Rotary tools and techniques for gold metallurgy during late prehistory in the Iberian Peninsula

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ABSTRACT: We have investigated goldwork technology by studying working and tool marks, ethnographic and iconographic analogies, written sources and by using non-destructive analytical methods. Our research focuses on the Iberian Peninsula where there is abundant archaeological material dating from the earliest times to the end of Antiquity. We understand technology as a cultural expression inseparable from the social, economic and political context in which it appears, and are interested in technological change, persistence and transmission. Traditional research had not detected the metallurgical use of rotary motion tools until the introduction of Roman technology. We have identified the use of a reciprocating lathe with a horizontal axis for shaping the wax model used in lost wax castings, at least as early as the late Bronze Age, mainly along the Atlantic seaboard. The use of this sophisticated working process appears restricted to specific ritual or symbolic objects in gold and bronze. The synthesis presented is based on the study of Iberian gold hoards. They include the Late Bronze Age Villena hoard, the El Carambolo and Lebrija hoards of the Orientalizing period (both illustrating technological transmission and persistence), and the Castro culture gold torcs of the Second Iron Age.

Introduction

Interdisciplinary and inter-institutional collaboration can only yield scientific results when it is based on research planned over the long term. For the past 10 years, the Archaeometallurgy research group of the CSIC and l'Unité Mixte de Recherche 5608 of the CNRS, have been working together on the history of gold metallurgy in the Iberian Peninsula, from its origins until the end of Antiquity. It is time to present a balance sheet of the results obtained over the past decade.

Our research has always kept clearly in mind that technology will never be properly understood or explained if it is divorced from its social, political and economic setting. We therefore emphasise the mechanisms that govern technological change, persistence and transmission, and also the significance of a gold object within its ideological context (Perea 1999). For these reasons we present the historical development of the first rotary tools used in the work of preparing the wax models for lost wax castings. This new technique was developed during the Bronze Age on the Atlantic seaboard of the Iberian Peninsula, and has a complex history, which is followed through a series of finds and gold hoards with very different meanings and various chronologies that continue into the Second Iron Age (Armbruster and Perea 2007). Each of them demonstrates a different stage of social and technological development.

Rotary mechanisms in prehistory

We have no archaeological finds that document the characteristics of rotary tools such as perforators or drills, and lathes, but we know that they were used throughout Prehistory thanks to the marks they left on the surface of objects worked. There are many examples of bone beads, antler maceheads and polished stone axes that have been perforated by using an instrument with a vertical axis and conical point, operated by alternating rotation that cuts, wears away or alters the shape. The device used to turn the tool could have been the worker's hands, a rope or a bow.

The lathe is a more complex tool than earlier devices, and is used for working relatively soft or malleable materials, such as wood, bone, amber, wax or even metal. Because it has a rotating horizontal axis, entire objects can be made with cylindrical symmetry, hollow or solid. The mechanisms used to operate it are the

1 Lebuçao
2 Cantonha
3 Sintra
4 Aljustrel
5 Torre Vâ
6 Estremoz
7 Aliseda
8 Berzocana
9 Carambolo
10 Acebuchal
11 Lebrija
12 Trayamar
13 Abía de la Obispalía
14 Villena

Figure 1: The Iberian Peninsula showing places mentioned in the text.

same as those used for drills—a cord or a bow—and therefore the rotation continues to be reciprocating. The tool or point which exerts pressure on the object being worked obviously has to be harder and more resistant than the material to which it is applied. The first image of a lathe of this kind comes from a bas relief in the Egyptian tomb of Petosiris, dated to the 3rd century BC (Lefebure 1924, Pl 10).

Until little more than ten years ago, no archaeological evidence for the use of the lathe for making gold objects during the Bronze or Iron Ages had been recognised. Now we know that lathes were used for working gold and even copper-based alloys (Armbruster 1993), though the details of the mechanism, whether it was operated with a cord, with a bow or in some other way, is still unknown. What we can say is that in the Iberian Peninsula the lathe was used before the potter's wheel, so its invention cannot derive from the latter.

Villena/Estremoz-type bracelets

These bracelets have been found in a series of hoards without context on the Atlantic seaboard of the Iberian Peninsula. They generally appear isolated or in pairs. The only exception is the hoard found in Villena, Alicante, near the Mediterranean coast, which contained 28 bracelets associated with other items such as bowls, flasks and weapon fittings. The hoard contained 9kg of gold (Armbruster and Perea 1994) which makes it unique in Europe. As well as gold and silver, the hoard contains items of adornment made from iron, treated as a precious metal. For this reason it has been dated to a period before the true introduction of iron metallurgy in the south of the peninsula by the Phoenicians, around the 8th century BC, the *ante quem* date for the manufacture of the Villena/Estremoz-type bracelets.

Villena/Estremoz-type bracelets are cylindrical objects with perfectly circular symmetry, whose surface has a complex topography based on numerous combinations of three repeated elements: mouldings, spikes and open work (Fig 2). The largest and most perfect example is that from Estremoz, Evora, which weighs 978 gr. Observations with a binocular microscope and scanning electron microscope of the marks left by

Figure 2: Three Villena/Estremoz-type bracelets of increasing complexity, combining mouldings, spikes and open work. Villena hoard, Alicante. Museo Arqueológico J M Soler, Villena.

Figure 3: Casting defects, in this case a linear fracture at the edge of the bracelet, were repaired by casting on. Villena hoard, Alicante. Museo Arqueológico J M Soler, Villena.

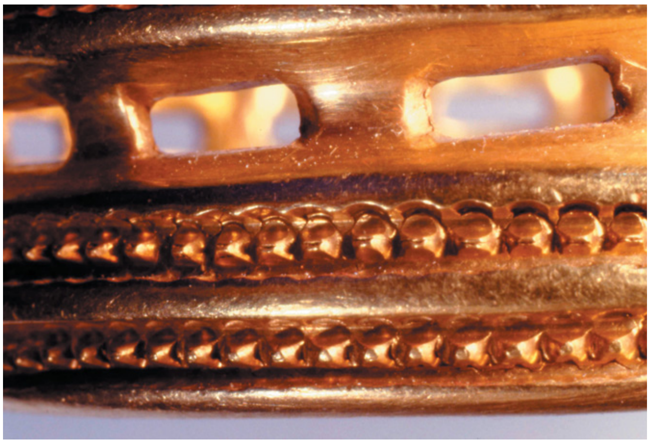

Figure 5: The circular marks at the base of the spikes were made in the wax model with a hollow tool in order to transform pyramid-shaped spikes into conical ones. Villena hoard, Alicante. Museo Arqueológico J M Soler, Villena.

Figure 4: Marks left by a heated blade at the base of the pyramid-shaped spikes in the wax model are reflected in the final casting. Villena hoard, Alicante. Museo Arqueológico J M Soler, Villena.

Figure 6: Bronze patera from the Berzocana hoard, made by lost wax casting, probably an import from the eastern Mediterranean. Diameter 175mm. Museo Arqueológico Nacional, Madrid.

tools and the metallographic microstructures confirm that the technique used was lost wax casting, using a wax model worked on a reciprocating lathe that had a horizontal axis.

On the unpolished surface of the inside of the bracelets it has been possible to observe a rough cast dendritic microstructure that confirms the solidification of the metal after it was cast. Casting defects and even repairs made by casting on can also be seen (Fig 3).

The most obvious tool marks are those from polishing with fine abrasives to give the surface its final finish, a process that must have been done using a lathe. The pyramid-shaped spikes were created from cuts made on the wax model, using heated blades, and these cuts are reflected exactly in the final casting (Fig 4). Another type of conical spike has a circular mark round the base showing that a special tool was used to shape the wax model, probably a hollow stylus with a circular cross-section (Fig 5).

This technology was used exclusively in the manufacture of gold bracelets and rings, and we do not know of any cast bronze object from Iberia using the lost wax process and a lathe. There is only one exception (Fig 6) that proves the rule, and that is the bronze patera found together with two gold torcs characteristic of the Atlantic late Bronze Age in the hoard of Berzocana, Cáceres, (Armbruster 2000, pl 32–33). Recent studies have identified the Berzocana dish as an import from the eastern Mediterranean, probably of Egyptian or Cypriot manufacture (Matthäus 1985, pl 28 and 30).

Around the 8th century BC, goldwork produced using the Villena/Estremoz technology was concentrated along

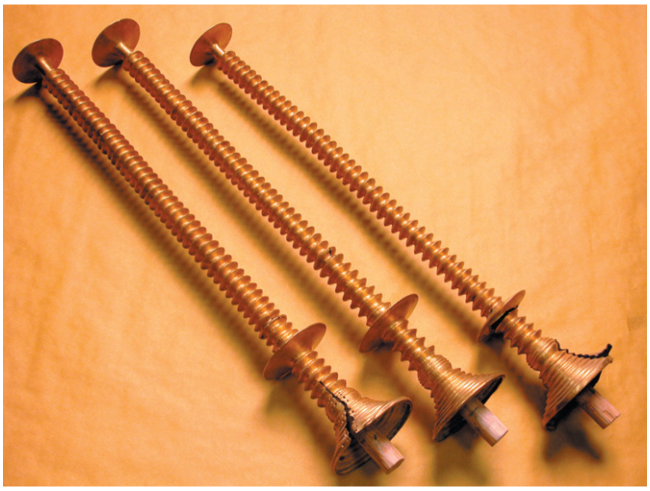

Figure 7: Three of a set of six gold candelabra from Lebrija, Seville. Each one is about 700mm tall. Museo Arqueológico Nacional, Madrid.

Figure 8: Detail of the left-hand object in Figure 7 showing the join in the shaft where the second part was cast on. Museo Arqueológico Nacional, Madrid.

the lower reaches of the Guadalquivir river, because the centres of power had been displaced with the establishment of permanent settlements of Phoenician population on the south coast of Iberia. At that time the estuary of the Guadalquivir formed a great seawater lagoon that extended inland as far as Seville where merchants and sailors coming from all over the Mediterranean came as if to a promised land, to make a profit from colonial trade. Two important gold hoards, from Lebrija and El Carambolo, provide clues about the interaction between the indigenous populaton and newcomers and also about technological change and transmission.

The Lebrija hoard

The Lebrija hoard, found by chance in 1923, consists of six large gold objects traditionally described as candlesticks or candelabra and identified as Phoenician *thymateria*,

Figure 9: Pin/peg holes of varying sizes in the split base of the left-hand object in Figure 6. Museo Arqueológico Nacional, Madrid.

lamp holders or incense burners (Fig 7). A very recent acquisition made by the National Archaeological Museum (Perea *et al* 2003) and the Royal Academy of History (Almagro-Gorbea *et al* 2004, 179–182, pl 10), consisting of three more gold objects of the same Lebrija type, confirms that they are not functional but rather an-iconic representations of the divinity, like the Mediterranean sacred stones or *baetyls*, which belonged to a sanctuary. We have suggested that the Labrija hoard should be interpreted as the double representation of a triad of Phoenician divinities, perhaps Tanit-Ashera-Astarte. The symbol of Ashera was a tree trunk, which is precisely what the tall ringed shaft of the so called candlesticks appears to represent.

Each of the six Lebrija candlesticks is hollow, consisting of a perfectly symmetrical shaft of parallel discs, with a disc of greater diameter at the top and a conical base. They are about 700mm tall and each weighs ~1kg, with intermediate measurements so similar that they appear to have been made in the same workshop. They were cast in two parts using the lost-wax process, the second part being cast on. The join is visible in all of them, but can be clearly seen in one example that has split open at that point (Fig 8). The clay core of the mould had wax applied to its outer surface, which was then turned on a reciprocating lathe to make the model of the candlestick. The lathe, which had a horizontal axis, must have been dismantled to remove the wax model on its clay core. It must also have been equipped with a support for the tool used to work the wax so it could produce the perfect cylindical ringed model, as has been shown by archaeological experimentation.

The cone that forms the base has been splayed by plastic deformation to strengthen it because the cast metal is too soft to support its own weight. Even so, the bases

Figure 10: Some of the the plates and pectorals of the Carambolo hoard, Seville. Museo Arqueológico de Sevilla.

of all except one of the candlesticks were broken and had been repaired on many occasions using pins into the filling material (Fig 9), which is thought to have been a cement or resin, probably combined with wood, deduced from the hole marks and the way pins were arranged. One candlestick has as many as 37 perforations. These repairs must have been made while the object was in use as different tools were used, which confirms that the candlesticks were used over several generations.

The technology of the Lebrija-type candlesticks has all the basic features characteristic of the Villena/Estremoz technology of the Atlantic Late Bronze Age; it only differs from the process used for making the Villena/Estremoz bracelets in that the candlesticks are hollow rather than solid objects. However, some bracelets of the same type have a concave/convex cross-section instead of the traditional flat/convex section which makes them lighter, that is, they are no longer solid, which we interpret as an attempt to save on the raw material. Examples are the bracelet from Aljustrel, Beja (Armbruster 1993, 269, pl 4, 29–31; Armbruster 2000, pl 9, 1–4), and a fragment of unknown origin in the National Archaeological Museum in Madrid (Armbruster 2000, pl 114, 1–4). Another plate bracelet of unknown origin, now in the National Archaeology Museum in Lisbon, which does not strictly belong to the Villena/Estremoz type, was made using this technology and is a fluted cylinder with relatively thin walls (Armbruster and Parreira 1993, 128–129; Armbruster 2000, pl 115, 1–3). These examples show that the Villena/Estremoz technological domain was capable of adapting its manufacturing processes to save metal, making hollow laminate objects when required.

The analyses of the Lebrija hoard and one of the new examples using PIXE (proton induced X-ray emission) support this contention (Perea *et al* 2003). The type of metal used for making the seven examples is gold with a silver content of between 11 and 15%, with copper impurities that are always less than 1%. This gold composition is characteristic of Late Bronze Age goldwork, for example the hoard from Abía de la Obispalía, the one from Villena, and the Portuguese bracelets from Estremoz and Aljustrel. The composition is clearly different from that used in the Orientalizing sets of goldwork, such as those from Trayamar, Carambolo, Aliseda or Acebuchal (Hartmann 1982), which is generally purified gold with very variable silver and copper contents.

The Carambolo hoard

This hoard was found by chance near Seville in 1958 on a hill on the outskirts of the city overlooking the surrounding territory. It was the site of a sanctuary where the famous bronze statuette of Astarté with a Phoenician inscription was found (Lipinski 1995, 132). The treasure consists of sixteen plates, two pectorals or pendants and two bracelets, which form a stylistically homogenous and coherent group (Fig 10). A necklace with very different characteristics, made at a much later date and probably Cypriot in origin, was added to these pieces at the time they were hidden.

From the technological point of view the Carambolo hoard is completely different from the Lebrija one (Perea and Armbruster 1998). These are very light sheet objects, consisting of a great many small pieces, such as capsules, hemispheres, wires, cords, ribbons, rings, etc, all of them hammered into shape and soldered together, in which the ornamental element takes precedence over the structural. One of the first figurative motifs on Iberian goldwork, a rosette with 11 petals, is here incorporated into a geometric composition. For all these reasons we suggest that the technological origin of the set is in a Mediterranean rather than Atlantic technological domain (*ibid*).

However, closer observation has revealed two facts that are fundamental for the interpretation of the hoard. One of the secondary ornamental features of the plates is the rows of conical spikes, which are placed between the lines of capsules with rosettes and hemispheres. The spikes are solid and were made using the lost wax process using a peculiar tool that has left a circular mark round the base of each of them (Fig 11). Both the tool and the technique are the same as those used in the manufacture of the Villena/Estremoz-type bracelets of the Late Bronze Age, which are decorated in the same way. We can only conclude that when the Carambolo

Figure 11: A row of solid conical spikes with a circular mark round the base that proves lost wax casting of this ornamental element (cf Figure 5). El Carambolo hoard. Museo Arqueológico de Sevilla.

Figure 12: A row of hollow conical spikes with dents (left of centre) proving a plastic deformation process was used to make them. El Carambolo hoard. Museo Arqueológico de Sevilla.

hoard was made, the Villena/Estremoz-type technology belonging to the Atlantic domain was still in use.

The second technological fact relates to the two bracelets in the hoard. The linear ornamental motifs include rows of spikes, identical in appearance to those on the plates. However, closer examination shows that these spikes are not solid, but hollow. They were not made using the lost wax process but by hammering a strip of metal (Figs 12 and 13), which indicates, firstly, that the goldsmith who made the bracelets was not the same one who made the plates. Secondly, the goldsmith who made the bracelets was acquainted with the ornamental motif of the spikes, but was not familiar with the lost wax technique, so he simply imitated the motif as closely as his technical skills allowed, *ie* according to the Mediterranean technological domain.

Although the concealment of the Carambolo treasure can be dated to around 600 BC on the basis of the most recent piece in the hoard (the Cypriot necklace), the age of the pieces themselves must be determined in relation to the Villena/Estremoz technology and to the Lebrija hoard, which shows them to be of a fairly early date, perhaps around the beginning of the 7th century BC (Perea and Armbruster 1998). No other gold object of a later date made with Villena/Estremoz technology has been found in the south of the Iberian Peninsula.

Atlantic goldwork in transition

We can date some finds that demonstrate the persistence of Villena/Estremoz technology, and the appearance of new forms that would give rise to the so-called Castro culture goldwork of the northwest, to the transition

Figure 13: Small holes at the base of the hollow spikes as a result of punching a strip of metal to produce a conical shape. El Carambolo hoard. Museo Arqueológico de Sevilla.

from the Late Bronze Age to the First Iron Age on the Atlantic seaboard.

The bracelet from Cantonha, Guimarâes (Fig 14), consists of a Villena/Estremoz-type bracelet to which has been added two bracelets of another type, known as Sagrajas/Berzocana, which is also characteristic of the Late Bronze Age. The join was made by casting on, a technique that also served to produce terminals in the shape of a cup with an internal point (Armbruster and Perea 1994, pl II), a shape that was probably symbolic since it endured for several centuries, until the Romanisation of the area around the 1st century BC, although its symbolism is now lost.

The other transitional object is the triple torc of Sintra, Lisbon (Fig 15), of the Sagrajas/Berzocana type, with a clasp made from a fragment of Villena/Estremoz-type bracelet (Armbruster 1995). At some point four

Figure 14: The Cantonha bracelet, the central piece a Villena/ Estremoz-type bracelet and two Sagrajas/Berzocana-type arm rings attached to either side. Museu Nacional de Arqueologia, Lisboa.

Figure 15: The Sintra triple torc with a clasp made from a piece of a Villena/Estremoz-type bracelet. British Museum, London.

decorative elements in the shape of a cup with an internal point were added to it; they were made using the lost wax process with the aid of a lathe to achieve a perfectly circular shape (Fig 16).

Figure 16: Detail of Figure 15 showing the ornamental cups with an internal point. British Museum, London.

Figure 17: Bracelets from Torre Vâ, Beja. Museu Nacional de Arqueologia, Lisboa.

Both the Cantonha bracelet and the Sintra torcs can be interpreted as the last prestige objects of a world that was about to disappear. But what must be emphasised is that the use of lost wax technology and the lathe continued to be transmitted from generation to generation, although the forms they were used to create had nothing in common with those found in the Late Bronze Age. Examples are the two bracelets from Torre Vâ, Beja (Fig 17), complex objects made up of many pieces. Striking features are the accomplished terminals in the shape of a cup with an internal point made using Villena/Estremoz technology (Fig 18) and the granulated ornamentation, a new technique introduced by the Phoenicians from the south.

The Castro culture goldwork of the northwest

The Castro culture developed throughout the Iron Age in the northwest of the Iberian Peninsula. One of its best known manifestations is its abundant gold work, mainly torcs, bracelets and pendant earrings (Ferreira

Figure 18: Detail of Figure 17 showing the terminals in the form of a cup with an internal point. Museu Nacional de Arqueologia, Lisboa.

Figure 19: Bracelet from Lebuçao, Vila Real. Museu da Sociedade Martins Sarmento, Guimarâes.

da Silva 1986; Fernández-Posse 1998; García-Vuelta 2007). Their chronology is much disputed due to the systematic absence of contexts for the finds, and the general tendency to date most of the production to the period when the territory was Romanised, ie after the 1st century BC. However, their origins, or at least their technological origins, must be in the Late Bronze Age (Perea 2003).

The bracelet from Lebuçao, Vila Real (Figs 19 and 20), formed part of a hoard that contained various typically

Figure 21: Two Castro culture torcs with double scottia terminals. British Museum, London.

Castro torcs, with double scottia terminals (Fig 21; Ferreira da Silva 1986, pl CXVII). The process used to make and decorate this object was very complex and combined casting and plastic deformation techniques. Part of this process consisted of moulding a wax cylinder on a lathe for a lost wax casting; the traces of this work are visible on the lower and upper edge of the bracelet, with perfectly parallel and extremely fine mouldings (Fig 20). After casting, the central part of the cylinder was embossed and decorated with a punch with typical motifs from the Castro culture repertoire.

The persistence of Villena/Estremoz technology in the Castro culture area of the northwest during the Second

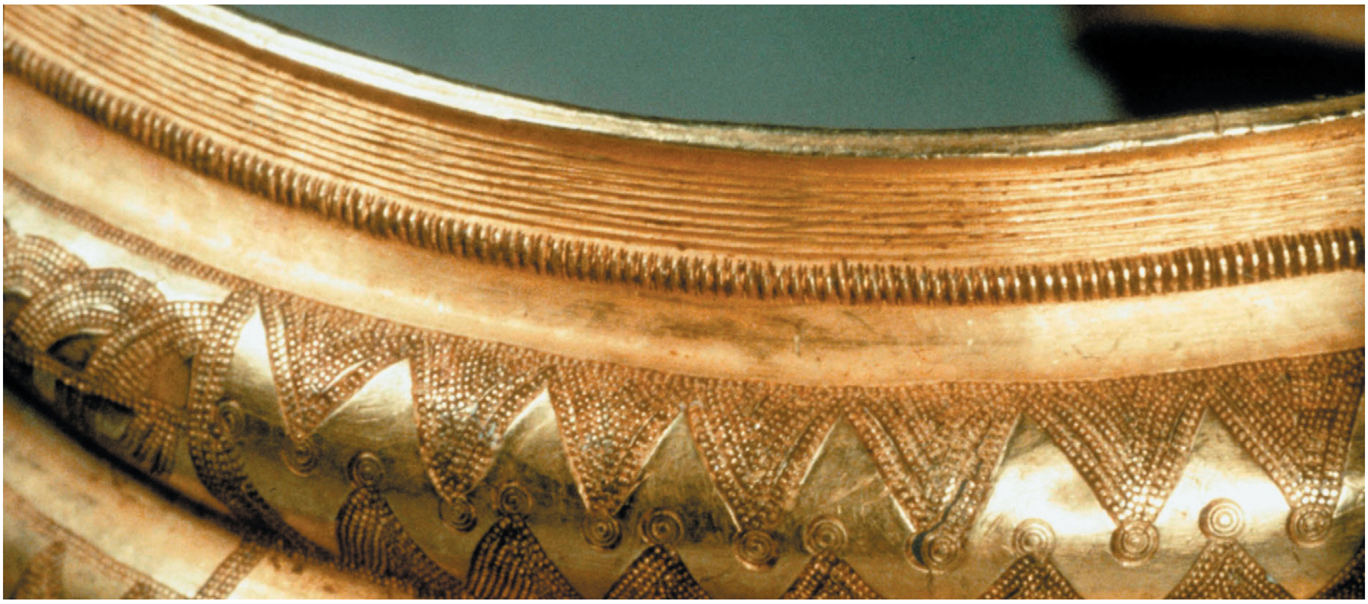

Figure 20: Detail of Figure 19 showing perfectly parallel and extremely fine mouldings that were shaped in the wax model before casting.

Figure 22: Detail of torc in Figure 21 showing the end of the double scottia terminal in the form of a cup with an internal point.

Iron Age is also shown by torcs, particularly those with double scottia terminals, complex pieces with perfect rotational symmetry (Fig 21). The conservative character of Castro society is also reflected in one of the most enduring symbols on the Atlantic seaboard: the cup with an internal point (Fig 22). A Castro torc preserved in the British Museum is one of the last examples with this symbolic expression before it was lost for ever to other forms of power: Roman organisation and law.

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