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Ivory technology: tools, techniques and production modes in the Iberian Copper Age. Valencina de la Concepción (Seville) as a case study

Tecnología del marfil: herramientas, técnicas y modos de producción en la Edad del Cobre de la península ibérica. Valencina de la Concepción (Sevilla) como caso de estudio

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Abstract: The use of ivory in the Mediterranean region dates to the Palaeolithic period, with a significant increase taking place during the Copper Age in southern Europe. This article explores, in-depth, the exploitation of elephant tusks and the processes behind manufacturing ivory objects during the Copper Age on the Iberian Peninsula. For this purpose, the mega-site of Valencina in southern Spain is used as a case study because of the abundant and varied collection of ivories it has yielded. The technological, morphological, and contextual dimensions of Copper Age ivory will be examined here. Standardised exploitation was observed, oriented towards the manufacture of specific types of blanks, based on the knowledge and use of different parts of the tusk (hollow and compact) in a differential and very specific manner. The main form of exploitation is longitudinal, that is, to produce plates, allowing for more efficient exploitation of this raw material. Furthermore, this study has revealed the only case so far in the Iberian Peninsula of a sawing process by abrasion, and not with a saw ("sciage au fil sablé"), extending our knowledge of the craftsmanship of Prehistoric societies.

Keywords: Ivory; technology; craftsmanship; operational sequence; abrasive sawing (with cord); Copper Age; Iberian Peninsula.

Resumen: *El uso del marfil en el Mediterráneo se remonta al Paleolítico, con un importante desarrollo durante la Edad del Cobre en el sur de Europa. Este artículo profundiza en la forma de explotación de los colmillos de elefante y en el proceso de fabricación de objetos de marfil durante la Edad del Cobre en la península ibérica. Se utiliza como muestra de estudio el mega-sitio de Valencina, en el sur de España, por la abundante y variada colección de marfiles que ha proporcionado. Este estudio examina en profundidad las dimensiones tecnológicas, morfológicas y contextuales del marfil de la Edad del Cobre. Como resultado, se observa una explotación estandarizada, orientada a la fabricación de soportes específicos, basada en el conocimiento y uso de las distintas partes del colmillo (huecas y compactas) de manera diferencial y muy específica. La principal forma de explotación es la longitudinal, es decir, la producción de placas, que permitía un mayor rendimiento de la materia prima. Además, este estudio ha revelado el único caso hasta ahora en la península ibérica de un procedimiento de aserrado por abrasión, y no con sierra* (sciage au fil sablé)*, ampliando nuestro conocimiento sobre la artesanía de las sociedades prehistóricas.*

Palabras clave: *marfil; tecnología; artesanía; cadena operativa; aserrado por abrasión (con cuerda); Edad del Cobre; península ibérica.*

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1. INTRODUCTION AND OBJECTIVES

The farming societies that developed in southern Europe, particularly in the Iberian Peninsula, from the mid-sixth millennium, began to experience a huge social expansion (including demographic growth, intensification of the agricultural economy, copper metallurgy, supra-regional exchange networks, etc.) by the last quarter of the fourth millennium (García Sanjuán and Murillo-Barroso, 2013). One particular indication of these changes during the Copper Age was the acquisition of a great number of exogenous raw materials and the appearance in funerary contexts of "special" individuals or collectives, buried with sophisticated grave goods. This phenomenon has been interpreted as indicative of an emerging "elite", something that is quite palpable in the lower Guadalquivir River valley during the Chalcolithic Period (between 3200 and 2200/2300 cal BC). The presence of ivory objects seems to be one of the common denominators in local elite grave goods there (García Sanjuán *et al.,* 2018b; Luciañez-Triviño *et al.,* 2021). The presence of significant amounts of ivory, and other extra-peninsular materials (such as ostrich eggshell) in some of the largest Chalcolithic settlements in Iberia reflect the intensification of these trans-Mediterranean exchange networks.

Ivory has been a widely appreciated raw material since the Paleolithic and throughout human history. In the Iberian Copper Age, elephant ivory was used to produce many different kinds of prestigious objects such as handles, zoomorphic and anthropomorphic figurines, combs, decorated and undecorated plates, vessels, boxes, lunulae, and beads. Ivory was not used during the Chalcolithic to make utilitarian objects, like tools to produce other goods, but exclusively for showy personal objects for display, as body ornaments or to be carried by individuals (Luciañez-Triviño *et al.,* 2021).

The study of this raw material is at the core of current research on resources in Iberian prehistory, providing as it does, valuable information about social change, crafts, long-distance contacts, and sociocultural organisation. Since the end of the nineteenth-century scholars have noted the presence of ivory on Iberian sites from the Late Neolithic to the Iron Age. The study of this raw material still raises a great deal of interest even today, something reflected in a vast literature that greatly exceeds the scope of this paper. Despite the extensive literature about these Iberian ivories, there has been less research on ivory manufacturing and technology (*e. g.* Altamirano García, 2014a, 2014b)[1]. Most references deal with material from later periods, mainly the Bronze and Iron Ages (*e. g.* Barciela González, 2006, 2007, 2012[2]; Altamirano García, 2011, 2012a, 2012b; López Padilla and Hernández Pérez, 2011; Liesau von Lettow-Vorbeck and Schuhmacher, 2012; López Padilla, 2012; Pascual Benito, 2012; Blasco Martín, 2015; Pau *et al.,* 2018). In contrast, the study of ivory technology elsewhere in Europe is most developed for the Palaeolithic period (*e. g.* Hahn *et al.,* 1995; Christensen, 1999; Khlopatchev, 2001; Heckel, 2009; Khlopatchev and Girya, 2010; Hein, 2011, 2014), with contributions including the experimental approach (*e. g.* Hahn, 1986; Hahn *et al.,* 1995; Christensen, 1999; Malina and Ehmann, 2009; Khlopatchev and Girya, 2010; Heckel and Wolf, 2014).

This article explores the evidence for ivory technology during the Chalcolithic, based on the materials from the site of Valencina de la Concepción-Castilleja de Guzmán (hereafter Valencina) in southern Spain. The results concerning production modes, techniques, and the tools used in manufacturing these objects will be discussed in this article, in order to understand all aspects involved in the production of ivory artefacts, from the supply of the raw material, manufacturing processes, to their end use (the object biography), with special attention to *debitage* (blanks production). Thus, all products from the technical chain – blocks, blanks, pre-forms (or roughouts), and production waste (or *debris*) – were studied.

Valencina is located in North Aljarafe, ca. 8 km from the city centre of Seville (Fig. 1). The radiocarbon dates place the activity there between ca. 3200 cal BC and ca. 2300 cal BC (García Sanjuán *et al.,* 2018a). This site is considered to have played a prominent role in the networks at the time due to its proximity to multiple resources of economic and social value as well as the abundant flow of exogenous materials (*e. g.,* ivory, amber, ostrich eggshell, etc.) (Vargas Jimenez, 2003; Vargas Jimenez *et al.,* 2010; García Sanjuán, 2017). The intense research carried out at Valencina over the last decade has brought advances in human anthropology (*e. g.* Lacalle Rodríguez *et al.,* 2000; Robles Carrasco and Díaz-Zorita Bonilla, 2013; Pecero Espín, 2016; Díaz-Zorita Bonilla, 2017; Robles Carrasco *et al.,* 2017; Cintas Peña *et al.,* 2018) as well as in faunal studies (*e. g.* Liesau von Lettow-Vorbeck *et al.,* 2014)[3], chronology (García Sanjuán *et al.,* 2018a) and its material culture (*e. g.,* Hunt Ortiz and Hurtado Pérez, 2010; Hunt Ortiz *et al.,* 2011; Rogerio-Candelera *et al.,* 2013; Odriozola Lloret and García Sanjuán, 2013; Schuhmacher *et al.,* 2013a; Lu-

[1] See also unpublished theses: M. Altamirano García. *Hueso, asta, marfil y concha aspectos tecnológicos y socioculturales durante el III y II milenio a.C. En el sur de la Península Ibérica.* Doctoral thesis. Universidad de Granada, Granada, 2013. M. Luciañez-Triviño. *El marfil en la edad del cobre de la península ibérica. Una aproximación tecnológica, experimental y contextual a las colecciones ebúrneas del mega-sitio de Valencina de la Concepción - Castilleja de Guzmán (Sevilla).* Doctoral thesis. Universidad de Sevilla, 2018.

[2] V. Barciela González. *El lenguaje de los adornos: tecnología, uso y función. Adornos personales de la Edad del Bronce en Alicante y Albacete*. Doctoral thesis. Unpublished, Universidad de Alicante, 2015.

[3] J. Escudero Carrillo. *A good place to live? The management of livestock resources in the Lower Guadalquivir Basin in the Southern Iberia during the 3rd mill. BC.* Doctoral thesis. Unpublished. Eberhard Karls Universität Tübingen, Tübingen, 2021.

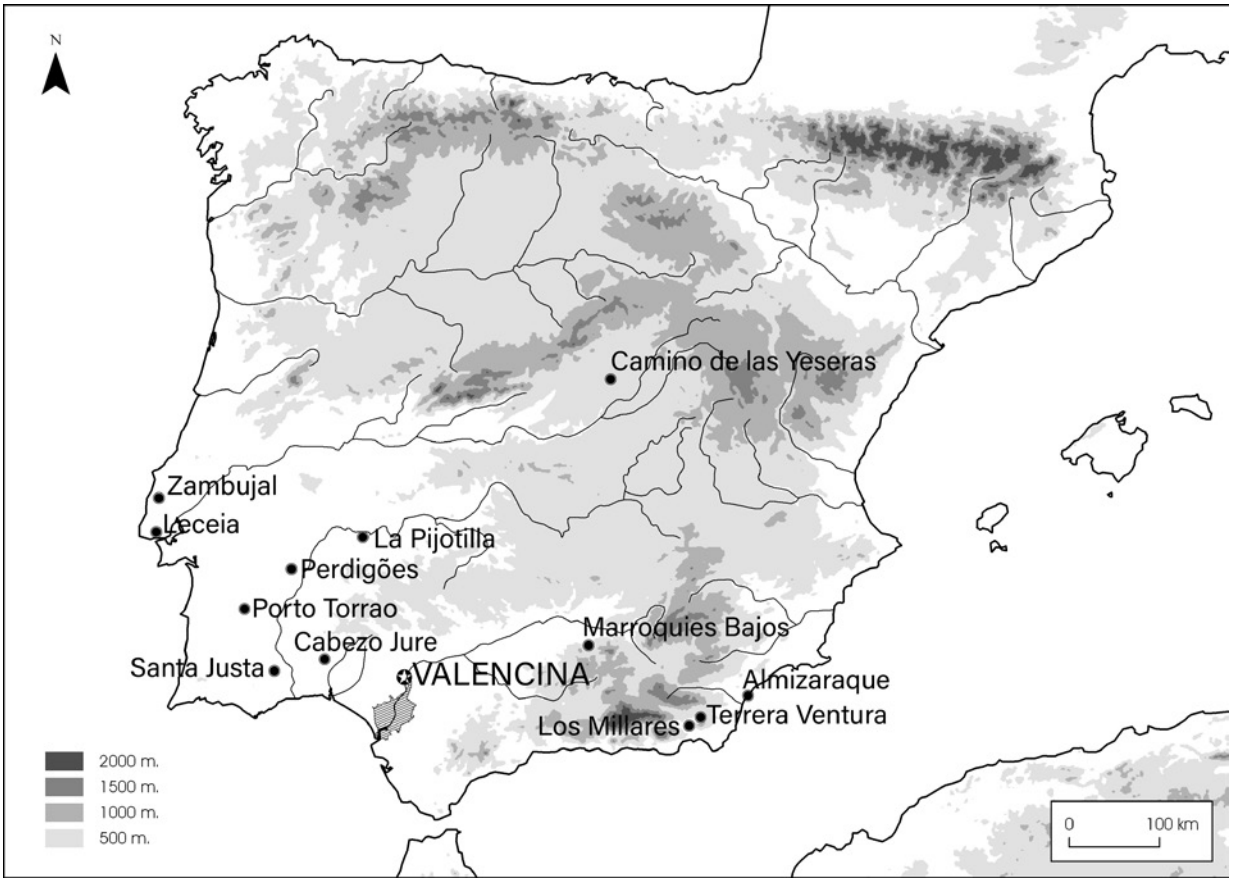


Fig. 1. Location of Valencina de la Concepción and other Chalcolithic sites showing the approximate coastline (lake area) in the 3rd millennium BCE.

cianez-Triviño *et al.,* 2014; García Sanjuán *et al.,* 2016; Luciañez-Triviño and García Sanjuán, 2016; Morgado Rodríguez *et al.,* 2016; Murillo-Barroso, 2016a, 2016b). For a historiographic synthesis see *e. g.* García Sanjuán (2013) and García Sanjuán *et al.* (2018a). Some papers regarding typology, contexts, or raw material characterization of Valencina's ivories have been published (*e. g.* Schuhmacher, 2012; Vargas Jiménez *et al.,* 2012; García Sanjuán *et al.,* 2013; Nocete Calvo *et al.,* 2013; Schuhmacher *et al.,* 2013a; Luciañez-Triviño *et al.,* 2014; Luciañez-Triviño and García Sanjuán, 2016; García Sanjuán *et al.,* 2018a). Very little, however, is yet known about technology's specifics.

A total of 8.8 kg of ivory has been found at Valencina. To date, it represents the largest published ivory assemblage in the Iberian Peninsula and Europe for this period. The ivories were recovered from 12 Chalcolithic structures coming from eight sectors of the site (for a description of the archaeological contexts see Luciañez-Triviño *et al.,* 2021). Ivory accounts for 65% of the whole osseous industry in the structures where ivory is present, followed by objects made from animal bone (21%). With only a few exceptions, the ivory generally appears in large burial monuments (mainly *tholoi*).

2. MATERIAL AND METHODS

The ivory material was found in a very poor state of preservation so the assemblage was highly fragmented. This circumstance imposes limits on the study, making it difficult to get a true picture of the number of analytical categories that actually would have been present. However, previous restoration work on several of the artefacts permitted a more realistic picture and also allowed observation of the technological traces hidden by dirt, sediment, etc.

In order to identify the raw material, the entire ivory assemblage was carefully examined with a stereomicroscope Nikon SMZ800 (up to 126X), and a digital microscope ShuttlePix P-400R (up to 400X). In order to discriminate between raw materials and to identify the artefacts made from ivory, these observations were compared with our own reference collection and with the structural characteristics of different raw materials based on what is available in the scholarly literature (*e. g.* MacGregor, 1985; Krzyszkowska, 1990; Espinoza and Mann, 1991, 1993, 1999; Haynes, 1991; Deschler-Erb, 1998; Christensen, 1999; Feldhamer *et al.,* 1999; Kardong, 1999; Ábelová, 2008; Locke, 2008; Rijkelijkhuizen, 2008; Virág, 2012; Choyke and O'Connor,

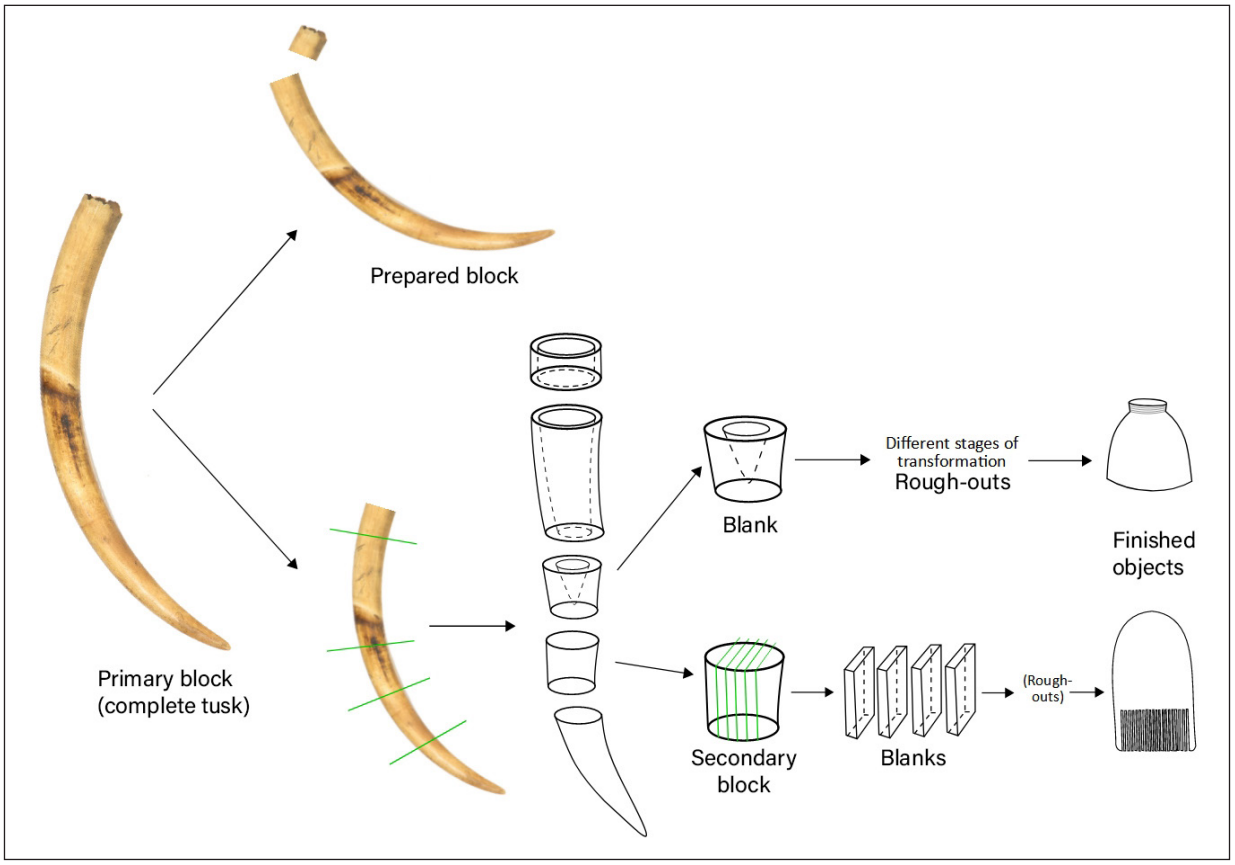


Fig. 2. Categories of analysis of ivory work. Drawings and photos by the author.

2013; Tolksdorf *et al.,* 2015). Additionally, for a better understanding of the observed tool traces, some focussed experiments were carried out. The specific characteristic of the proboscidean ivory and its cracking patterns were studied in depth in order to infer the relative position of the object within the tusk as well as the production modes.

The material was catalogued according to five categories of analysis*:* blocks, blanks, pre-forms/rough-outs, *debris*/production waste, and finished objects/end products. The definition of the categories of analysis (Fig. 2) are as follows (some definitions and categories were adapted from the work of A. Averbouh, 2001): a primary block is the complete anatomical support, that is, the complete tusk. A secondary block (a, more or less, large segment of the initial block) or a prepared block (a primary block where the unwanted or useless parts have been removed) can be extracted from the primary block. Blanks/supports are elements displaying little manipulation or transformation. They derive from the *debitage* and are obtained from primary or secondary blocks. These items are produced with the direct and specific intention of manufacturing a particular object. The *pre-forms/*rough-outs occupy an intermediate position between the support and the finished object. They have been more intensively manipulated, and already contain an approximation of the morphology of the final object. The *debris/*production waste comes from all the stages in the ivory working. Their production was not intentional but resulted from the transformation operations and includes chips, flakes, and fragments. The description of the surface technical traces and general vocabulary for technology is based on Averbouh and Provenzano (1998-1999) and the *Multilingual Lexicon of Bone Industries* (Averbouh, 2010). Cataloguing and definitions of finished objects and decorations are based on Luciañez-Triviño[4] and Luciañez-Triviño *et al.* (2021).

A total of 242 items were studied. Within the assemblage, there are Blocks (N = 6), Pre-forms/Rough-outs (N = 1), *Debris*/production wastes (N = 14), and Finished objects/End products (N = 175) (Table 1). Possible unintentional errors or omissions during excavation must be considered when identifying and recovering small fragments, such as chips. Besides, the excavation report is not specific about the structures whose contents were sieved[5]. Consequently, these numbers may not correspond to the totality of the material culture

[4] Vide note 1.

[5] J. Peinado Cucarella. *Memoria Arqueológica del Plan Parcial Sector PP4 "Dolmen de Montelirio" en el término municipal de Castilleja de Guzmán (Sevilla).* Junta de Andalucía, Consejería de Cultura. Sevilla. Unpublished, 2008.

	Transversal	Possibly transversal	Longitudinal	Possibly longitudinal	Undetermined	Total
Waste	7	0	4	0	3	14
Block	6	0	0	0	0	6
Blank	0	0	0	0	0	0
Rough-out	0	0	1	0	0	1
Finish object	26	2	90	31	26	175
Undetermined	3	4	1	0	38	46
Total	42	6	96	31	67	242

Table 1. Categories of analysis by type of tusk exploitation.

that may have been present. There are a huge variety of finished objects such as Receivers (rectangular boxes, containers with cylindrical mouths, curved/oval based vessels, cornucopia-like objects, handles, hilts, and "others"); Perforated objects (rings, bracelets, perforated discs, and beads); Toothed elements (combs and ornamental combs); Figures (human, animal, vegetal figurines or other shapes) and Plates (see Luciañez-Triviño *et al.,* 2021).

In order to understand the methods of exploitation, it was necessary to develop an in-depth knowledge of the characteristics of the ivory that could be observed on the artefacts. Therefore, part of the research focused on identifying the features of the ivory that can be observed by the naked eye or at low magnifications. The most relevant characteristics observable in each of the cuts or views are described in the following paragraphs.

3. IVORY MACRO-IDENTIFICATION: STRUCTURE AND FEATURES

Some vertebrate teeth have been enlarged or lengthened in response to very different evolutionary processes into what are commonly called "tusks." Such is the case of extant proboscideans and their extinct relatives. Elephant tusks are the second continuously growing maxillary or upper incisors (I2) (Feldhamer *et al.,* 1999, p. 314; Virág, 2012, p. 1406). Proboscidean ivory has a complex architecture characterized by successive steps or stages of organization (Locke, 2008). This issue has been addressed by multiple scholars resulting in a variety of proposed growth models (*e. g.,* Miles and White, 1960; Raubenheimer *et al.,* 1990; Raubenheimer *et al.,* 1998; Espinoza and Mann, 1999; Su and Cui, 1999; Palombo and Villa, 2001; Nalla *et al.,* 2003; Trapani and Fisher, 2003; Ábelová, 2008; Locke, 2008; Virág, 2012; Albéric, 2014).

The physical structure of the elephant tusk, described from the inside out comprises: the pulp cavity, dentin, cementum and enamel (for a better understanding of the anatomy of this tooth consult: Virág, 2012, fig. 1). The cross-section of the tusk is round or oval. For the most part, it is composed of dentin, covered by a layer of cementum, which can be very thick and have a laminar appearance in the case of extinct genera (Espinoza and Mann, 1991). At the tip, there is a conical enamel layer, which, however, is worn away during the life of the animal (Haynes, 1991). Consequently, it is not usually found in archaeological material, let alone in very elaborate artefacts. Elephant ivory has an advantage over other raw materials because of the amount of material it provides (dentine constitutes 95% of the tusk), especially in tusks from older animals. The proboscidean tusk is a continuously growing tooth, so the older the animal, the more raw material the tusk provides. Dentine is a mineralized connective tissue with an organic matrix of collagen proteins (Roylance, 2000-2001). It is a very durable material because the collagen fibres reinforce the inorganic matrix and give it elasticity (Virág, 2012, p. 1406), while the inorganic part gives ivory strength and rigidity, and its laminar configuration and tubule arrangement make it resistant to flexion (Locke, 2008, p. 447).

Here, four cuts or views of ivory with specific characteristics have been identified to aid in a first taxonomic identification and for the technological study: 1) Transverse plane/cross-section; 2) Natural tangential plane; 3) Artificial tangential plane; and 4) Radial plane.

3.1. Transverse plane / Cross-section

One of the most important patterns used to recognize proboscidean ivory can be found in the cross-section: the so-called "Schreger Pattern", also known in the literature as "Schreger Lines" or "Schreger Structure" (Schreger, 1800; Espinoza and Mann, 1991, 1993; Virág, 2012). It is described as two sets of alternating light and dark traces/lines which begin at the centre of the tusk and curve towards its periphery. One set curves clockwise and the other counterclockwise, crossing each other and creating rhomboid-shaped areas between them (Virág, 2012, pp. 1408-1410). In addition, alternating light and dark concentric bands display a system similar to the annual rings of deciduous trees. These bands are a result of the way the dentine

is deposited (in conical layers). These bands represent weak zones in the tusk, and are responsible for its separation into concentric cones, which are often visible as concentric cracks (Fig. 3) (Krzyszkowska, 1990; Virág, 2012, pp. 1408-1411).

When the natural cross-section surface breaks, this Schreger pattern emerges as a "bulky" surface with small elevations and depressions (Fig. 4a). Two characteristic patterns could be observed in the transverse profile of a very altered ivory: (1) a column-like crack-pattern (cracked) (Fig. 4b and 4c) or (2) a crack-pattern of intertwined filaments (Fig. 3b).

The intersections of the aforementioned lines form concave or convex angles (also known as "Schreger angles", Virág, 2012, p. 1415). These angles differ between the different proboscidean taxa (Espinoza and Mann, 1999; Locke, 2008, p. 433). Therefore, the measurement of these angles is used to discriminate between extinct and present-day species, with sharper angles in extinct species such as mammoth, compared to ivory from modern elephants (Espinoza and Mann, 1991, 1993, 1999; Palombo and Villa, 2001; Trapani and Fisher, 2003; Ábelová, 2008). This distinction has its limitations. On the one hand, it cannot be used for small or highly modified archaeological pieces, because it is not possible to know what angles are being measured (internal or external). On the other hand, although some scholars disagree (Nocete Calvo *et al.,* 2013, p. 1583), the measurement is not valid to differentiate between African and Asian elephants for several reasons. Firstly, Schreger's lines and angles are more evident near the dentine-cementum area and less clear near the pulp cavity (Espinoza *et al.,* 1990), making only external angles useful in principle (Espinoza and Mann, 1991, 1999). Thus, using these angles is of limited use or even impossible on archaeological artefacts (which have been heavily manipulated and modified). Secondly, the net of Schreger's lines may change during ontogenetic growth, so that sections of the same tusk can look quite different (Palombo and Villa, 2001, p. 657). Thirdly, despite the increased likelihood of finding more acute angles in extinct species, there is an overlap of between ~117-132° between *Elephas antiquus* compared to African and Asian elephants while a full overlap exists between *Loxodonta africana* and *Elephas maximus* (see Palombo and Villa, 2001, p. 659, fig. 3).

Fig. 3. Valencina de la Concepción. A. Montelirio tholos. Concentric cracks in an ivory mouth for a vessel; B. Matarrubilla tholos. Crack-pattern of intertwined filaments in a very altered ivory segment. Photos by the author.

3.2. Natural tangential plane

The natural tangential plane/profile is defined here as the plane which coincides with the separation of the growth cones. On the one hand, the innermost surface of the cementum in contact with the dentine (Cementum-dentine junction = CDJ) is rough, with elevations and depressions, so that occasional cement inclusions can be found in the outermost area of the tusk. On the other hand, the appearance of fine dark and light parallel lines is characteristic, formed by subtle grooves and parallel elevations between them, running along the longitudinal axis of the tusk (tip to basis) (Fig. 5a-c). However, not all proboscidean tusks display this characteristic as this feature can be very subtle (Virág, 2012, pp. 1412-1413).

The so-called feather-pattern is also typical of this section (Locke, 2008). This feature resembles inverted "U"s or "V"s (Locke, 2008, p. 437, fig. 15; Virág, 2012, p. 1413, fig. 6). The pattern was identified in thin sections or on the stained natural crack surface (Locke, 2008; Virág, 2012). However, we have verified that it is visible without preparation or magnification like a particular crack pattern in degraded archaeological material that was termed here: the feather-like crack pattern (Fig. 5d).

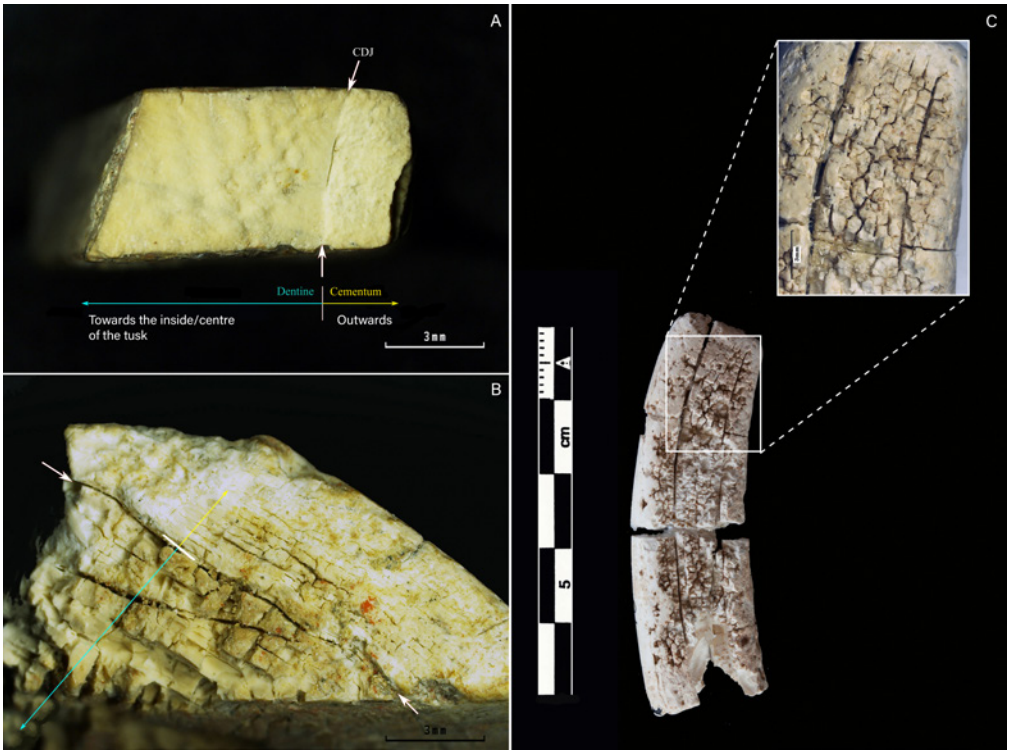


Fig. 4. Valencina de la Concepción. Transverse profile in archaeological material. A. 10.042-10.049 tholos: "bulky" surface with small elevations and depressions characteristic of natural fracture; B. Matarrubilla tholos: column-like crack-pattern (cracked) in dentine and cementum delamination; C. Matarrubilla tholos: Column-like crack-pattern (cracked) in a small ivory handle. Photos by the author.

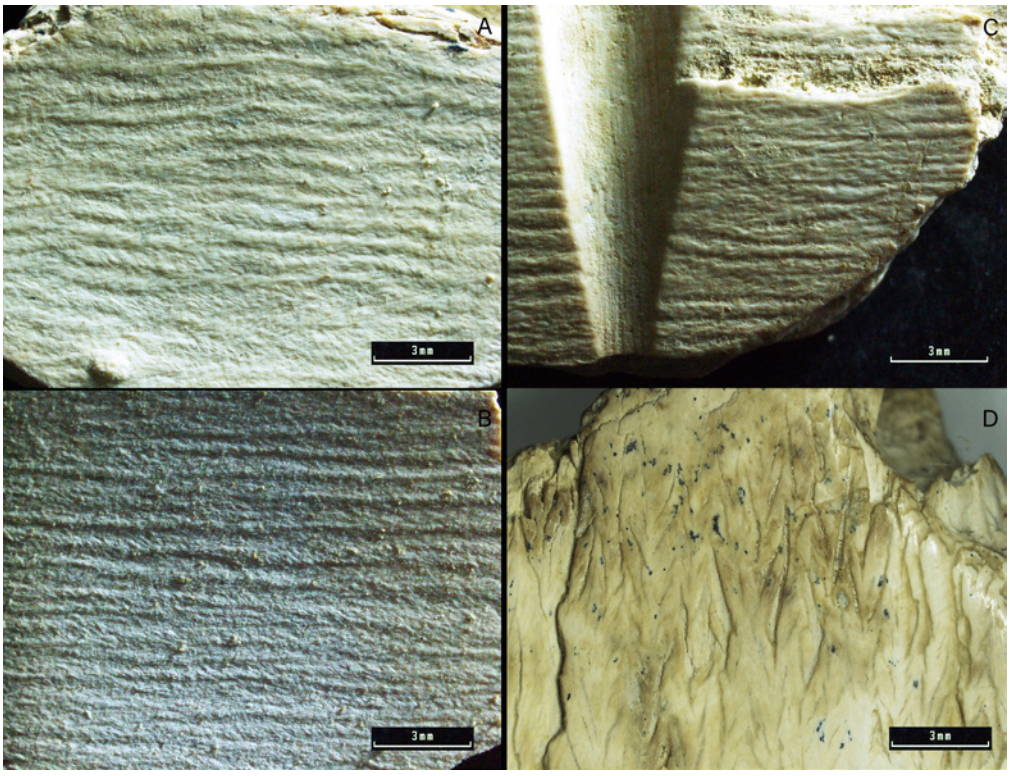


Fig. 5. Valencina de la Concepción: A-C. Separation plane of two dentine cones. See the dark and light parallel lines formed by subtle grooves and parallel elevations between them; D. Feather-like crack pattern. Photos by the author.

3.3. Artificial tangential plane

An artificial tangential profile is defined here as one produced when the tusk is cut parallel to its longitudinal axis, that is, the growth cones are tangentially cut, the result of clear anthropic manipulation. The axial cut represents a special tangential cut (one that passes right through the centre of the tusk). Light and dark parallel lines can be observed in the artificial tangential plane and are associated with straight fissures or cracks with the same arrangement. This crack pattern corresponds to the longitudinal view of the growth cones. In addition, darker and lighter, slightly translucent wavy lines can be observed, indicative of various adjacent cones (Fig. 6). The same features can be observed on a radial cut although, with a natural radial fracture, radially oriented sinuous curves could be observed, in parallel between them (from the cavity wall towards the periphery). These curving lines may be associated with a mineral discoloration of the material (Virág, 2012, pp. 1411-1412). Table 2 summarizes the main characteristics and crack-patterns of proboscidean ivory in each of the aforementioned sections or cuts.

4. RESULTS

4.1. Techniques and tools

Scraping, abrading, polishing. These techniques were mainly used in the surface preparation and finishing of most objects, in many cases interspersing scraping and coarse abrasion with chiselling. Polishing, or fine-grained abrasion, was implemented for a final finishing process. Scraping has been identified on the inner side of several, mainly cylindrical, objects. After an initial hollowing out, the internal shape of the pieces was reduced by the progressive removal of material with a lithic or metal tool.

Chiselling was used to shape the pieces or in procedures of thinning the blank, for hollowing or shaping the form as well. For this purpose, tools with an active, slightly convex cutting edge, were used.

An incision was used to mark the area of the decorations or to produce the decorations themselves. Many of the incisions are shallow and have straight, parallel walls. Due to their regular and straight shape, they may have been made with a knife, not necessarily serrated, made from metal, or with a punch.

Fig. 6. Valencina de la Concepción. Montelirio tholos. Front and back of an object manufactured on plate. Note the multiple straight and parallel fissures characteristic of the separation of the dentine layers and dark and light, slightly translucent wavy lines, indicative of several tangentially cut cones. Photos by the author.

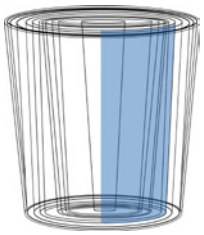
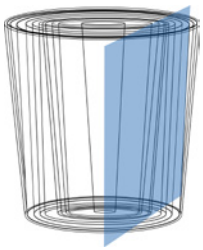
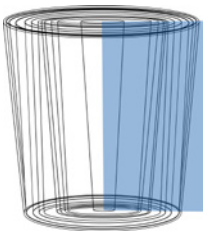
Transverse /Cross section	**Natural tangential**	**Artificial tangential**	**Radial**
			
Schreger structure: In polished section: lines cutting into each other forming tiny diamond-shaped areas. If naturally broken: "bulky" surface with small elevations and depressions If very poorly preserved: intertwined filaments crack-pattern Growth rings: Light and dark concentric bands Concentric cracks Other characteristics: Radial cracks Column-like crack-pattern (cracked) Occasional cementum inclusions in the outermost zone	Feather crack pattern Subtle grooves and parallel longitudinal elevations Occasional cementum inclusions in the outermost zone	Growth rings: Dark and light almost parallel longitudinal lines Straight longitudinal cracks or fissures	Growth rings: Dark and light almost parallel longitudinal lines Straight longitudinal cracks or fissures Other characteristics: If naturally broken: radial sinuous curves with occasional association of colour change.

Table 2. Synthesis of the observable cracks/features in each cut/section of a proboscidean tusk. Drawings by the author

Grooving was also a technique used to separate, not-very-thick, fragments of different sizes. The traces indicate that a lithic tool like a burin was used.

Sawing. This technique was used in both longitudinal and transversal actions. The traces identified so far, seem to indicate, on the one hand, the use of metal tools, and on the other hand, the clearly visible signs of abrasive sawing (see definition and characteristics below). However, the use of lithic tools cannot be ruled out since it has been demonstrated that flint, for example, is perfectly efficient for working ivory (*e. g*., Hein, 2011, 2014). The author herself demonstrated experimentally that flint tools can be used to work ivory. Examples of metal saws have been found in Valencina itself and many other Chalcolithic settlements in the region. Nonetheless, our experimentation with copper-based saws (forthcoming) has documented the low penetration efficiency of these tools, especially when working very thick pieces (such as when the complete tusk is segmented).

4.1.1. A unique case of "sciage au fil sablé" or abrasive sawing in the Iberian Prehistory

The only documented case so far found on the Iberian Peninsula of sawing with a sandy cord was documented during this research. This term in French could be translated into Spanish as *aserrado por abrasión (con cuerda)* and as "abrasive sawing (with cord)" in English. The determining stigmata used to identify this technique were developed by Poplin (1974) (Fig. 7):

– Sawing groove with parallel walls, non V-section.

– A very regular, wavy sawing plane. These undulations are marked by slight lateral displacements in the sawing "path" during the action created when the cord lacks a fixed path and is not as guided in the way the serrated edge of a saw would be. Once properly engaged, a saw can move only within its own plane.

– Striations are observed running parallel to the undulations. The striations are produced by the abrasive grains.

– Since this is an abrasive action, the characteristic sawing traces are blurred. The ripples referred to above and associated fine grooves and striations are not very evident and have more rounded cusps connected to the continuous abrasion.

– Both the undulations and the striations have a concave-convex shape, following the circular contour of the elephant's tusk, to which the tool (a cord) adapts. The manufacturing traces are practically concentric where segmentation was attempted, showing that the movement with the cord was rotary, impacting the surface of the ivory from different angles, as either the cord or the tusk was turned.

Fig. 7. Valencina de la Concepción. 10.042-10.049 tholos. View of the basis of a cylindrical vessel. On the one hand, the separation of the growth cones (concentric cracks) can be observed; on the other hand, a very smooth and regular sawing plane and concentric undulations can be observed. See the circular pedicle in the centre of the surface. Photos by the author.

– Some traces of straight striations can be observed, produced by the rubbing of the cord at the point it leaves the groove.

– A circular pedicle (or small, round, wart-like protuberance) can be observed located almost at the centre of the worked surface. This indicates not only that the movement of the action was rotating, but also that the final separation was completed by bending. This small protuberance is the remainder of the part that remained attached after sawing with the cord, and which was separated when this small bridge was broken off. This small 'tongue-shaped' material was generated by bending, then slightly regularised by abrasion but not completely removed.

This technique has been identified in other European contexts dating back to Neolithic times. R. Bosch (1939) described it on material from the excavations at Seematte (ca. 4000 BC- Nielsen, 2016, p. 155). Pétrequin (1970) identifies it on a deer antler specimen from the Xb level at Gonvillars (4500–3900 cal BC, 1 σ – Denaire, 2009, p. 671, table 1) and it was later described again on a deer antler from Neolithic materials coming from the French-Swiss border (Billamboz, 1977). In addition, F. Poplin (1974) describes this same technique on a hippopotamus ivory specimen from the Egyptian Predynastic (3731-3238 cal BC (95%), Dee *et al*., 2013).

4.2. Exploitation modes and derived blanks

There were two modes of action seen on the raw material in relation to the longitudinal axis of the block (the longitudinal axis is understood as the distance between the tip of the tusk to the base). The first is transversal exploitation (an action that is perpendicular to the longitudinal axis) and the second is longitudinal exploitation (an action that is parallel to the longitudinal axis). Since no blanks have been found as such within the study material, the types of blanks were inferred theoretically by observing the shape of the object and its relative position within the tusk in light of the structural peculiarities of the ivory as described in preceding paragraphs.

Transversal exploitation (Fig. 8a) was carried out using a variety of procedures, namely abrasive sawing with a cord and bending as well as possibly by percussion using a cutting tool (axe). All segments obtained by this method of exploitation are cylindrical, or semi-cylindrical. They have in common two oval bases (sawing or percussion planes) and a curved lateral surface coinciding with the external surface of the tusk. The distance between the bases marks the height of the blank. In that way, the ancient craftspeople exploited hollow and compact areas to produce a variety of supports and objects.

Different types of hollow blanks can be obtained from the area of the pulp cavity:

a) Annular blanks: blanks with two opposing, open, circular bases and closed curved walls that are hollow inside and whose wall thickness varies depending on the area of the tusk from which it was extracted. The height of the blank depends on the type of object to be manufactured although it must be less than 2.5/3cm;

b) Tubular blanks: These supports also have closed curved walls, are cylindrical in shape, and open at both opposing ends or bases. This type of segment can have a height of more than 3 cm.

The compact part of the tusk extends from the end of the pulp cavity toward the tip. If this tusk section is exploited it is possible to obtain massive, large-volume blanks.

The following kind of support has been identified as coming from this part of the tusk:

c) Slice: compact flat blanks with two ovoid bases that are less than 2.5/3cm high. Within the material so far studied, the slice fragments are less than 1cm high;

d) Cylindrical blanks: These solid supports have a more or less cylindrical shape with heights of more than 3 cm;

e) Compact natural blanks: These supports are produced from the distal end of the tusk, including the tip of the tusk, thus preserving the natural shape of the tooth.

In addition, the mixed zone of the tooth, where the transition from the pulp cavity to the solid part of the tusk is located, could be very cleverly exploited. It is possible to obtain supports with one open and one closed base from this intermediate area producing blanks of type:

f) Open cylinder blanks: These supports have one of their bases open, coinciding with the pulp cavity while the opposite end is closed, and

g) Open natural blanks: These supports are manufactured from the pulp cavity as well and include part

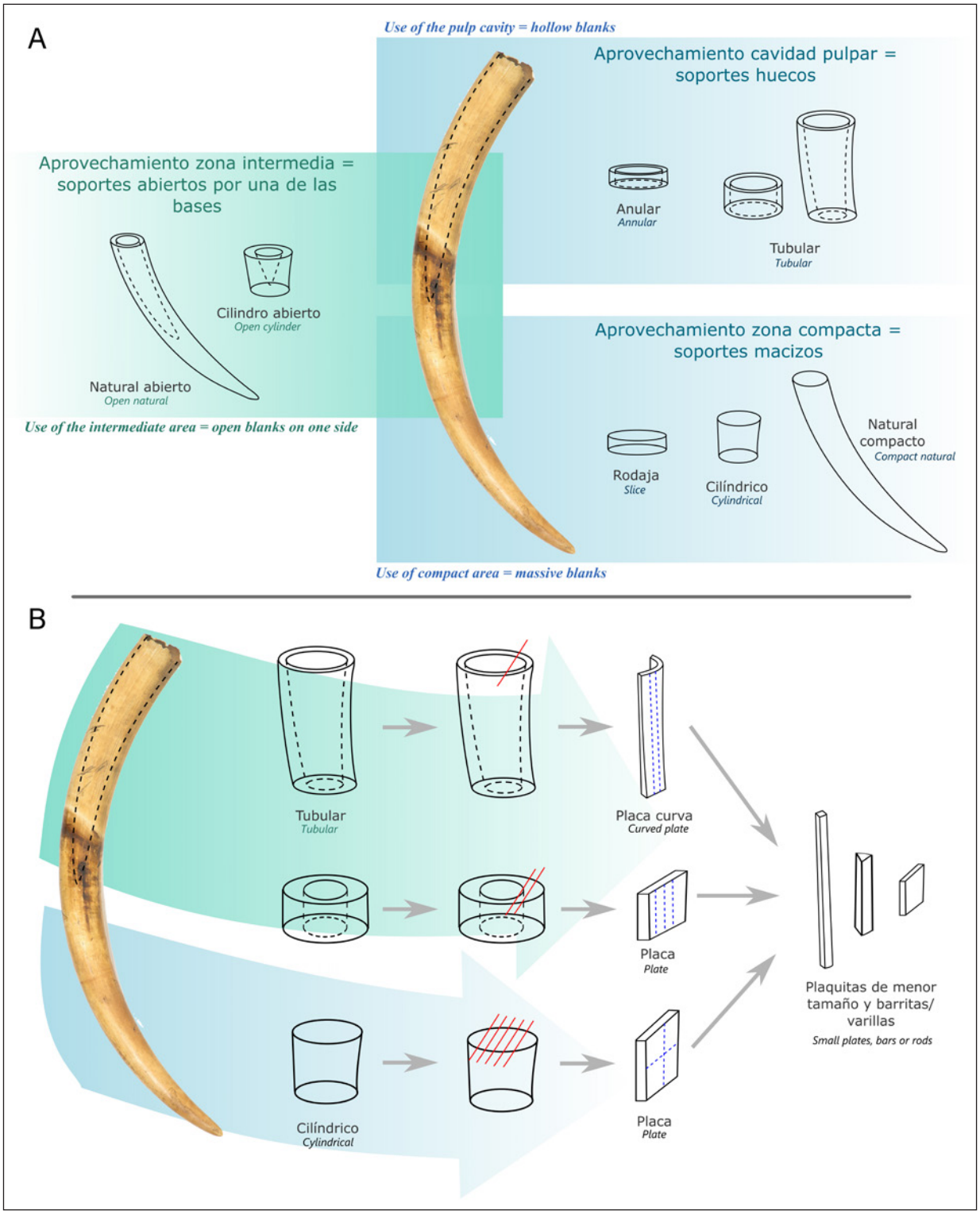


Fig. 8. Elephant tusk exploitation modes and derived blanks: A. Transverse exploitation; B. Longitudinal exploitation. Drawings and photos by the author.

of distal end, including the tip, thus, preserving the natural shape of the tusk.

Longitudinal exploitation (Fig. 8b) is produced from a first segment obtained by transversal exploitation (terminological synonyms include *tronçonnage* or segmentation). The intention was to obtain, in most cases, a flat blank of a certain size (plate), or elongated and narrow supports. Rectangular plates can be obtained from transversal blanks by making parallel "cuts", tangential to the growth cones, or by breaking off a section. In the case of compact cylindrical support, this kind of extraction permits a greater number of plates to be obtained. It is also possible to obtain thin curved blanks (or curved plates) from tubes produced from the proximal area of the tusk.

Longitudinal exploitation provides the following types of blanks:

h) Plate: These supports are much thinner in relation to their length and width dimensions. The lower and upper surfaces coincide with the longitudinal sawing planes and the distal and proximal edges with those produced by the *segmentation*. The left and right edges coincide with the outer wall of the tusk (and as found in some objects also include the cementum);

i) Curved plate: These supports are thin and concave-convex. The concave face coincides with the wall of the pulp cavity and the convex face with the external surface of the tusk. The distal and proximal edges are formed by the cutting planes produced by segmentation, and the left and right edges coincide with the outer wall of the tusk (including the cementum). Third-generation longitudinal supports are represented by:

j) Bars or rods (of varying cross-sections depending on the orientation of the cuts) and

k) Small plates obtained by multi-partitioning a plate.

Of the pieces in the studied ensemble, 48 items were obtained using the transversal mode while 127 were obtained longitudinally (Table 1).

Of the few 14 production waste pieces identified from the site, 7 are remains of transversal actions and come from the adjacent sectors IES and DIA (for a description of the contexts, we refer the reader to Luciañez-Triviño *et al.,* 2021). These remains correspond to fragments of indeterminate shape (N = 3), small fragments of slices less than 8mm thick (N = 3), as well as a portion of a larger slice that corresponds to almost 1/4 of a slice (16mm on its thickest side). The following artefacts (N = 26) were obtained by segmentation: small diameter rings, bracelets, rectangular boxes, cylinders, oval-based vessels, a cornucopia or musical instrument, and a possible handle, as well as other fragments of unidentifiable objects. Therefore, most of the studied assemblage was obtained by longitudinal mode. The longitudinal manufacturing waste corresponds to fragments or segments of geometric shapes, mainly elongated prisms, all coming from the archaeological structures of IES and DIA sectors. A wide range of objects was produced on longitudinal supports: plates (decorated or undecorated), with or without perforations; lids of composite objects, all the combs, all the discs with central perforations, a spiral, all acorn figurines (except one), all zoomorphic figurines, all barrel vault beads and square beads, as well as a large handle.

5. DISCUSSION AND CONCLUSIONS

The characteristics set out in this paper are observable both in fresh or well-preserved ivory, as well as in archaeological or deteriorated ivory. In the case of the latter, as we outlined, these pieces develop crack patterns that reveal the underlying, specific structure of the ivory as raw material. Knowledge and recognition of these characteristics and structures are essential in order to recognise the ways ivory was worked and how the blanks were extracted from the tusk. Observing these details in archaeological artefacts and particularly in the finished objects themselves, helps to identify the position, at least the relative position, of the blank (and the object) and where it was taken out from the tusk. In short, both the characteristics described above and the proposed methodology and vocabulary can be applied to any material, regardless of the period. The use of this methodology could facilitate knowledge of ivory craftsmanship generally and allow assemblages to be compared.

The traces still preserved on the artefacts and the production waste enabled the reconstruction of part of the sequence of ivory working in the third millennium BC in the Iberian Peninsula. The tool kit used by the craftspeople was much more extensive than has been generally thought. The ivory processing involved metal and lithic tools, various abrasives, cords (possibly made of plant matter), as well as probably many other supporting materials made of wood, such as workbenches, grips, etc. The use of abrasive sawing dates to approx. 4000-3200 BC, as the evidence described indicates, including this study. The objects with abrasive sawing marks on them come from structure 10.042-10.049, whose first use dates back to around 3725 cal BC (García Sanjuán *et al.,* 2018a). The use of this technique could be traced back to the inefficiency of copper-based saws from the Chalcolithic period, at least as far as the material culture of the Iberian Peninsula is concerned. This inefficiency would have led to the search for a more efficient method of working on osseous materials. The author demonstrated experimentally that the model based on the Valencina-type saws that were used was not able to penetrate the ivory. On the contrary, experimentation with abrasives and cords proved to be a very effective segmentation method[6].

All parts of the tusk can be exploited in such a way as to maximise its productivity and therefore the final object to be manufactured determined the part of the tusk

[6] Details of the experimentation will be published soon.

that would be exploited. It can be concluded that there was standardised exploitation during the Chalcolithic period. The standardization was aimed at the manufacture of particular blanks, based on the knowledge and use of the different tusk parts (hollow and compact) in a differential and specific way. Thus, the proximal part of the tusk was specifically used for the manufacture of objects that required a hollow internal area while the distal area of the tusk toward the tip was used for the manufacture of solid and round objects and plates.

The transversal mode was the first kind of exploitation with the aim of segmenting the tusks and obtaining, more or less, thick, compact, or hollow portions. Sometimes segmentation was carried out to facilitate the handling of the tusk (which can be very heavy and large) and in other cases to obtain secondary blocks to produce supports from which vessels, cylindrical boxes, or rectangular boxes were made.

The longitudinal method of exploitation is clearly independent of the first transverse mode, even though it is necessary for the first instance to obtain segments of ivory by segmentation. Conceptually, what was sought after were flat rectangular supports to manufacture flat objects such as combs or plates, but also all kinds of beads or discs.

Among the pieces studied here, 52.5% were manufactured on longitudinal blanks. This proportion makes it appear that both modes of exploitation were used to the same extent, but this is an unrealistic picture when all the indeterminate pieces are counted (N = 67). If only those items whose mode has been clearly identified are considered (Transversal, N = 48; Longitudinal, N = 127; Total, N = 175) then a truer picture emerges: Altogether, 72.6% of the objects are manufactured on longitudinal plates, while 27.4% are produced from transversal blanks.

The data obtained clearly show that longitudinal mode was the preferred method, probably because it permitted the greatest number of objects to be obtained, even in the production of disc-shaped objects for which it would seem to be more convenient and obvious to use thin slices. The discs with central perforations found in Montelirio tholos were made this way (Fig. 9). They were manufactured from longitudinal plates and clearly not from slices. The discs appeared in the Large Chamber of Montelirio in even numbers (N=10) and are "paired" according to their size (see Table 3): four larger discs with very regular diameters of between 40 and 41.25 mm (in decreasing order of size: CG/328-61, CG/328-60, CG/328-60 and CG/327-1): CG/328-61, CG/328-60, MONT-DJ09/19-CG/337-1 and CG/328-138); two medium disks of ø32.8 and ø33.45mm (CG/337-2 and CG/337-3) and four small ones of diameters between 22.26 and 23.3 mm (in decreasing order: CG/318-104, CG/328-105, CG/318-102 and CG/318-103). Not all discs display traces of cementum, so they were not all produced from precisely the same area of the tusk. The study of the disc sizes, the absence or presence of cementum, its location, and

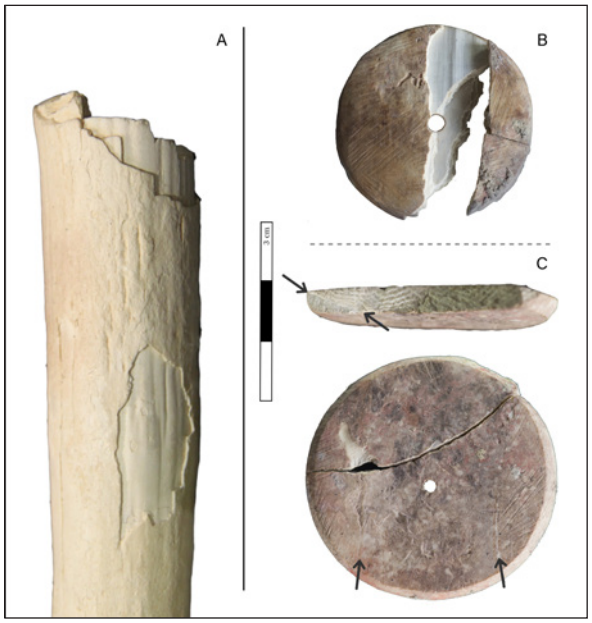


Fig. 9. A. San José de la Rinconada (Seville): Detail of a fragment of an *Elephas* (*Palaeoloxodon*) *antiquus* tusk from museum of San José de la Rinconada (Seville) with delamination of the growth layers; B. Montelirio: Reverse of disc 337-3: note the surface with straight and parallel undulations on the fracture surface. These undulations are characteristic of the separation of concentric layers near the periphery, similar to the specimen shown in A; C. Montelirio: Reverse of disc 328-61: the black arrows indicate the Cementum Dentine Junction (CDJ), evidenced by two opposing zones, with different colouring and texture than the central area where the dentine is located. The arrows in the transversal view also indicate CDJ, in addition, the Schreger structure can be seen in the dentine. 3 cm scale. Photos by the author.

extent permit reconstruction of the manufacturing sequence and propose with some reliability that, in this case, all 10 objects may have been efficiently extracted from the same segment of a tusk, that is, from a cylindrical blank, as an example of the high performance of the procedures and methods employed (Fig. 10).

This manner of working the material is several millennia ahead of what in prolific areas such as Anatolia would not be seen until the end of the Bronze Age. A similar level of exploitation can only be found in the eastern Mediterranean and from much more recent periods. For example, a set of decorative plaques from Tiglat-pileser II-I's palace (745-727 BC) at Ugarit, the modern city of Arslantaş (De Pietri, 2020) revealed a similar kind of production method. The plates, used to decorate some kind of furniture, possibly a bed, were extracted longitudinally, possibly from a single large tusk, or more likely, from a pair of tusks (Caubet and Poplin, 1987, fig. 16, p. 287). Nevertheless, similarly but in a different way, high-performance exploitation was also characteristic of hippopotamus ivory in the same area. In Syria and Anatolia, hippopotamus ivory, rather than elephant ivory, was the preferred raw material from the IV millennium BC and until the end of the Bronze Age, as evidenced by some objects com-

Invent. Num. (MONT-DJ09/19-)	Conservation	State	Weight (gr)	Thickness Average (mm)	Ø máx (mm)	Ø perfo (mm)
CG/337-1	Complete	Complete	7,72	6,41	40,07	3,91
CG/337-2	Complete	Complete	3,95	4,26	32,8	3,31
CG/337-3	Complete	Fragmentary	5,77	5,87	33,45	3,2
CG/318-103	Half disc	Fragmentary	0,53	3,18	22,26	3,09
CG/318-102	Almost complete	Fragmentary	1,49	3,7	23,1	2,29
CG/318-104	Half disc	Fragmentary	0,85	3,8	23,3	x
CG/328-60	Complete	Complete	6,68	3,8	40,25	3,37
CG/328-61	Complete	Fragmentary	7,78	4,92	41,25	2,67
CG/328-105	Half disc	Fragmentary	1,72	4,35	23,1	x
CG/328-138	Half disc	Fragmentary	4,42	4,05	40	3,82

Table 3. Data of discs with central perforation of the tholos of Montelirio (Valencina de la Concepción, Seville).

ing from IV and III millennium, high-status contexts (Schwartz *et al.,* 2003; Frangipane, 2004; Caubet, 2013, p. 450; De Pietri, 2020). Later, from contexts dating to around 1800 BC, craftspeople cleverly exploited the anatomic possibilities of the hippo tusks: the proximal area to produce plaques and the distal (solid) region for creating objects with three-dimensional volume. However, two major technical changes took place in ivory working during the Late Bronze period: 1) the number of artifacts made from ivory increased and 2) the use of elephant ivory was introduced on a large scale, although without replacing hippo ivory (Caubet, 2013, p. 451). In the Iberian Peninsula, however, from the III millennium BC, elephant ivory was the dominant material, with very occasional exploitation of other types of ivory (*e. g.*, sperm whale; Schuhmacher *et al.,* 2013b).

On the other hand, the question of the local or non-local production of objects is a recurrent debate among scholars. The main and general problem lies in linking (that is, whether the pieces belong to the same *chaîne opératoire*) the wastes in so-called workshops with the objects in the tombs, something which is often not possible, or has simply not been attempted. In the case in point, there are some indications that this ivory material

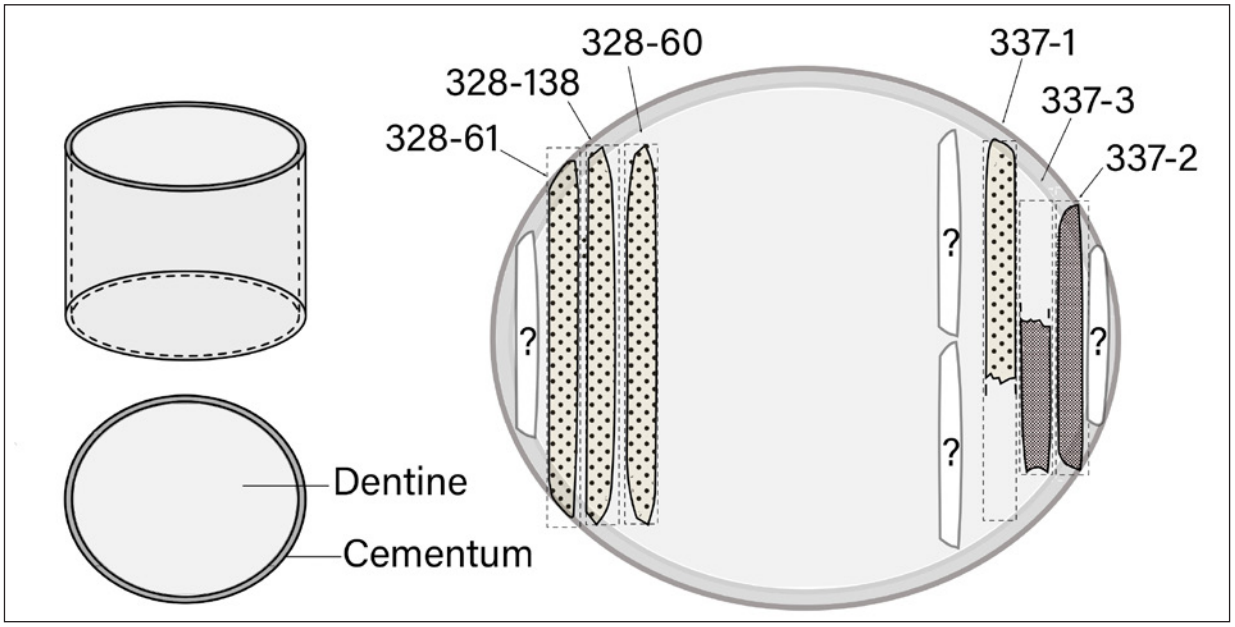


Fig. 10. Hypothetical reconstruction of the manufacture of the Montelirio discs. The inventory number of the discs that can be most reliably located within a segment are indicated. The four largest discs are shown in yellow with dotted background and the two medium-sized ones in shaded orange. The hypothetical positions of the four smaller discs whose position could not be located with any degree of certainty are shown in white with a question mark. Drawings by the author.

was worked locally but to what extent is yet unknown. In any case, local working of ivory could not have started before ±2800 cal BC. Two radiocarbon dates are available directly on two pieces of ivory waste from Structure 402 (IES Sector). Both fragments could derive from the same episode of ivory working dating back to 2855-2580 cal BC (2σ) (García Sanjuán *et al.,* 2018a). The activity in the tholos of Montelirio, dates to 2875-2635 cal BC (2σ), while the use of Structure 10.042 (the first section of structure 10.042-10.049) yielded an older dating of 3725-1840 cal BC (2σ) (García Sanjuán *et al.,* 2018a). The recurrent failure to date some sectors and structures containing ivory objects in Valencina (García Sanjuán *et al.,* 2013, 2018a) makes it difficult to get a clearer vision of the arrival, use, and consumption of ivory as well as the production of objects. Given the current data, a much more varied and fluid scenario should be considered. Before the 29th century BC this raw material, together with several finished or semi-finished objects and the know-how of how to manufacture it, could have come to Valencina from other areas in the Mediterranean. Subsequently, local craftspeople, or even foreign craftspeople established in the area, could have worked the imported ivory locally.

Much still needs to be learned about ivory craftsmanship in general and in particular around the Mediterranean because of a lack of technological studies. Missing information makes it impossible or very difficult to compare assemblages and therefore to observe the emergence, evolution, or change and the transfer of knowledge of this craft. Nevertheless, it can be said that from its beginnings, ivory working emerged as a specialised craft, with highly refined procedures, possibly based on previous manufacturing experience with working other materials such as wood and bone.

DECLARATION OF COMPETING INTEREST

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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