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First evidence of hippopotamus ivory exchange networks in north-eastern Iberian Peninsula: The object of Bòbila Madurell (Barcelona, Spain)

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ABSTRACT

This study examines a Late Neolithic-Chalcolithic ivory object (Véraza facies) found at the Bòbila Madurell settlement (Sant Quirze del Vallès, Barcelona, Spain). The main objective was to date the object and determine the provenance of the raw material. The radiocarbon analysis places it in the second quarter of the 3rd millennium BC. FTIR analysis identified it as hippopotamus ivory, marking the first and currently the oldest discovery in north-eastern Iberia. While most Iberian ivory is attributed to Asian or African proboscideans, hippopotamus ivory is known in southern Iberia during the Chalcolithic and Early Bronze Age, reflecting emerging trade networks from the Near East and Africa. Though the object is fractured, the archaeological context, together with morphological and residue analyses, suggests a possible use in textile work.

1. Introduction

The earliest evidence of ivory in the Iberian Peninsula dates to the Chalcolithic and Early Bronze Age. Over the last two decades, there has been growing recognition of ivory artefacts in this region, with the Iberian Peninsula pioneering scientific methods applied to ivory studies since the 2000 s (Banerjee et al., 2008). Many items made from elephant ivory (from both African and Asian species, neither native to the region) have been found in southern Iberian sites, dating to the Early Chalcolithic period. These discoveries have raised questions about the origins of the ivory, exchange networks, and the role of such objects in the increasing social complexity of the Chalcolithic Iberian Peninsula (García-Sanjuán et al., 2013; Luciañez-Triviño et al., 2022). While elephant ivory has been the primary focus of research, other sources of ivory, including sperm whales, fossil elephants, and hippopotamuses, have also been identified. Sperm whale and fossil ivory are generally considered opportunistic resources (Schuhmacher et al., 2013; Chapman, 1990), while the discovery of hippopotamus ivory is more rare but significant (Pau et al., 2018). African elephant ivory was traditionally thought to come from the Western Maghreb, where the species lived until Roman times, while Asian elephant ivory likely arrived from the Amuq and Orontes Valley in the Levant (Schuhmacher and Banerjee, 2012; Pfälzner, 2016; Schuhmacher, 2016, 2017; Morillo León et al., 2018). These sources suggest distinct trade networks in the Early Chalcolithic, with African elephant ivory found mainly at sites in Portugal and Extremadura, and Asian ivory more common in Andalusia (Schuhmacher, 2012a,b, 2016, 2017; Schuhmacher and Banerjee, 2012; Nocete et al., 2013). Fossil ivory from *Palaeoloxodon antiquus* has been identified in central and southern Iberia (Liesau and Blasco, 2011–2012; Liesau, 2016).

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In contrast, hippopotamus ivory has been found sporadically, excluding later colonial and Phoenician contexts (Banerjee et al., 2017). Notable examples include a trapezoidal pendant from Cerro de la Virgen in Granada, dated to before 2500–2450 cal BC, and V-perforated buttons from the same site, dating to the Bell Beaker and Early Bronze Age transition (Pau et al., 2018). Also associated with the Bell Beaker is the hippopotamus ivory button from the Convento do Carmo (Schuhmacher and Banerjee, 2019, in Carvalho, 2019). Processing remains of hippopotamus ivory have also been found at Illeta dels Banyets in Alicante, dating to the early 2nd millennium cal BC (Belmonte and López Padilla, 2006; Schuhmacher, 2012a,b).

In summary, the presence of ivory in Iberia was initially linked to the diffusion of Asian elephant ivory from the Near East, possibly the Syrian-Palestinian coast or Egypt (Schuhmacher et al., 2013). The movement of this material likely involved intermediary areas such as Early Minoan Crete (around 2200 cal BC), as suggested by the spread of Cretan tholoi or the remarkable similarities between anthropomorphic figures like the example in ivory from the Mitsotakis collection (Morillo León, 2019; 2021; Mederos Martín, 2020; Bilotti et al., 2024). Whether the communities were directly involved in such exchange or just affected by the technocultural flow is beyond the scope of this work.

In this study, a Late Neolithic–Chalcolithic (Véraza facies) ivory object found at the settlement of Bòbila Madurell (Sant Quirze del Vallès, Barcelona, Spain) is examined. The main objective was to date the object and determine the provenance of the raw material. Radiocarbon analysis places it in the second quarter of the 3rd millennium cal BC. This study also addresses key questions to better understand the object. It seeks to identify the raw material, determine its origin and date, analyze use-wear traces, and characterize the reddish surface residue. These findings help infer the object's function and discuss its broader significance within Late Prehistoric Iberian contexts.

The object, found on the floor of a hut, is fractured at one end, complicating its typological and functional classification. The Véraza group, which the item belongs, occupied regions between southern France and north-eastern Iberia, including Catalonia and parts of Huesca, and existed from around 3600/3500 to 2500 cal BC, before disappearing around 2100 cal BC (Martín et al., 2023). Their distinct ceramic typology included hemispherical bowls and large cylindrical storage vessels with plastic decorations. These societies, primarily agropastoral, managed livestock and agricultural lands and constructed communal structures, including collective burials in caves and dolmens (Martín and Ávila, 2023).

2. The site of Bòbila Madurell and the structure 3BM/4.2

The Bòbila Madurell site, located 20 km from the Barcelona coast, spans approximately 28 ha in a pre-coastal depression (Fig. 1). Along with the nearby Can Gambús site, it houses one of Europe's largest Middle Neolithic funerary complexes, dated between 4210 and 3670 cal BC (Martín et al., 2017; Díaz-Zorita et al., 2021). The Bòbila Madurell-Can Gambús area was occupied from the Early Neolithic to Late Antiquity, with Late Neolithic to pre-Bell Beaker Chalcolithic structures mainly associated with storage and residential functions, reflecting stable land use. These are concentrated in the Can Feu sector (CF), where the ivory object was found in structure 3BM/4.2 (Fig. 1). Additional features include a deep ovoid pit (BM4.3) and five pits from the 3rd millennium BC. In the Mas Duran sector (MD), semi-subterranean huts (C1, C11) and nine silo pits, also dated to the 3rd millennium BC, were uncovered (Bordas et al., 1994; Díaz et al., 1995; Plasencia, 2016). At Can Gambús-1, 53 structures, including ovens and silos, were documented (Roig and Coll, 2007, 2016), with radiocarbon dating indicating a late 4th millennium BC origin (Martín et al., 2023).

Faunal analysis from hut 3BM/4.2 and silo BM4.3 points to an agropastoral economy focused on cattle, goats, pigs, and cereal cultivation, supplemented by wild resources, similar to findings at Mas Duran (Plasencia, 2016). The presence of silos and residential structures

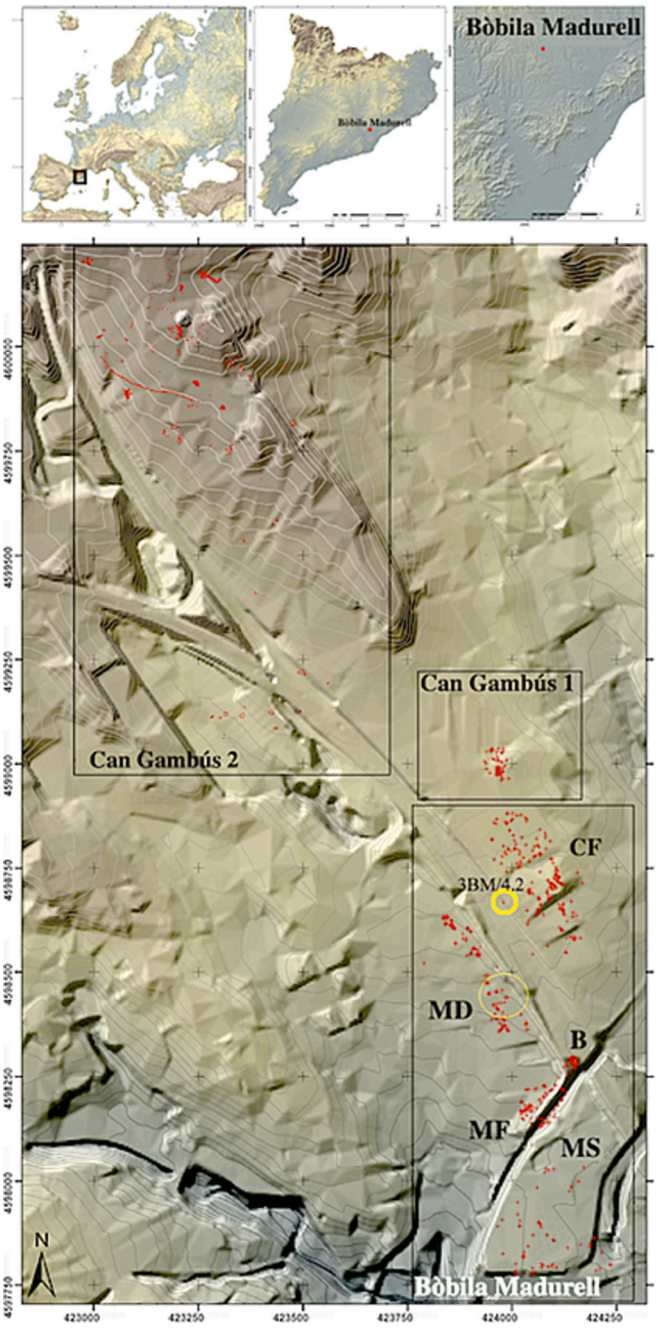

Fig. 1. Structures from the Middle Neolithic to the Late Antiquity in the archaeological area. Bòbila Madurell sectors (CF: Can Feu, MD: Mas Duran, B: sector B, MF: Madurell Ferrocarrils, MS: Madurell Sud) and Can Gambús (Cartographic Database of Gerard Remolins, ReGiraRocs SLU, Andorra).

across sectors, along with the remodelling of huts, suggests a settlement with successive reoccupations (Plasencia, 2016; Martín et al., 2023). This pattern of repeated temporary occupations is also seen at other open-air sites like La Prunera in the Pre-Pyrenees (Alcalde et al., 2016).

Structure 3BM/4.2, excavated in 1974 and 1987, is interpreted as a semi-subterranean, subcircular hut, 1.50 m deep, measuring 4 m by 3 m. The walls are divergent and concave, with step-like benches around the perimeter, possibly for access or storage. No postholes were found, though some daub fragments were recovered. The floor featured a hearth, flat stones arranged as pavement, and a large fragmented pot. Materials include Verazian ceramics, two spindle whorls, faunal and malacological remains, and the object analysed in this work, initially identified as a bone awl or tool (Roig, 1974; Ten, 1977). Radiocarbon

dating of cattle bones from the 1974 and 1987 excavations (Table 1) confirmed both contexts belong to the same period (OxCal R_Combine test).

3. Materials and methods

3.1. Description of the ivory object

The object measures 100.4 mm in length, 13.2 mm in diameter, and weighs 11 g (Fig. 2). Both faces are brightly polished, with a pointed distal end and a fractured proximal end. A reddish substance is clearly present at the object's surface (Fig. 3). It has been proposed that it resembles a stylized human figurine or idol (Martín, 1985), similar to idols from southern Iberia (Mederos Martín and Jiménez Ávila, 2023). However, the lack of limbs, facial features or wear marks rules out its use as a pendant, and it remains unclear whether it represents a figurine or a functional tool.

3.2. Methodology in the analysis of the ivory object

3.2.1. Anatomic and taxonomic identification

After macroscopic examination and preliminary determination of a hippopotamus ivory object according to the methodology described by Espinoza and Mann (1992), FTIR analysis was carried out to discriminate between different species (Banerjee and Huth 2012; Banerjee et al. 2012; Banerjee et al., 2017) (S1). While the differentiation obtained through this method is certainly quite small, according to our previous experience with known samples offered consistently reliable results. Its combination with the canonical method described by Espinoza and Mann (1992) offers a double check strategy of species determination at the species level (Morillo León et al., 2018; Rodríguez González et al., 2019).

This method is effective in discerning the provenance of proboscideans (African or Asian), but for the case of hippopotamuses, it can only be approximated by isotopic analysis, as hippopotamuses belongs to the same species in the different biotopes it inhabits. However, isotopic analysis has not been carried out in this case study due to its destructive nature.

In the anatomical and taxonomical identification of the support, the morphometric characteristics of teeth from different taxa (extant forms such as *H. amphibius* and the dwarf *Choeropsis liberiensis* and fossils such as *H. antiquus*) have been compared (S1). The distinction was based on the congruence of size and shape (curvature) of the incisors with the shape of the object, as well as their excellent preservation, which allowed us to rule out the fossil option.

4. Functional nature of the ivory object?

4.1. Traceology

We carried out use-wear analysis following the methodology consolidated by the works of Bradfield (2015), Buc (2010), Évora (2015), Semenov (1964), Legrand and Sidéra (2007) and Stemp et al. (2015). The authors used the collections of experimental material from the IMF-CSIC (Mozota et al., 2017; Mozota et al., 2018) as reference material. We studied the object with the naked eye, with a stereomicroscope (10x to 50x), and with a reflected light microscope (100× to 200×) (S2).

4.2. Colouring materials

In order to locate and describe the red residues present at the surface, the object was first observed and photographed with an optical microscope (OM). Afterwards, it was submitted to microscopic and elemental analyses through a scanning electron microscope coupled with an energy dispersive X-ray spectrometer (SEM-EDS). Subsequently, the red

Table 1
Radiocarbon dating from the structure BM/4.2. Two dates were calibrated at 2-sigma using OxCal 4.4 software (Bronk Ramsey, 2024) and the IntCal20 calibration curve (Reimer et al., 2020).

Site	Period	Structure	Sample	Species	Lab Ref	Date BP	sd	Method	Calibrated date 2σ	IRMS d13C	IRMS d15N	C:N	Wt %C	Wt %N	Source
BM-Can Feu	NL-C	3BM (1974)	Animal Bone	Bos	Beta-640297	4090	30	AMS	(18.6 %) 2859—2806 cal BC (7 %) 2753—2721 cal BC (64.2 %) 2703—2567 cal BC (5.6 %) 2527—2497 cal BC	−20.3	4.2	3.3	32.34	11.32	In this work
BM-Can Feu	NL-C	BM/4.2 (1987)	Animal Bone	Bos	Beta-640298	4160	30	AMS	(89.7 %) 2879—2661 cal BC (5.7 %) 2655—2631 cal BC	−20.1	4.2	3.3	30.97	10.86	In this work

Radiocarbon dating from the structure BM/4.2. Two dates were calibrated at 2-sigma using OxCal 4.4 software (Bronk Ramsey, 2024) and the IntCal20 calibration curve (Reimer et al., 2020).

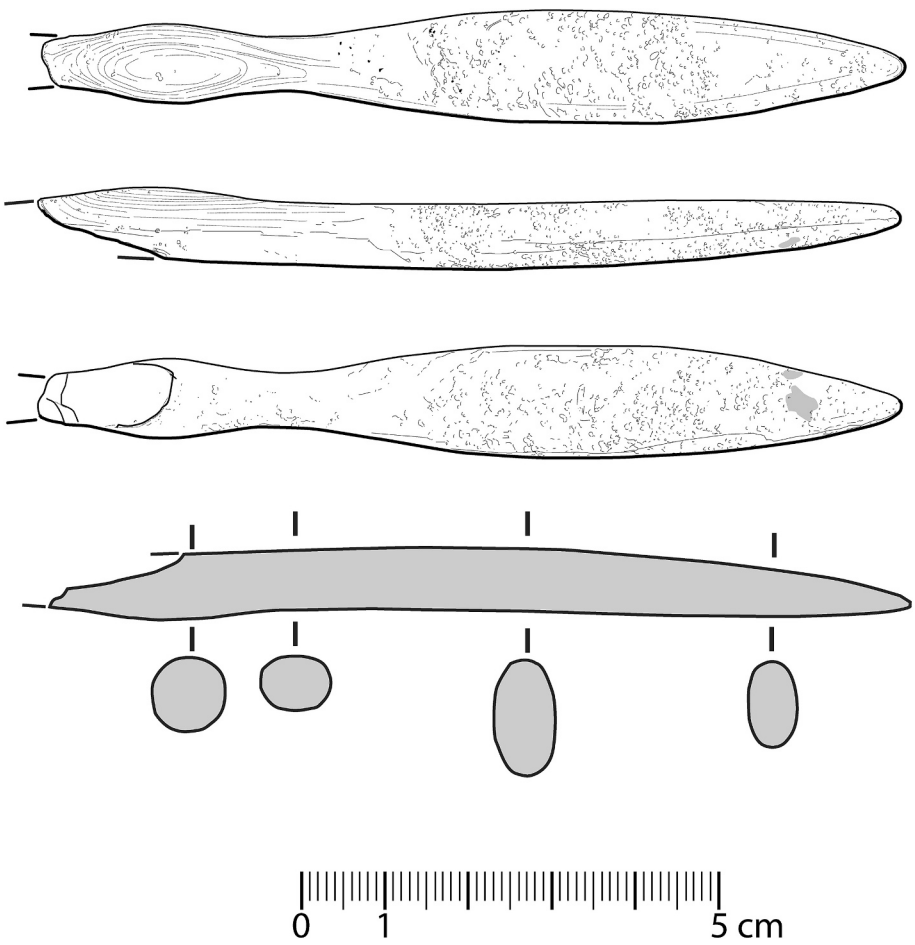

Fig. 2. Drawing of the ivory object (Ramón Álvarez Arza, Universitat de Barcelona).

residues were analysed by means of FTIR.

Finally, a proteomics approach was carried out with the aim of identifying organic binders by analysing the peptides present in a red residue micro-sample previously removed with a sterilized scalpel (S2).

5. Results

5.1. Ivory object: origin of the raw material through dentine characterization

Microscopic examination reveals fine concentric and wavy laminar lines, characteristic of hippopotamus ivory (Fig. 3), which are in agreement with the results of the FTIR analysis (S1). Extant and fossil hippopotamuses have a stable tooth formula consisting of incisors (2/2), canines (1/1), premolars (3–4/3–4) and molars (3/3). The size and essentially strait shape of the object are only compatible with one permanent lower first incisor (I/1). In comparison, the lower I/2 is too small, and the upper and lower canines as well as the upper incisors are too curved to be the origin of the object. Obviously, the shape of molars and premolars is not compatible with the shape and size of 3BM/4.2 object. Hippopotamus I/1 shows a slight mediolateral curvature that conforms a divergent pair of left/right incisors when are placed on the jaw. The apparent slight curvature of the specimen (Fig. 3) is compatible with the original incisor being from the right side. This will be correct, if the carving process does not have altered the original tooth curvature. One of the apical ends of 3BM/4.2 object shows an irregular area that has been interpreted as a fracture (Fig. 3). One possible alternative explanation is that this area corresponds to remains of the wear zone of the original I/1. However, if this is correct, the curvature does not reflect the original tooth curvature, indicating that the carving process has altered it. Close inspection of this apical area, however, cannot be interpreted unequivocally as the wear facet against the upper canine. It is irregular with an abrupt transition to the polish external region, facts that usually are not present in wear facets of Hippopotamus I/1.

FTIR analysis indicates a significant presence of organic material, likely collagen, associated with hydroxyapatite, suggesting a sub-recent origin rather than fossil (Dobberstein et al., 2009).

The ivory's white colour contrasts sharply with the darker, iron-oxide-like appearance of fossil ivory from H. antiquus at the nearby Vallparadís site (Madurell-Malapeira et al., 2010; Fidalgo et al., 2023). Fossilized ivory from Vallparadís also exhibits increased fragility and would be difficult to polish without cracking.

5.2. Taphonomic analysis

Evidence from taphonomic assessments indicates micro-alterations with a corroded appearance that could suggest the functional nature of the artefact (S2).

The study of the reddish substance at the distal end of the artefact indicates it was composed of a mixture of iron oxyhydroxides and an organic binder such as animal fat, animal glue, blood, egg, honey, or milk (S2).

6. Discussion

The artefact from Bòbila Madurell, attributed to the Véraza Chalcolithic period, is the first and currently the oldest documented hippopotamus ivory piece in north-eastern Iberia. Its analysis provides

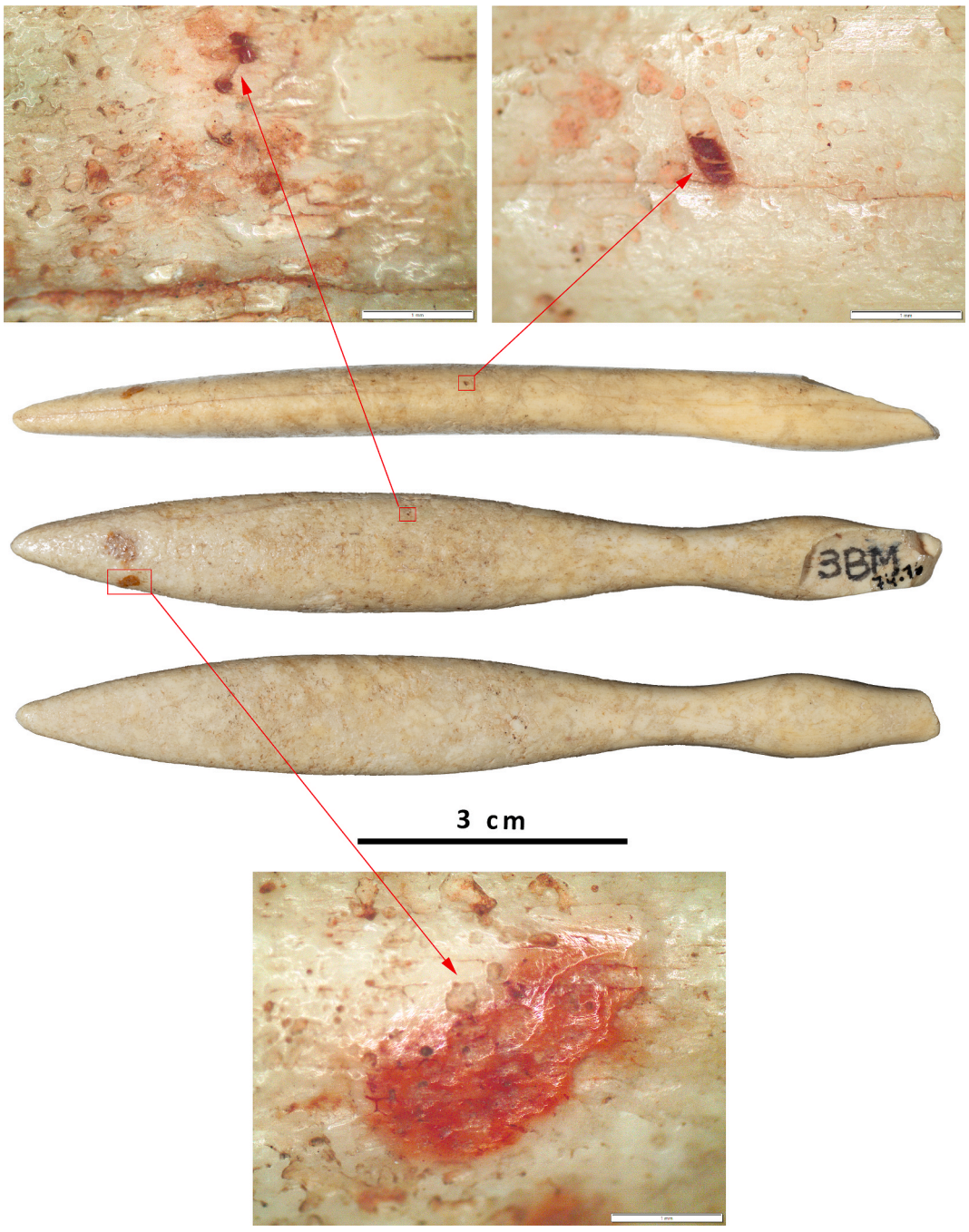

Fig. 3. Photograph of the ivory object (author: Ramón Álvarez Arza, Universitat de Barcelona) with detail images where the presence of a reddish substance on the surface is clearly visible.

significant insights into the long-distance networks involved in the trade of ivory, which had been previously established in southern and central Iberia but not in this region. The established dating, from the second quarter of the 3rd millennium BC, is notably older than any previously documented examples of this material across Iberia. The object's narrow, elongated shape with a distinct neck in the proximal area, along with comparisons to European weaving swords from a broad chronological framework (Neolithic – Late La Tène) (Grömer, 2016), suggests its possible function as a weaving sword or hand-thread winder. Evidence of textile production in structure 3BM/4.2 is supported by the discovery of two ceramic spindle whorls (Fig. 4), characteristic of the north-eastern Iberian Chalcolithic (Basso Rial and Soriano, 2023).

To date, ivory artefacts in north-eastern Iberia have been rare. Previous examples, such as perforated buttons from Cova de Can Sadurní (Begues, Barcelona) and the Gardunya hypogeum (Barcelona), date to later periods, including the Bell Beaker Chalcolithic and Early Bronze Age (Oliva Poveda, 2014, 2023). However, the specific species of ivory in these cases has not been identified. The presence of a reddish residue composed of iron oxyhydroxides and organic matter (e.g., animal fat, glue, blood, egg, honey, or milk) on the Bòbila Madurell piece suggests a purposely mixed mineral pigment with an organic binder, rather than the result of natural accumulation. The high symbolic value of red colour in Neolithic and Chalcolithic Iberian contexts, as evidenced in recent studies (Zarzalejos Prieto et al., 2020; García Sanjuán et al., 2024), raises the possibility that this object was associated with the production of textiles for activities in which colour played a significant

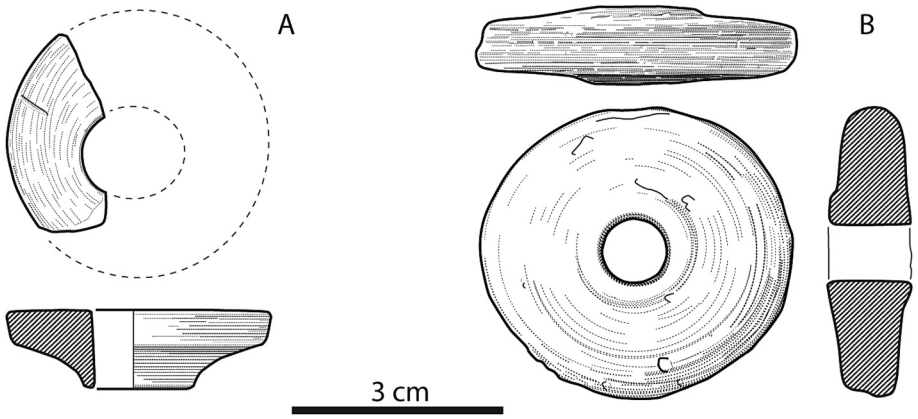

Fig. 4. Spindle whorls from structure 3BM/4.2 (Drawings: Ramón Álvarez Arza, Universitat de Barcelona): A. BM/4.2.-3A-31: discoidal shape with a flat face and another with a concave profile. Its approximate diameter is 37 mm, the central hole would be more than 10 mm in diameter and its height ranges from 24 mm (in the center) to 10 mm (in the contour). B. BM/4.2-4B-7: discoidal shape with central perforation. Its diameter ranges between 44.5 and 43.3 mm, the central hole measures 8.3 mm in diameter and the height ranges between 14.49 mm (in the center) and 10.1–9 mm (in the contour). Its weight is 29.7 g.

role.

The Véraza group, emerging after the decline of the Pit Graves Culture, occupied a vast area north and south of the eastern Pyrenees. Early traditions persisted, as evidenced by the burial goods from the collective tomb at Cova del Frare (3634–3363 cal BC), which included Baltic amber, shell bracelets, large Monegros-type blades, Bedoulian flint, and local flint trapezoids (Martín et al., 2023; Murillo-Barroso et al., 2023). Regional and supra-regional exchange networks are evident in materials such as flint from the Ebro Basin, Ulldemolins, Apt-Forcalquier, Collorgues, and Grand Pressigny (Vaquer et al., 2014; Mangado Llach et al., 2016; González-Olivares, 2023). Connections with contemporary groups in southern France, such as Ferrières, Fontbouisse, and Treilles, are reflected in shared materials and technologies. The trade networks responsible for the appearance of ivory in north-eastern Iberia date back to the Middle Neolithic. The Pit Grave culture, marked by grave goods from local and foreign materials (variscite, flint, obsidian), facilitated exchanges across the north-western Mediterranean, from Sardinia to the Alps, including south-eastern France and the Pyrenees (Gibaja et al., 2017). These networks collapsed, and Pit Grave necropolises were abandoned around 3655–3550 cal BC, giving way to new funerary practices (Morell et al., 2022).

The introduction of copper jewellery, awls, and gold beads marks the end of the 4th millennium BC and the beginning of the 3rd millennium in north-eastern Iberia (Soriano et al., 2012; Rovira et al., 2014). Bell Beaker culture and the arrival of the first tanged daggers in the second quarter of the 3rd millennium BC reflect increased contact and exchange, as seen in the finds from Cova del Calvari (Soriano, 2013).

The presence of hippopotamus ivory in this region aligns with evidence of long-distance trade. A southern route, supported by findings in Andalusia (Bilotti et al., 2024), remains plausible. However, a northern land and maritime network may also explain the presence of ivory in Catalonia and south-eastern France, such as the V-perforated button from the Grotte-Basse de la Vigne Perdue (Guilaine, 1963). Earlier Neolithic exchanges, such as the distribution of Sardinian obsidian (Gibaja et al., 2017) and the presence of Asian elephant ivory in Bell Beaker contexts in Sardinia (Morillo León et al., 2018), further support these connections.

The colonization of the Balearic Islands may have been influenced by these networks, as evidenced by the discovery of materials such as tabular flint, ivory (e.g., the comb from Abric de Son Metge), and Beaker-associated artefacts, including archers' bracers and V-perforated buttons. While these items often date to the Bronze Age and are linked to the megalithic phenomenon of Mallorca and Menorca (Calvo and Guerrero, 2002), the arrival of Baltic amber at Cova de Frare by the mid-4th millennium cal BC indicates terrestrial routes (Murillo-Barroso et al., 2023).

7. Conclusions

The hippopotamus ivory object is an exceptional case of the Chalcolithic in the north-east of the Iberian Peninsula, verified by microscopic analysis, FTIR, dated between the second quarter of the 3rd millennium BC. It is a milestone for understanding the importance of these materials in the peninsular exchange networks of this period. The presence of hippopotamus ivory in this region is consistent with evidence of long-distance trade. A southern route, supported by finds in Andalusia, makes the arrival of materials by overland routes plausible. Earlier Neolithic trade, such as the distribution of Sardinian obsidian and the arrival of Baltic amber at Cova de Frare in the mid-4th millennium BC indicates long-distance routes in the northeast. On the other hand, the presence of elephant ivory in the Balearic Islands and Sardinia in Bell Beaker contexts supports maritime connections.

X-ray spectrometer analysis (SEM-EDS) in the red residues of the object indicate a composition of iron oxyhydroxides and organic matter suggesting the use of a mineral pigment mixed with an organic binder. In addition, the narrow and elongated shape of the object, with a pronounced neck in the proximal area compared to European weaving swords of a broad chronological frame, suggests a possible use of the object in textile work.

CRediT authorship contribution statement

José Miguel Morillo León: Writing – original draft, Methodology, Conceptualization. **Africa Pitarch Martí:** Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Silvia Albizuri:** Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **F. Javier López-Cachero:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Araceli Martín Cólliga:** Writing – original draft, Methodology, Data curation, Conceptualization. **Millan Mozota:** Writing – original draft, Methodology, Data curation, Conceptualization. **Salvador Moyà-Solà:** Writing – original draft, Methodology, Data curation. **Jordi Nadal:** Writing – original draft, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2025.105375.

Data availability

No data was used for the research described in the article.

References

Alcalde, G., Borrell, F., Casellas, S., Oliva, M., Saña, M., Vicente, O., 2016. La Prunera (Sant Joan les Fonts, la Garrotxa), un assentament neolític del IV/III mil·lenni cal BC en el Prepirineu Català. Universitat Autònoma de Barcelona i Ajuntament de Sant Joan les Fonts.

Banerjee, A., Schumacher, T., Cardoso, J.L., López Castro, J.L., Ferjaoui, A., Mederos Martín, A., Martínez Hahnmüller, V., Ben Jerbania, I., 2017. Marfil de hipopótamo procedente de estratos fenicios arcaicos en Utica (Túnez). Madrider Mitteilungen 58, 80–105.

Banerjee, A., Huth, J., 2012. Investigation of Archaeological Ivory, in: Banerjee, A.; López Padilla, J.A., Schuhmacher, T.X. (eds.), 2012. Elfenbeinstudien. Faszikel I. Marfil y elefantes en la Península Ibérica y el Mediterráneo occidental Actas del coloquio internacional en Alicante el 26 y 27 de noviembre 2008, Iberia Archaeologica 16:1. Deutsches Archäologisches Institut/Diputación de Alicante/ Museo Arqueológico de Alicante. Philipp von Zabern, pp. 15-28.

Banerjee, A. Bortolaso, G., Dindorf, W., 2008. Distinction between African and Asian ivory, in: Bortolaso, G. (Ed.), Elfenbein und Artenschutz. INCENTIVS – Tagungsbeiträge der Jahre (2004-2007). Bundesamt für Naturschutz 28, pp. 37-49.

Banerjee, A.; López Padilla, J.A., Schuhmacher, T.X. (eds.), 2012. Elfenbeinstudien. Faszikel I. Marfil y elefantes en la Península Ibérica y el Mediterráneo occidental Actas del coloquio internacional en Alicante el 26 y 27 de noviembre 2008, Iberia Archaeologica 16.1, Deutsches Archäologisches Institut/Diputación de Alicante/ Museo Arqueológico de Alicante. Philipp von Zabern.

Basso Rial, R.E., Soriano, E., 2023. Actividades textiles durante el III y II milenio cal ANE en el Nordeste peninsular: los instrumentos de hilado. Complutum 34 (2), 375–394. https://doi.org/10.5209/cmpl.92260.

Belmonte, D., López Padilla, J.A., 2006. Productos, desechos y áreas de actividad en la Illeta deis Banyets de El Campello (ca. 1900- ca. 1400 ANE): Actuaciones de 2000-2001, in: Soler Díaz, J.A. (Ed.), La ocupación prehistórica de la Illeta dels Banyets. Museo Arqueológico Provincial de Alicante. Serie Mayor 5, pp. 173-210.

Bilotti, G., Kempf, M., Morillo Leon, J.M., 2024. Modelling land and water based movement corridors in the Western Mediterranean: a least cost path analysis from chalcolithic and early bronze age ivory records. Archaeol. Anthropol. Sci. 16, 122. https://doi.org/10.1007/s12520-024-02029-x.

Bordas, A., Diaz, J., Pou, R., Parpal, A., Martín, A., 1994. Excavacions arqueològiques 1992–1993 a la Bòbila Madurell-Mas Duran (Sant Quirze del Vallès, Vallès Occidental), Tribuna d'Arqueologia 1992–1993, 31-47.

Bradfield, J., 2015. Use-trace analysis of bone tools: a brief overview of four methodological approaches. S. Afr. Archaeol. Bull. 70, 3–14. https://www.jstor.org/stable/24643604.

Bronk Ramsey, C., 2024. OxCal v4.4. Available in: https://c14.arch.ox.ac.uk/oxcal.html.

Buc, N., 2010. Experimental series and use-wear in bone tools. J. Archaeol. Sci. 38, 1–56. https://www.sciencedirect.com/science/article/abs/pii/S030544031000364X.

Calvo, M., Guerrero, V., 2002. Los inicios de la metalurgia en las Baleares. El Calcolítico (c. 2500-1700 cal BC). El Tall, Palma de Mallorca.

Chapman, R., 1990. Emerging Complexity. The later prehistory of south-east Spain, Iberia and the west Mediterranean. Cambridge University, Cambridge.

Díaz, J., Martí, M., Pou, R., Bordas, A., 1995. Dos estructuras de habitación del Neolítico Final en el yacimiento de la "Bòbila Madurell" (Sant Quirze del Vallès, Barcelona). In: I Congresso de Arqueologia Peninsular, vol. V. Trabalhos de Antropologia e Etnologia 35 (1), 17-34.

Díaz-Zorita, M., Subirá, M.E., Fontanals-Coll, M., Knudson, K.J., Alonzi, E., Bolhofner, K., Morell, B., Remolins, G., Roig, J., Martín, A., González Marcén, P., Plasencia, J., Coll, J.M., Gibaja, J.F., 2021. Neolithic networking and mobility during the 5th and 4th millennia BC in north-eastern Iberia. J. Archaeol. Sci. 125, 105272. https://doi.org/10.1016/j.jas.2020.105272.

Dobberstein, R.C., Collins, M.J., Craig, O.E., Taylor, G., Penkman, K.E.H., Ritz-Timme, S., 2009. Archaeological collagen: why worry about collagen diagenesis? Archaeol. Anthropol. Sci. 1, 31–42. https://doi.org/10.1007/s12520-009-0002-7.

Espinoza, E.O., Mann, M., 1992. Identification Guide for Ivory and Ivory Substitutes. World Wildlife Fund & Conservation Foundation, Richmond.

Évora, M., 2015. Use-Wear Methodology on the Analysis of Osseous Industries, in: Marreiros, J., Gibaja, J. F., Ferreira Bicho, N. (Eds), Use-Wear and Residue Analysis in Archaeology. Manuals in Archaeological Method, Theory and Technique. Springer, pp. 159-170. doi: 10.1007/978-3-319-08257-8_8.

Fidalgo, D., Rosas, A., Bartolini-Lucenti, S., Boisserie, J.-R., Pandolfi, L., Martínez-Navarro, B., Palmqvist, P., Rook, L., Madurell-Malapeira, J., 2023. Increase on environmental seasonality through the European Early Pleistocene inferred from dental enamel hypoplasia. Sci. Rep. 13, 16941. https://doi.org/10.1038/s41598-023-42936-y.

García-Sanjuán, L., Luciañez Triviño, M., Schuhmacher, T., Wheatley, D.W., Banerjee, A., 2013. Ivory craftsmanship, trade and social significance in the southern Iberian Copper Age: the evidence from the PP4- Montelirio sector of Valencina de la Concepción (Seville, Spain). Eur. J. Archaeol. 16 (4), 610–635.

García Sanjuán, L., Montero, R., Emslie, S., Lozano, J.A., Luciañez-Triviño, M., 2024. Beautiful, magic, lethal: a social perspective of cinnabar use and mercury exposure at the valencina copper age mega-site (Spain). J. Archaeol. Method Theory 31, 1006–1061.

Gibaja, J.F., Morell, B., Barceló, J.A., Duboscq, S., Masclans, A., Remolins, G., Roig, J., Martín, A., González, P., Plasencia, J., Coll, J.M., Subirà, M.E., 2017. Tell me when: the chronology of the Neolithic necropolis "Bòbila Madurell-can Gambús" in the NE of Iberian Peninsula (second half of the 5th millennium – first half of the 4th millennium cal BC). using time to understand long-distance exchanges. Radiocarbon 59 (6), 1713–1736.

González-Olivares, C.B., 2023. Las grandes láminas de sílex: materiales, movilidad y simbolismos durante el Neolítico final - Calcolítico en Europa. Tesis Doctoral De La Universitat De Barcelona.

Grömer, K., 2016. The Art of Prehistoric Textile making. The development of craft traditions and clothing in Central Europe, Natural History Museum Vienna, Vienna, Austria.

Guilaine, J., 1963. Boutons perforés en V du Chalcolithique pyrénéen. Bulletin De La Société Préhistorique Française 60 (11–12), 818–827.

Legrand, A., Sidéra, I., 2007. Methods, means, and results when studying European bone industries Bones as Tools. In: St. Pierre, C., Walker, R.B. (Eds.), Current Methods and Interpretations in Worked Bone Studies, BAR International Series 1622. BAR publishing.

Liesau, C., 2016. Some prestige goods as evidence of interregional interactions in the funerary practices of the Bell Beaker groups of Central Iberia. In: Guerra, E., Liesau, C. (Eds.), Analysis of the Economic Foundations Supporting the Social Supremacy of the Beaker Groups. Proceedings of the XVII UISPP World Congress, pp. 69–93.

Liesau, C., Blasco, C., 2011-12. Materias primas y objetos de prestigio en ajuares funerarios como testimonios de redes de intercambio en el horizonte campaniforme. Cuadernos de Prehistoria y Arqueología de la Universidad Autónoma de Madrid 37-38, 209-222. doi: 10.15366/cupauam2012.38.010.

Luciañez-Triviño, M., García-Sanjuán, L., Schuhmacher, T., 2022. Crafting Idiosyncrasies. Early Social Complexity, Ivory and Identity-making in Copper Age Iberia. Camb. Archaeol. J. 32 (1), 23–60. https://doi.org/10.1017/S0959774321000287.

Madurell-Malapeira, J., Minwer-Barakat, R., Alba, D.M., Garcés, M., Gómez, M., Aurell-Garrido, J., Ros-Montoya, S., Moyà-Solà, S., Berástegui, X., 2010. The Vallparadís section (Terrassa, Iberian Peninsula) and the latest Villafranchian faunas of Europe. Quat. Sci. Rev. 29 (27–28), 3972–3982. https://doi.org/10.1016/j.quascirev.2010.09.020.

Mangado Llach, J., Vaquer, J., Gibaja, J.F., Oms, F.X., Cebrià, A., González Olivares, C.B., Martín, A., Marín, D., 2016. New data concerning "large blades" in Catalonia: Apt-Forcalquier chert in the Penedès (south of Barcelona) during the late Neolithic-Chalcolithic. J. Lithic Stud. 4 (2), 481–496. https://doi.org/10.2218/jls.v3i2.1833.

Martín, A., 1985. De la cultura de los sepulcros de fosa al grupo de Veraza en el Vallés. Estudios De La Antigüedad 2, 3–57.

Martín, A., Blanch, R.M., Albizuri, S., Alaminos, A., Mercadal, O., Vives, E., Lázaro, P., Bosch, J., Colomer, S., Miret, J., Enrich, R., Aliaga, S., 2017. El paraje de Bòbila Madurell (Sant Quirze del Vallès, Vallès Occidental, Barcelona), in: Gibaja, J.F.,

Mozota, M., Subirà, M.E., Martín A., Roig, J., Mirando a la muerte: las prácticas funerarias durante el Neolítico en el noreste peninsular. Vol. 1, e-DitARX Publicaciones digitales, pp. 101-274.
Martín, A., Oms, F.X., Martínez, P., Moya, A., 2023. Le groupe de Véraza au Sud des Pyrénées: Néolithique final et Chalcolithique pré-campaniforme, in: Guilaine, J., Gandelin, M. (Eds.), Véraza et le Verazien. Les fouilles aux Grottes de La Valette (1963-1964) et le Vérazien aujourd'hui. Archives d'Écologie Préhistorique, Toulose, pp. 393-491.
Mederos Martín, A., 2020. De vuelta al Mediterráneo. Los contactos e intercambios del sur de la Península Ibérica durante el Campaniforme y El Argar con el Egeo y Levante (2500-1600 AC). Estudos Arqueológicos De Oeiras 27, 197–280.
Mederos Martín, A., Jiménez Ávila, J., 2023. Al servicio de la divinidad. Figuras antropomorfas oculadas calcolíticas del sur de la península ibérica en piedra, marfil y hueso. Cuadernos de Prehistoria y Arqueología de la Universidad Autónoma de Madrid 49 (2), 51–96. doi: 10.15366/cupauam2023.49.2.003.
Morell, B., Gibaja, J. F., Masclans, A., Duboscq, S., 2022. Cronología y dinámica temporal de los contextos funerarios del NE de la Península Ibérica entre finales del V milenio e inicios del IV milenio cal BC, in: Gibaja, J. F., Mozota, M., Subirà, M. E., Martín, A., Masclans, A. (Eds.), Mirando a la muerte. Las prácticas funerarias durante el Neolítico en el noreste peninsular, Vol. 4, e-DitARX Publicaciones Digitales, pp. 319-329.
Morillo León, J.M., 2021. In: Warriors, Sailors and Traders across the Sea: a Study of Mediterranean Islands in the 3rd Millennium BC and the Bell Beaker Culture Phenomenon. Artemide, Rome, pp. 51–67.
Morillo León, J.M., 2019. Exotic raw materials in Early Minoan Crete: cretaceous ivory and amber. a connection with the Iberian Peninsula?. In: In: Proceedings of the 12th International Congress of Cretan Studies, pp. 1–12.
Morillo León, J.M., Pau, C., Guilaine, J., 2018. The proboscidean ivory adornments from the hypogeum of PadruJossu (Sanluri, Sardinia, Italy) and the Mediterranean Bell Beaker. Zephyrus 82, 35–63.
Mozota, M., Diego, M., Quevedo, I., Gibaja, J. F., 2017. Nuevos aportes desde la experimentación al estudio funcional del utillaje óseo neolítico. Cuadernos de prehistoria y arqueología de la Universidad de Granada 27, 269-291. https://digital.csic.es/handle/10261/187808.
Mozota, M., Borrell, F., Clemente-Conte, I., Gibaja, J.F., Ibáñez-Estévez, J.J., Nieto-Espinet, A., Ortega, D., Terradas-Batlle, X., Valenzuela-Lamas, S., 2018. Reference Collections of the Institución Milà i Fontanals for the study of prehistoric societies: archeology from an experimental and technological perspective. Butll. Arqueol. 40, 355–359. https://digital.csic.es/handle/10261/178126.
Murillo-Barroso, M., Cólliga, A.M., Martinón-Torres, M., 2023. The earliest Baltic amber in Western Europe. Sci. Rep. 13, 14250. https://doi.org/10.1038/s41598-023-41293-0.
Nocete, F., Vargas, J.M., Schuhmacher, T.X., Banerjee, A., Dindorf, W., 2013. The ivory workshop of Valencina de la Concepción (Seville, Spain) and the identification of ivory from asian elephant on the Iberian Peninsula in the first half of the 3rd millennium BC. JAS 40, 1579–1592.
Oliva Poveda, M., 2014. Les peces d'ornament personal prehistòric del jaciment de la Gardunya (Barcelona). Informe inédito.
Oliva Poveda, M., 2023. Els botons de perforació en V de can Sadurní, in: Edo, M., (Coord.), La prehistòria de Begues i el Massís de Garraf nord-oriental. Edicions del Llobregat, Begues, pp. 228-229.
Pau, C., Morillo, L.J.M., Cámara Serrano, J.A., Molina González, F., 2018. Los objetos de adorno en marfil del yacimiento del Cerro de la Vírgen (Orce, Granada). Complutum 29 (2), 267–298. https://doi.org/10.5209/CMPL.62581.
Pfälzner, P., 2016. The Elephants of the Orontes. Syria IV 159–182. https://doi.org/10.4000/syria.5002.
Plasencia, F.J., 2016. Bòbila Madurell-Mas Duran: Formas de vida en el Neolítico medio y final del nordeste peninsular. Tesis Doctoral De La Universitat Autònoma De Barcelona.
Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., Talamo, S., 2020. The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62 (4), 725–757.
Rodríguez González, E., Celestino Pérez, S., Herranz Redondo, A., Morillo León, J.M. (2019). Comerciar con Occidente. Las placas de marfil y hueso de la caja de madera de la estancia 100 de Casas del Turuñuelo (Guareña, Badajoz, España). Pyrenae. Edicions de la Universitat de Barcelona.
Roig, A., 1974. Turó de can Feu, 3BM. Diari d'excavacions. Unpublished.
Roig, J., Coll, J.M., 2007. El paratge arqueològic de can Gambús-1 (Sabadell, Vallès Occ.). Tribuna D'arqueologia 2006, 85–109.
Roig, J., Coll, J.M., 2016. La necròpolis neolítica de can Gambús-1: un conjunt funerari rellevant del IV mil·lenni cal. aC a Catalunya. Arraona: Revista D'història 36, 78–89.
Rovira, M.C., Borrell, F., Oliva, M., Saña, M., Vicente, O., Alcalde, G., 2014. Early gold remains in the northeast of the Iberian Peninsula, in: Meller, H., Risch, R., Pernicka, E. (Eds.), Metalle der Macht - Frühes Gold und Silber. Metals of Power - Early Gold and Silver. Tagungen des Landesmuseum für Vorgeschichte Halle, Band 11/2, pp. 541-545.
Schuhmacher, T. X. 2012. Die Elfenbeinobjekte des Chalkolithikums und der Frühen Bronzezeit auf der Iberischen Halbinsel. Interdisziplinäre Studien zu Herkunft, Austausch, Verarbeitung und sozialer Bedeutung von Elfenbein. Iberia Archaeologica 16, 2. Darmstadt: Philipp von Zabern.
Schuhmacher, T., 2012. El marfil en España desde el Calcolítico al Bronce Antiguo, in: Banerjee, A., López Padilla, J.A., Schumacher, T. (Eds.), Elfenbeinstudien. Faszikel 1: Marfil y elefantes en la Península Ibérica y el Mediterráneo occidental. Actas del coloquio internacional. Iberia Archaeologica 16.1. Deutsches Archäologisches Institut/Diputación de alicante/Museo Arqueológico de Alicante, Verlag Philipp von Zabern, pp. 45-68.
Schuhmacher, T., Banerjee, A., 2012. Procedencia e intercambio de marfil en el Calcolítico de la Península Ibérica, in: Borrell, M., Borrell, F., Bosch, J., Clop, X., Molist, M. (Eds), Redes en el Neolítico. Circulación e Intercambio de Materias, Productos e Ideas en el Mediterráneo Occidental (VII-III milenio a.C.), Rubricatum 5, pp. 289-298.
Schuhmacher, T.X., Banerjee, A., Dindorf, W., Nocete Calvo, F., Vargas Jiménez, J.M., 2013. Los marfiles del yacimiento de Valencina de la Concepción (Sevilla) en el contexto del Calcolítico del suroeste peninsular, in: García Sanjuán, L., Vargas, J.M., Hurtado, V., Ruiz, T., Cruz-Auñón Briones, R. (Eds.), El asentamiento prehistórico de Valencina de la Concepción (Sevilla): investigación y tutela en el 150 aniversario del descubrimiento de La Pastora. Universidad de Sevilla, Sevilla, pp. 495–510.
Schuhmacher, T. X. 2016. Elefanten und Elfenbein auf der Iberischen Halbinsel und in Nordwest-Afrika. Interdisziplinäre Studien zu Austauschsystemen im 3. und der ersten Hälfte des 2. Jts. v. Chr. Iberia Archaeologica 16, 3. Tübingen: Wasmuth.
Schuhmacher, T. X. 2017. Ivory Exchange Networks in the Chalcolithic of the Western Mediterranean. In: M. Bartelheim, P. Bueno Ramírez, M. Kunst, eds. Key Resources and Socio-Cultural Developments in the Iberian Chalcolithic. RessourcenKulturen 6. Tübingen: 291-312.
Schuhmacher T.X., Banerjee, A. 2019. Botão em marfim do hipopótamo, in: A. F. de Carvalho (Hrsg.), Hipogeu campaniforme do Convento do Carmo (Torres Novas), Estudos e documentos 12 (Torres Novas) 136–138.
Semenov, S. A., 1964. Prehistoric Technology. M. Thompson-Bath (Trad.). Adams & Dart.
Soriano, I., 2013. Metalurgia y sociedad en el Nordeste de la Península Ibérica (finales del IV-II milenio cal ANE). British Archaeological Reports, International Series 2502, Archaeopress. Oxford.
Soriano, I., Soler, J., Soler, N., 2012. ¿La primera orfebrería del nordeste de la Península Ibérica? Nuevas aportaciones a partir de la cuenta áurea de Cau del Tossal Gros (Torroella del Montgrí, Baix Empordà, Girona). Trab. Prehist. 69 (1), 149–161. https://doi.org/10.3989/tp.2012.12085.
Stemp, W.J., Watson, A.S., Evans, A.A., 2015. Surface analysis of stone and bone tools. Surf. Topogr. Metrol. Prop. 4 (1), 013001. https://iopscience.iop.org/article/10.1088/2051-672X/4/1/013001/meta.
Ten, R., 1977. Aportaciones al estudlo del eneolítico en el Vallés. Universitat de Barcelona, Memoria de licenciatura.
Vaquer J., Martin Colliga A., Juan Cabanilles J., Bordreuil M., Galant Ph., 2014. Les poignards à retouches parallèles couvrantes sur préformes polies en silex de Forcalquier dans la zone nord-occidentale de la Méditerranée, in: Arbogast, R.-M., Greffier Richard, A., (coord.), Entre archéologie et écologie, une préhistoire de tous les milieux. « Mélanges offerts à Pierre Pétrequin». Presses universitaires de Franche Comté, Annales littéraires de l'Université de Franche Comté, 928, série Environnement, Société et Archéologie, 18, Besançon, pp. 129-155.
Zarzalejos Prieto, M., Hevia Gómez, P., Mansilla Plaza, L. (Eds.), 2020. El 'oro rojo' en la Antigüedad: perspectivas de investigación sobre los usos y aplicaciones del cinabrio entre la Prehistoria y el fin del mundo antiguo, Universidad Nacional de Educación a Distancia, Madrid.