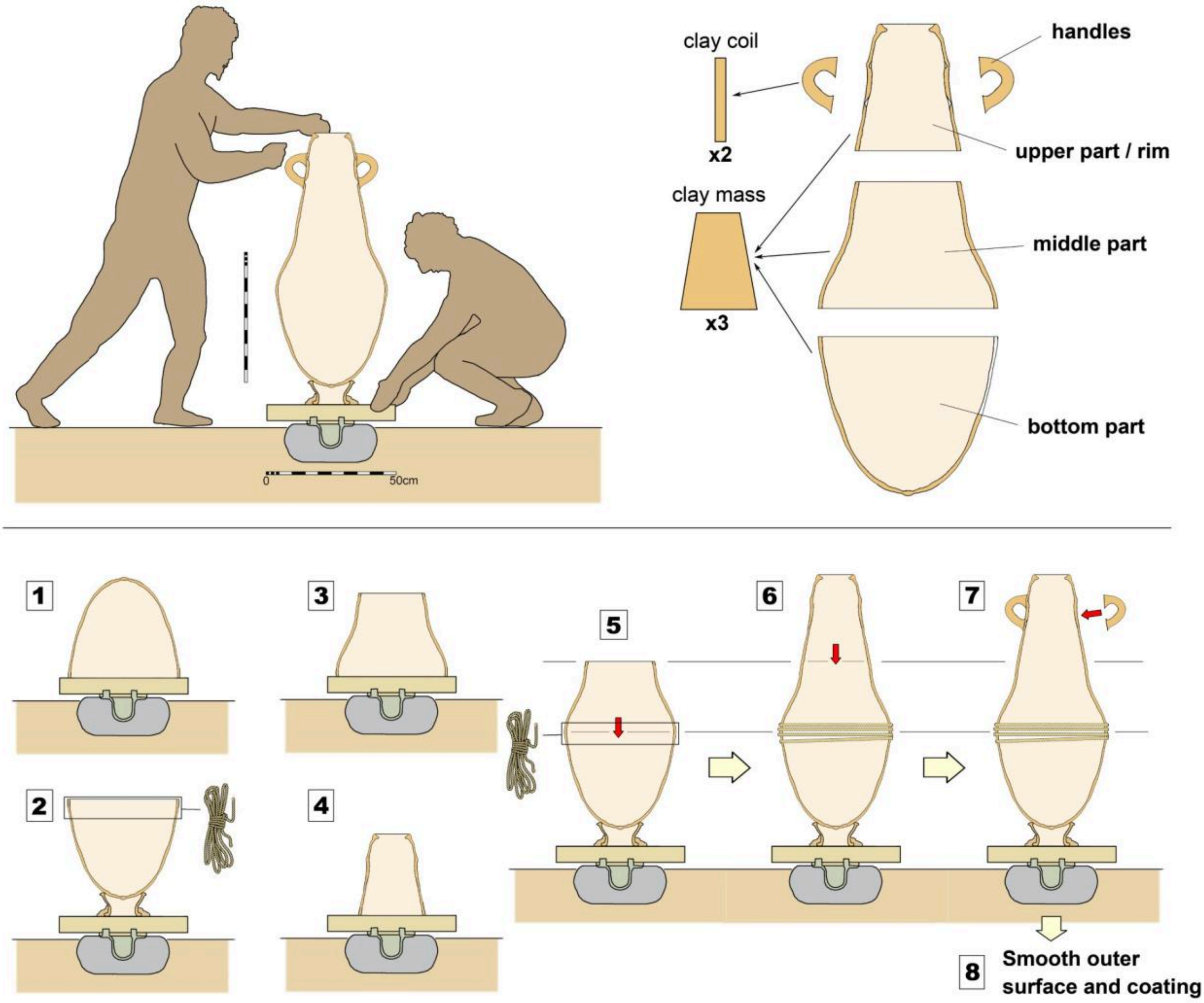

FIG 10. SECTION ON THE LIKELY USAGE OF THE 'LOW POTTER'S WHEEL' IN GADIR DURING THE 5TH CENTURY BC (ABOVE, LEFT); MAIN COMPONENTS OF A T-11213 TYPE AMPHORA AND CLAY BALLS/COILS NEEDED FOR THEIR MANUFACTURE (ABOVE, RIGHT); ALSO, SEE BELOW FOR A SUMMARY OF THE MAIN STAGES IN THE MANUFACTURE OF AN AMPHORA: SHAPING THE LOWER THIRD (1); TURNING-OVER AND PLACING IT ON A SUPPORT, WITH ROPES AROUND THE AREA OF THE TEMPORARY RIM (2); SHAPING THE CENTRAL PART (3) AND THE UPPER THIRD (4) OF THE AMPHORA; JOINING THE THREE MAIN SECTIONS WITH THE AID OF THE POTTER'S WHEEL (5-6); PLACING THE HANDLES (7); AND SMOOTHING AND COATING THE OUTER SURFACE. AUTHORS' DRAWING.

FIG 11A. THROWING REPLICAS OF LATE PUNIC PLAIN WARE AND AMPHORAE AT CERÁMICA RAMÍREZ. PHOTOS BY A. SÁEZ

FIG 11B. SOME OF THE AMPHORA TYPES AFTER FIRING. PHOTOS BY A. SÁEZ

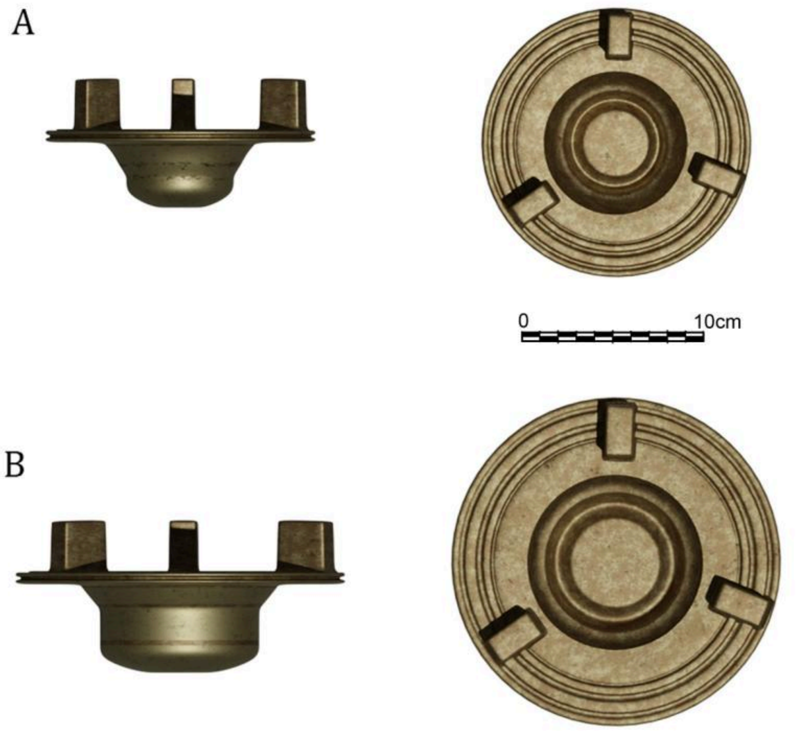

FIG 12. A: MODEL OF A METAL PIVOT FROM THE ALBACETE MUSEUM (FROM A 2D DRAWING IN MESEGUER Y GARCÍA 1995), B: ADAPTATION OF THE ALBACETE BRONZE PIVOT TO THE DIMENSIONS OF THE STONE SOCKETED BASE FOUND IN GALLINERAS. 3D MODELS BY R. BELIZÓN

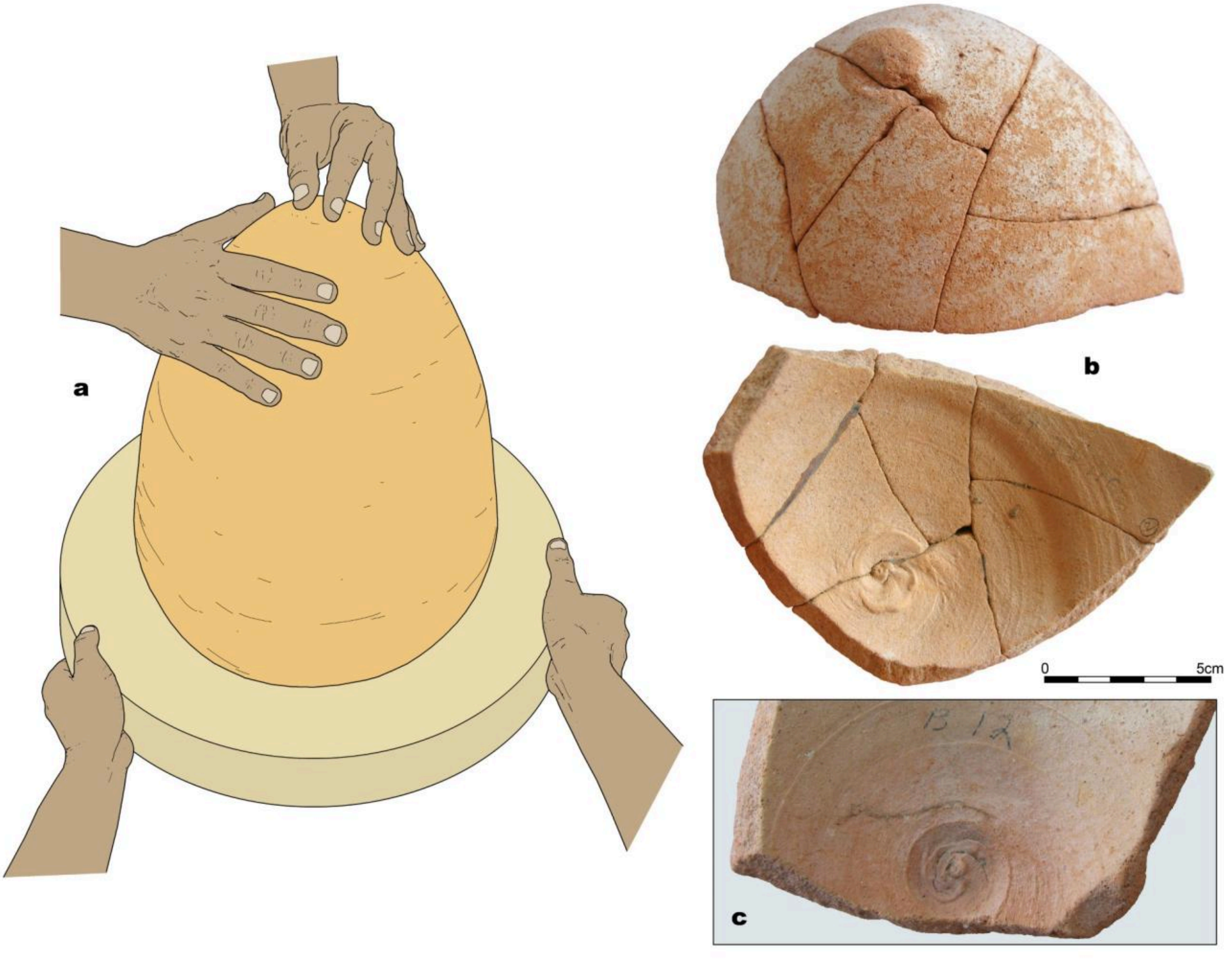

FIG 13. PROCESS OF TURNING THE LOWER THIRD OF THE PUNIC AMPHORAE T-11213 WITH THE HELP OF AN ASSISTANT (A), AND PHOTOGRAPHS OF THE EXTERIOR-INTERIOR (B) AND INTERIOR (C) OF THE BOTTOM PARTS OF AMPHORAE OF THIS TYPE FOUND IN THE PUNIC AMPHORA BUILDING AT CORINTH. PHOTOS BY AND DRAWING BY A. SÁEZ

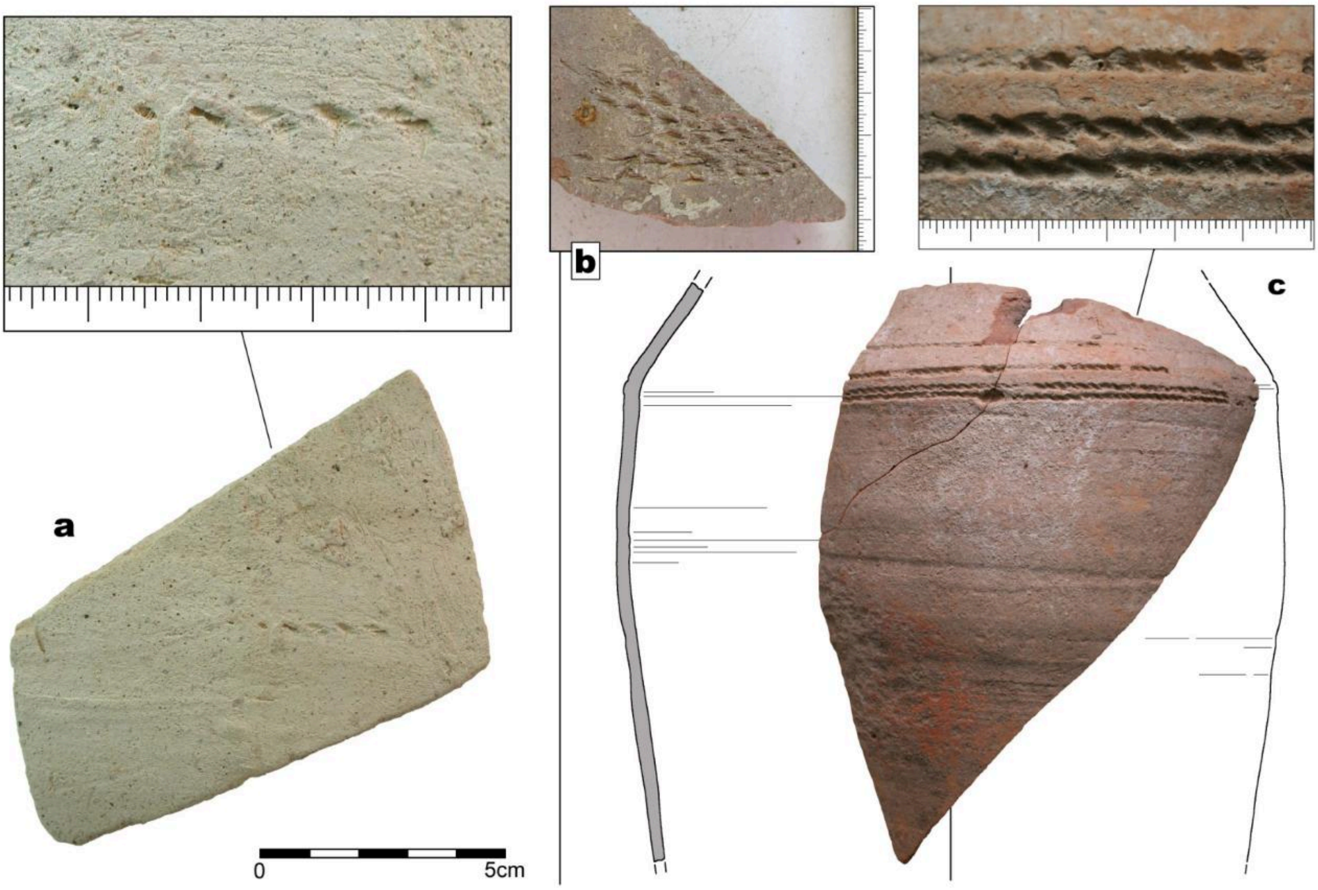

FIG 14. IMPRESSIONS OF CORDS DOCUMENTED ON T-11210 AMPHORAE PRODUCED IN GADIR (A) AND IN THE COAST OF MALAGA (B), RECORDED IN THE PUNIC AMPHORA BUILDING AT ANCIENT CORINTH; ALSO, TRACES OF SEVERAL CORDS ON THE SURFACE OF A T-12111 AMPHORA PRODUCED AS WELL IN WORKSHOPS LOCATED ON THE COAST OF MALAGA, FOUND IN THE BAY OF CADIZ (C). PHOTOS BY A. SÁEZ

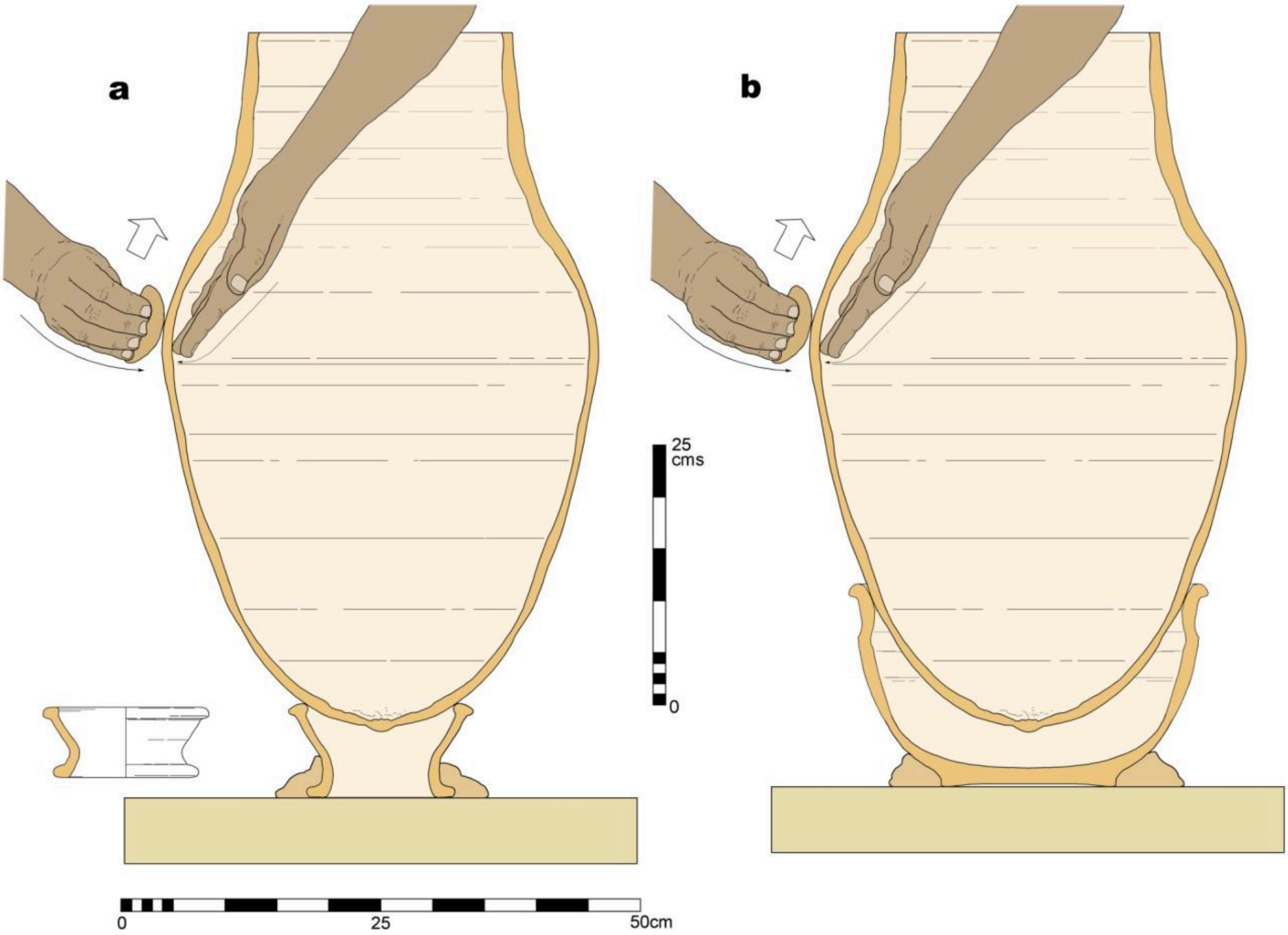

FIG 15. HYPOTHESES CONCERNING THE PROCESS OF JOINING THE LOWER THIRD AND THE CENTRAL SECTION OF THE T-11213 AMPHORAE: STANDING ON SMALL CERAMIC SUPPORTS (A) OR ON BASINS (LEBRILLOS) FIXED TO THE WHEEL WITH FRESH CLAY (B). DRAWING BY A. SÁEZ

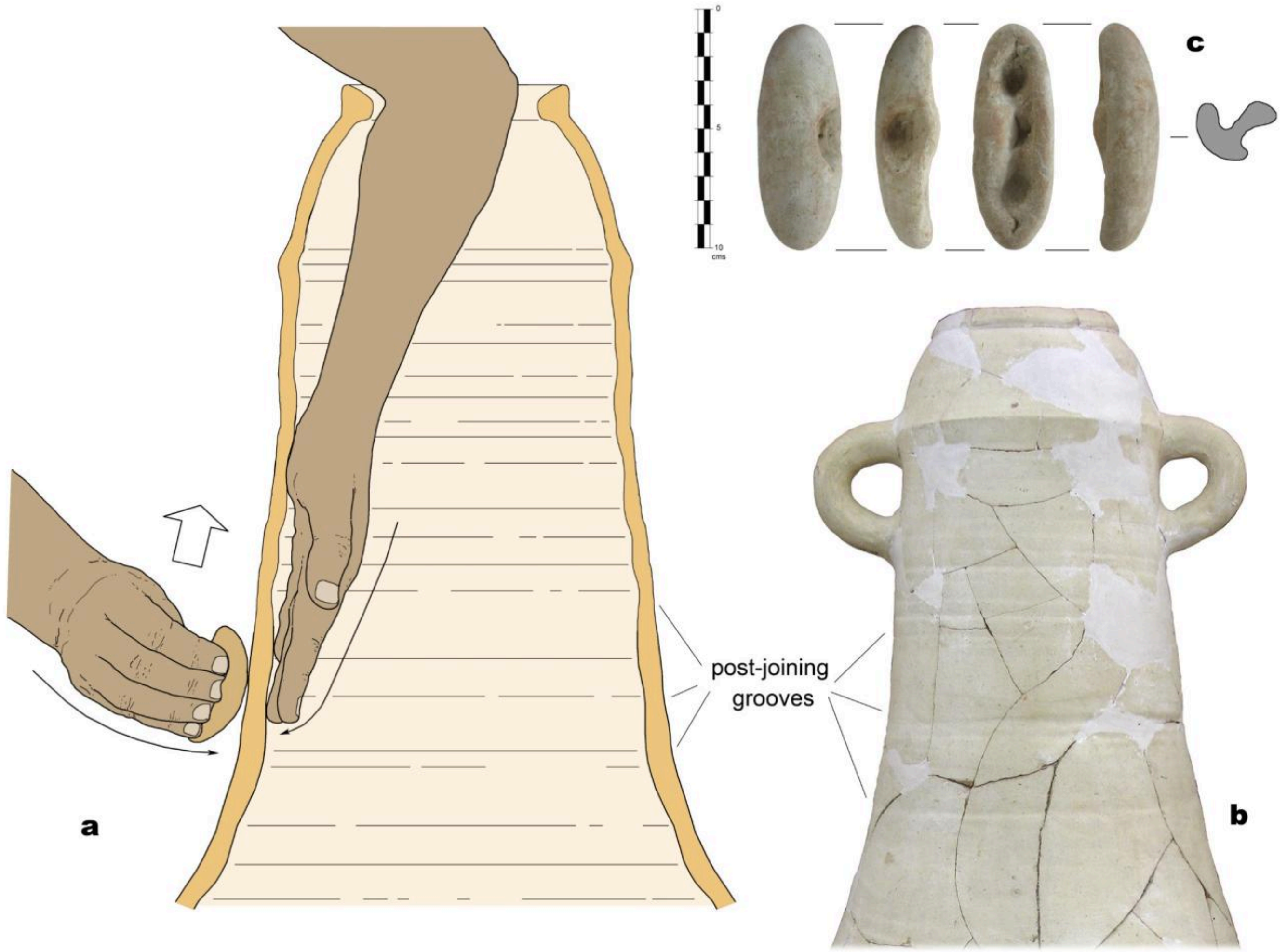

FIG 16. CLOSE-UP VIEW OF THE PROCESS OF JOINING THE CENTRAL SECTION AND THE UPPER THIRD OF THE T-11213 AMPHORAE (A). THIS JUNCTION USUALLY PRODUCED VISIBLE MARKS SUCH AS TURNING GROOVES, ESPECIALLY ON THE OUTSIDE (B). CERAMIC TOOL RECORDED IN THE TORRE ALTA PUNIC POTTERY WORKSHOP (SAN FERNANDO, CÁDIZ) (C). PHOTOS AND DRAWING BY A. SÁEZ

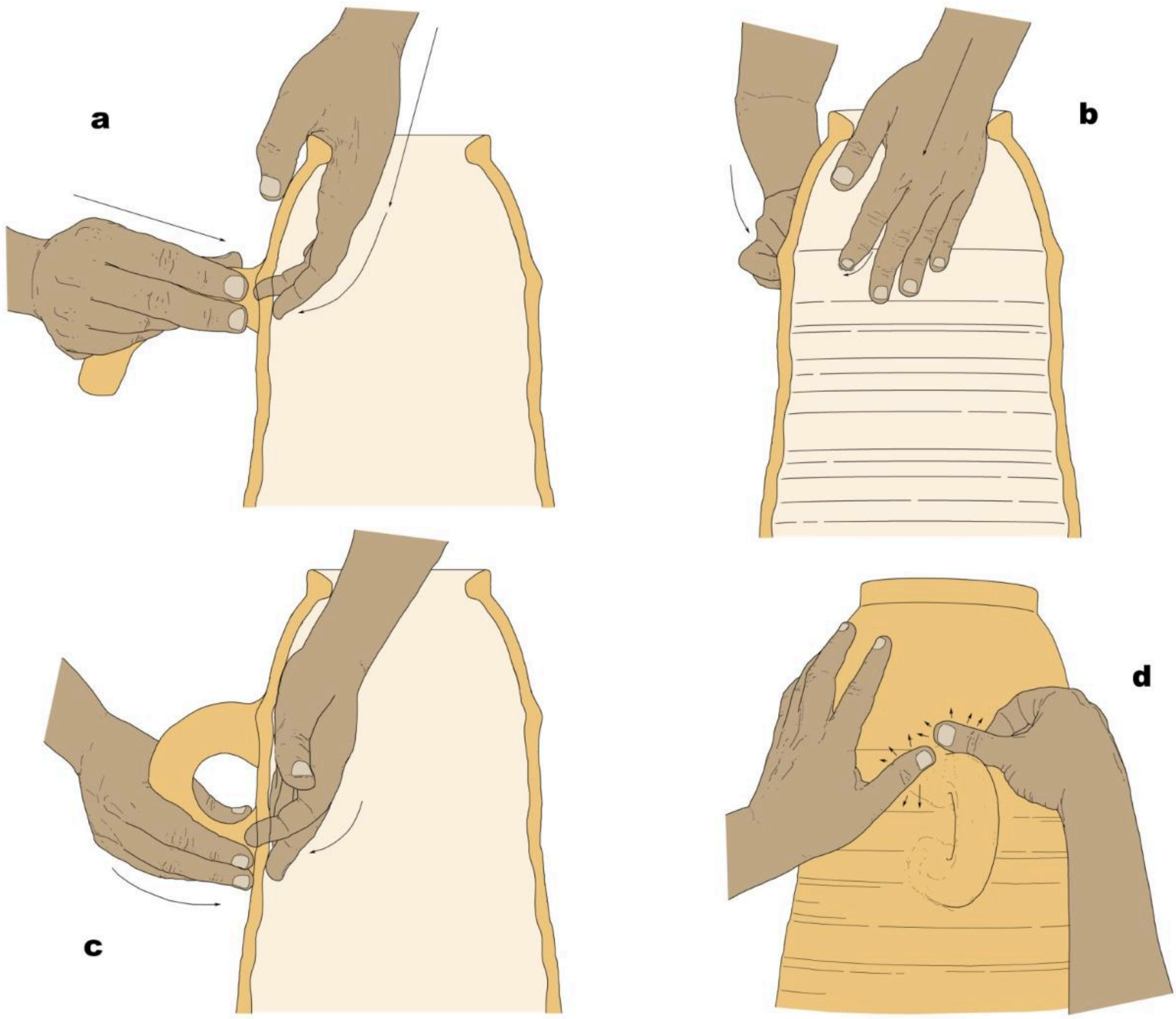

FIG 17. SUMMARY OF THE PROCESS OF ATTACHING THE HANDLES TO THE T-11213 AMPHORAE. DRAWING BY A. SÁEZ

FIG 18. FRAGMENTS OF HANDLES/SHERDS OF T-11213 AMPHORAE PRODUCED IN THE KILN SITES OF GADIR, AND FOUND IN THE PUNIC AMPHORA BUILDING AT ANCIENT CORINTH. DETAIL OF THE LACK OF ANY PREVIOUS SET-UP ON THE OUTSIDE OF THE AMPHORAE BEFORE THE HANDLES WERE ATTACHED (1), AND VARIOUS EXAMPLES OF FINGER MARKS MADE ON THE INSIDE. PHOTOS BY A. SÁEZ