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Northern exposure: Baltic amber and silver beads from the Iron Age reuse of the Bela Vista *tholos* (Sintra, Portugal)

Vientos del norte: el ámbar báltico y las cuentas de plata de la reutilización en la Edad del Hierro del tholos *de Bela Vista (Sintra, Portugal)*

José Ángel Garrido-Cordero Departamento de Prehistoria y Arqueología, Universidad de Sevilla / UNIARQ - Centro de Arqueologia da Universidade de Lisboa, Universidade de Lisboa, jgarrido8@us.es
Rita Loureiro UNIARQ - Centro de Arqueologia da Universidade de Lisboa, Universidade de Lisboa, ritasloureiro@edu.ulisboa.pt
José María Martínez-Blanes Departamento de Química Inorgánica, Universidad de Sevilla, blanes@us.es
Ana C. Sousa UNIARQ - Centro de Arqueologia da Universidade de Lisboa, Universidade de Lisboa, sousa@edu.ulisboa.pt
María Dolores Zambrana-Vega Departamento de Pintura, Universidad de Sevilla, mzambrana@us.es
Luz Marina Salas Acosta Departamento de Dibujo, Universidad de Sevilla, luzmar@us.es
Daniel Sánchez-Gómez UNIARQ - Centro de Arqueologia da Universidade de Lisboa, Universidade de Lisboa, dasa39@gmail.com
Carlos P. Odriozola Departamento de Prehistoria y Arqueología, Universidad de Sevilla / UNIARQ - Centro de Arqueologia da Universidade de Lisboa, Universidade de Lisboa, codriozola@us.es (corresponding author)

Abstract: This study re-examines the personal adornment assemblage from the Bela Vista *tholos* (Sintra, Portugal), highlighting the rediscovery of a long-lost amber bead and clarifying the chronology and provenance of associated artifacts. The bead has been identified as Baltic amber through the use of FTIR spectroscopy. This material is known to be exceptionally rare in Iberian contexts prior to the Bronze Age. Complementary analyses (MACLAS and VORTEX) link the greenstone beads to variscite and muscovite, with the variscite sourced from the Aliste mining region in northwestern Iberia. These materials suggest an initial Copper Age use of the monument, related to long-distance exchange networks centered on variscite. However, the presence of a Baltic amber bead and an associated silver coil, in addition to Iron Age ceramics and metal ornaments, provides substantial evidence that supports the hypothesis of a high-status Iron Age burial (7th-5th centuries BCE) within the reused megalith. Notably, no Iberian site has yet been found that securely associates Baltic amber with either Bell Beaker pottery or variscite, reinforcing the separate chronological contexts of these materials. This research underscores the significance of applying modern analytical methods to legacy collections, thereby challenging previous assumptions and demonstrating how prehistoric monuments were reutilized for ritual purposes over millennia.

Keywords: Baltic amber; variscite; silver; Bela Vista; Iron Age; Copper Age; FTIR; MACLAS; VORTEX; Prehistoric trade networks; Iberian Peninsula.

Resumen: *Este estudio reexamina el conjunto de adornos personales del* tholos *de Bela Vista (Sintra, Portugal), destacando el redescubrimiento de una cuenta de ámbar dada por perdida hace décadas y aclarando la cronología y procedencia de los artefactos asociados. Mediante espectroscopia FTIR, la cuenta ha sido determinada como ámbar báltico, un material excepcionalmente raro en contextos ibéricos anteriores a la Edad del Bronce. Análisis complementarios (MACLAS y VORTEX) identifican las cuentas de piedra verde con la variscita y la moscovita, procediendo la variscita de la región minera de Aliste, en el noroeste de Iberia. Estos materiales sugieren un uso primario inicial del monumento en la Edad del Cobre, relacionado con redes de intercambio de larga distancia centradas en la variscita. Sin embargo, la cuenta de ámbar del Báltico y la espiral de plata asociada, junto con la cerámica de la Edad del Hierro y los ornamentos metálicos, apoyan firmemente un enterramiento de alto estatus de la Edad del Hierro (ss. VII-V a. C.) en el megalito. Cabe destacar que en ningún yacimiento ibérico se puede asociar de forma segura el ámbar báltico con los vasos campaniformes o la variscita, lo que refuerza los contextos cronológicos separados de estos materiales. Esta investigación subraya la importancia de aplicar métodos analíticos modernos a las colecciones heredadas,*

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revisando supuestos anteriores y demostrando cómo se reactivaron los monumentos prehistóricos con fines rituales a lo largo de milenios.

Palabras clave: *ámbar báltico; variscita; plata; Bela Vista; Edad del Hierro; Edad del Cobre; FTIR; MACLAS; VORTEX; redes de intercambio prehistóricas; península ibérica*.

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1. INTRODUCTION

Amber has long captivated researchers due to its distinctive physical properties—its vibrant color, transparency, lightness, and aromatic qualities—as well as its rarity and origins in distant geological sources. Beyond its aesthetic appeal, amber plays a crucial role in archaeological research as a key material for reconstructing prehistoric exchange networks. Its geochemical composition allows for the identification of its geographical provenance through scientific analysis, offering valuable insights into long-distance interactions and mobility in the past.

Despite amber's archaeological significance, systematic studies in the Iberian Peninsula only became possible in the mid-20th century. A major breakthrough came with Beck's pioneering application of Fourier-Transform Infrared Spectroscopy (FTIR) (Beck *et al*., 1964), which enabled researchers to determine the origin of amber samples. This advancement spurred dedicated research into Iberian amber trade, beginning with Ferreira's (1966) inventory of prehistoric amber in Portugal and later expanded by Vilaça's comprehensive review of Portuguese amber artifacts (Vilaça *et al*., 2002). However, it was not until the synthesis by Murillo-Barroso and Martinón-Torres (2012) that a truly systematic overview of Iberian amber based on FTIR analysis emerged. This laid the foundation for subsequent provenance studies across the peninsula (Peñalver and Delclòs, 2010; Murillo-Barroso *et al.*, 2018; Odriozola *et al.*, 2019; Garrido-Cordero *et al.*, 2024; Romero-García *et al.*, 2024) and enabled the construction of a chronological model of amber consumption in Iberia from Late Paleolithic to the Iron Age. This model reveals a major shift in supply patterns: whereas Sicilian amber dominated between the 5th and 2nd millennia BCE, Baltic amber became increasingly prevalent from the 2nd millennium BCE onward (Odriozola *et al.*, 2019; Garrido-Cordero *et al.*, 2024). Notably, FTIR-based provenance has recently been proposed as a chronological proxy for undated amber artifacts, offering a powerful tool for contextualizing ambiguous finds (Garrido-Cordero *et al.*, 2024).

Nonetheless, important challenges remain. The degradation of amber through oxidation and polymerization has rendered many artifacts unrecognizable or entirely destroyed. In addition, inconsistencies in early excavation records, misclassification in museum collections, and the loss of materials during analytical procedures have introduced significant gaps in the archaeological record. The most recent inventory of Iberian amber (Garrido-Cordero *et al.*, 2024) documents 781 objects from 85 sites. However, five beads from five different sites remain unaccounted for—among them, the amber bead from Bela Vista, which has long been presumed lost.

Recently rediscovered in a fragmented and deteriorated condition at the *Museu dos Serviços Geológicos de Portugal* (Fig. 1), the Bela Vista bead offers a rare opportunity to reassess its provenance, chronology, and significance within prehistoric exchange systems. This study combines FTIR analysis of the amber bead with mineralogical characterization (MACLAS[1]) and provenance tracing (VORTEX[2]) of associated greenstone beads to clarify their origins and cultural meaning. Through the integration of these analytical approaches, we aim to:

1. Determine the amber's provenance and assess its implications for Iberian exchange networks.
2. Reconstruct the bead's chronological context, evaluating whether it corresponds to the Copper Age or the Iron Age.

[1] Mineral archaeological classification System (Sánchez-Gómez *et al*., 2024).
[2] Variscite origin recognition technology X-ray based (Sánchez-Gómez *et al.,* 2025, 2026).

Fig. 1. Macrophotograph of the Bela Vista (Sintra, Portugal) amber bead remains. A Dino-Lite Edge AM7915MZTL digital USB microscope was used for this purpose.

The Bela Vista *tholos*, a megalithic tomb located in the Sintra necropolis, exhibits a complex stratigraphy with materials spanning from the Copper Age to the Iron Age. By comparing the remaining assemblage with parallels from other archaeological contexts, we argue that the amber bead most likely dates to the Iron Age (7th-5th centuries BCE), a period marked by the expansion of Baltic amber trade into the Iberian Peninsula.

2. THE BELA VISTA *THOLOS*

The *tholos* of Bela Vista (CNS [*Código Nacional de Sítio*] 19452, 38.791550 N, -9.424610 [WGS84, EPGS:4326]) is a distinctive megalithic monument located within the Sintra megalithic necropolis (Mello *et al.*, 1961; Leisner, 1965; Boaventura, 2009, pp. 216-217) (Fig. 2). Discovered in 1957 and excavated between 1957 and 1959, the monument is classified either as a pseudo-*tholos* (Boaventura, 2009, p. 217) or an hybrid monument (Sousa, 2016, p. 223). The tomb is constructed among large granite outcrops and features a mixed stone masonry structure. While no vaulted dome has been identified, there is evidence of a substantial earthen mound (Mello *et al.*, 1961; Pina, 2019).

Excavations revealed three stratigraphic layers (Mello *et al.*, 1961):

– C3: The uppermost layer, consisting of humus, black topsoil, and modern-era debris.
– C2: Located between C3 and C1, this intermediate layer contained a mixed assemblage of ceramics ranging from the Iron Age to the medieval period. Due to extensive post-depositional disturbance, no discrete stratification could be distinguished.

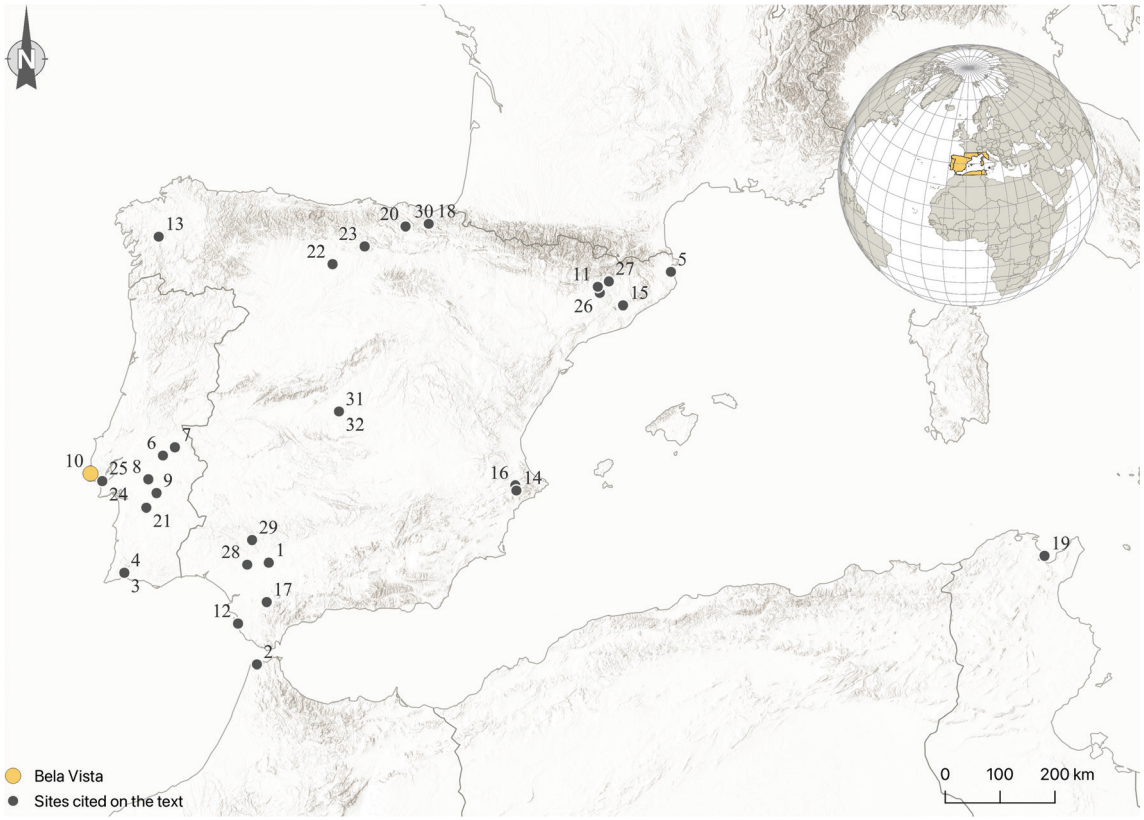

Fig. 2. Location of Bela Vista (Sintra, Portugal) and other referenced sites. 1. Acebuchal, 2. Aïn Dalia Kebira, 3. Alcalar 3, 4. Alcalar 4, 5. Ampurias, 6. Anta da Capela - Cavaleiros 1, 7. Anta dos Penedos de São Miguel, 8. Anta Grande da Comenda da Igreja, 9. Anta Grande do Zambujeiro, 10. Bela Vista, 11. Cabecinho de Capitõa, 12. Cal Rajolí, 13. Campo de Hockey, 14. Chousa Nova, 15. Cova de la Pastora, 16. Cova del Frare, 17. Cova del Llidoner, 18. Dolmen de Alberite, 19. Dolmen de Larrarte, 20. Douïmés, 21. Errekatxuetako Atxa, 22. Horta do Pinheiro 5, 23. La Velilla, 24. Las Arnillas, 25. Llano de la Sabina 99, 26. Quinta do Marcelo, 27. São Paulo 2, 28. Sepulcro de la Pera, 29. Sepulcro I de El Bosc, 30. *Tholos* de La Pastora, 31. *Tholos* de Palacio III, 32. Trikuaitzi I, 33. Valle de las Higueras 1, 34. Valle de las Higueras 3. Basemap: ESRI World_Hillshade. Site coordinates and details are provided in SF1. Source: https://www.arcgis.com/home/item.html?id=1b243539f4514b6ba35e7d995890db1d.

– C1: The lowest layer, directly beneath C2, was interpreted by the excavators as a predominantly prehistoric burial layer. Although partially disturbed, it was considered to represent a relatively intact Eneolithic (Iberian Copper Age, 3rd millennium BCE) context, with a minimum number of individuals (MNI) estimated at three (Pina, 2019).

Level C1 at Bela Vista yielded a diverse assemblage of artifacts spanning multiple periods. Notably, several Iron Age elements were recovered from this level, including wheel-thrown pottery fragments, a ceramic loom weight, and a silver arc fibula of Hallstatt type[3] (Mello *et al.*, 1961). These materials are clearly intrusive, contrasting with the core funerary assemblage, which includes handmade pottery, flint blades and flakes, an amphibolite axe head, a bone awl, two gold coils (now lost), an ivory V-perforated button, Palmela points, and eleven Bell Beaker vessels—objects that can be confidently attributed to the 3rd millennium BCE (Mello *et al.*, 1961; Leisner, 1965; Pina, 2019).

A particularly intriguing subset of this assemblage is a group of six beads—four made of greenstone, one of amber, and one of ceramic (Tab. 1; Fig. 3). Unfortunately, the original excavation records lack precise information

[3] *Também nos níveis superiores à camada eneolítica* [refers to C1] *foram encontrados muitos restos de cerâmicas de várias épocas assim como um peso de tear de idade do ferro e uma mola de prata de una fíbula de arco de tipo Hallstat* (Mello *et al*., 1961, p. 246). Translation to English: Also, in the levels above the Eneolithic layer [refers to C1] many remains of ceramics from various periods were found, as well as an Iron-Age loom weight and a silver spring from a Hallstat-type bow fibula.

regarding their findspot within Level C1 or their association with human remains or specific grave goods. This absence of detailed contextual data hampers interpretations of their chronological placement and ritual significance. Further complicating matters, museum catalogues group all artifacts under a general 'Bela Vista' label, without any stratigraphic distinctions or provenience metadata, obscuring the relationship between objects from different periods.

Bead ID	Height	Width	Perf. Ø	Shape*	Material	Color**
						L^* a^* b^*
533.6.4_1	4.69	13.34	3.30	Flat cylinder (I.D.1.b)	Variscite	45.9 -10.46 29.88
533.6.4_2	3.71	8.19	2.38	Disc (I.B.1.b)	Variscite	59.7 -22.19 35.6
533.6.4_3	3.64	6.01	1.60	Disc (I.B.1.b)	Muscovite	40.0 12.27 28.89
533.6.4_4	2.27	8.24	1.64	Disc (I.A.1.b)	Ceramic	32.7 25.05 16.28
533.6.4_5	2.40	7.94	1.67	Disc (I.A.1.b)	Variscite	– – –
533.6.4_6	3	7	–	Disc (I.A.1.b)	Amber	– – –

Tab. 1. Archaeological characteristics of the bead assemblage from Layer C1 of the Bela Vista *tholos* (Sintra, Portugal). * Follows Beck's (1928) classification system (e. g., I.A.1.b = small discoidal bead with central perforation). ** CIE Lab color coordinates were measured using a StellarNet StellaRAD+ color spectrophotometer, featuring a BLUE-Wave spectrometer with a 2k pixel detector (350–1150 nm) with a spectral resolution of <1 nm, an integrated halogen light source, a reflectance adapter, and a reflectance probe lens, making it ideal for field testing. The device was calibrated regularly during each run using an RS50 white reflectance standard to ensure consistent and accurate color measurements.

Fig. 3. Bead assemblage from Bela Vista (Sintra, Portugal).

Although beads are typically produced for use as personal adornments—such as necklaces, bracelets, anklets, pendants, or buttons—they are rarely found in direct association with specific individuals in megalithic burial contexts (Odriozola *et al.*, 2020). At Bela Vista, as in many other sites, beads were recovered from the basal levels of the burial layer, often scattered and not clearly linked to skeletal remains. In this case, only three teeth, several phalanges, and a skull cap fragment were found, making it impossible to determine whether the bead assemblage belonged to a specific individual or burial episode (Mello *et al.*, 1961).

3. THE AMBER BEAD OF BELA VISTA: A REDISCOVERY

The amber bead from Bela Vista was first documented by Otávio da Veiga Ferreira in his catalogue of prehistoric Portuguese amber artifacts, where he described it as *a small, brown, slightly translucent bead, fragile and poorly preserved* (Ferreira, 1966, p. 63). Despite this early reference, the bead subsequently vanished from scholarly view. During the first archaeometric study of Portuguese amber artifacts, Vilaça and colleagues were unable to locate it in the collections of the *Museu dos Serviços Geológicos de Portugal* (Vilaça *et al.*, 2002, p. 74), leading to the widespread assumption that the object had been lost (Odriozola *et al*., 2019, p. 572).

Aside from the original excavators (Mello *et al.*, 1961) and the last researchers known to have seen the bead (Leisner, 1965, p. 85; Ferreira, 1966), no subsequent documentation of its whereabouts has existed. This lacuna

persisted even during Pina's (2019) comprehensive review of the Bela Vista assemblage, which failed to relocate the artifact. The rediscovery of the amber bead by our team has resolved this decades-long uncertainty. Its identification corrects the archaeological record and enables new investigations into its composition, provenance, and cultural significance—issues that could not previously be addressed due to its presumed loss.

4. DISCREPANCIES IN DESCRIPTIONS OF THE BEAD ASSEMBLAGE

The bead assemblage from Bela Vista has been described inconsistently over time, with notable discrepancies among key publications by Mello *et al*. (1961), Leisner (1965), and Pina (2019). These inconsistencies have led to confusion regarding the composition and classification of the materials. A summary of the divergent accounts is presented in Tab. 2.

Author(s)	Description of Bead Assemblage	Notes
Mello *et al*., 1961	6 beads: 4 greenstone beads, 1 amber discoidal bead, and 1 ceramic discoidal bead	Provides a clear distinction between amber and ceramic beads.
Leisner, 1965	6 beads: 3 greenstone beads, 2 bone beads, and 1 amber bead	Substitutes the ceramic bead with two bone beads; retains mention of the amber bead.
Pina, 2019	7 beads: 2 ceramic beads, 4 greenstone beads, and 1 black stone bead	Misidentifies the amber bead as a ceramic bead; misclassifies a metal washer as a black stone bead.

Tab. 2. Descriptions of the Bela Vista bead assemblage by Mello *et al*. (1961), Leisner (1965), and Pina (2019), highlighting inconsistencies.

5. METHODOLOGY

5.1. Amber provenance and chronological analysis

Amber provenance was determined using Fourier-Transform Infrared Spectroscopy (FTIR), a well-established technique for distinguishing between amber types based on their diagnostic spectral characteristics. For example, Baltic amber is identified by its characteristic 'Baltic shoulder', consisting of prominent absorption peaks between 1160 and 1150 cm^{-1}, preceded by a broad horizontal band spanning 1250-1180 cm^{-1} (Beck *et al.*, 1964, 1965; Beck, 1982, 1986). In contrast, Sicilian amber exhibits a principal band at 1245 cm^{-1}, accompanied by secondary bands around 1182 cm^{-1} (Beck and Hartnett, 1993; Angelini and Bellintani, 2005). Iberian Cretaceous ambers are characterized by peaks at 1456, 1376, 1155, and 1030 cm^{-1}, along with a secondary feature at 1226 cm^{-1} (Peñalver *et al.*, 2007; Murillo-Barroso *et al.*, 2018).

The provenance of the amber bead from Bela Vista was determined by comparing its FTIR spectrum to these reference profiles. Spectral data were collected using a Nicolet iS5 FTIR spectrometer with an iD7 ATR module. Each sample was scanned 64 times across the 4000-525 cm^{-1} range, at a resolution of 4 cm^{-1}. This procedure ensures high accuracy and reproducibility, facilitating a reliable provenance determination.

In order to contextualize the bead chronologically, the FTIR results were integrated with stratigraphic and typological data (Garrido-Cordero *et al.*, 2024). This included evaluating the bead's stratigraphic position, associations with other artifacts, and typological traits. These data were cross-referenced with established chronological frameworks for amber consumption on the Iberian Peninsula, enabling assessment of whether the bead corresponds to the Bronze Age, Iron Age, or an earlier period.

5.2. Elemental composition and provenance analysis of greenstone beads ('callaite')

The greenstone beads—historically labeled as 'callaite'—were analyzed using the MACLAS framework, a supervised machine learning (ML) approach for mineral identification based on elemental composition. MACLAS employs a gradient boosting classifier trained on geochemical data to distinguish both major mineral classes (e. g., phosphates, silicates) and specific mineral species (e. g., variscite, muscovite), with confidence scores indicating the reliability of each classification. This non-destructive method enables fast and accurate mineral identification.

For beads identified as phosphate minerals, their provenance was further assessed using the VORTEX (Variscite Origin Recognition Technology X-ray based) framework. VORTEX applies a Random Forest classifier trained on a comprehensive dataset of Iberian variscite sources, enabling probabilistic assignment of beads to specific geological deposits. The model provides accurate provenance predictions with a confidence threshold of >0.7, and has been externally validated, achieving 95 % accuracy in source classification.

Elemental composition data were obtained using an Oxford Instruments XMET-7500 handheld X-ray fluorescence (XRF) spectrometer, equipped with a rhodium X-ray tube, silicon drift detector (SDD), and an automated 5-position filter changer. Quantification was conducted using the SOILS-LE calibration program, which applies the fundamental parameters (FP)[4] method for precise elemental analysis.

The combined use of MACLAS and VORTEX provides a robust and reproducible approach for characterizing the mineralogical composition and determining the geological provenance of green phosphate beads in archaeological contexts.

6. RESULTS AND DISCUSSION

6.1. Amber

The FTIR spectra of bead 533.6.4_6 confirm that the raw material is Baltic amber, as evidenced by the presence of the characteristic 'Baltic shoulder'. This feature is defined by strong absorption bands at ~1160 and 1150 cm^{-1}, preceded by a horizontal band from 1250 to 1180 cm^{-1} (Beck *et al.*, 1964, 1965; Beck, 1982, 1986), confirming a Baltic provenance (Fig. 4).

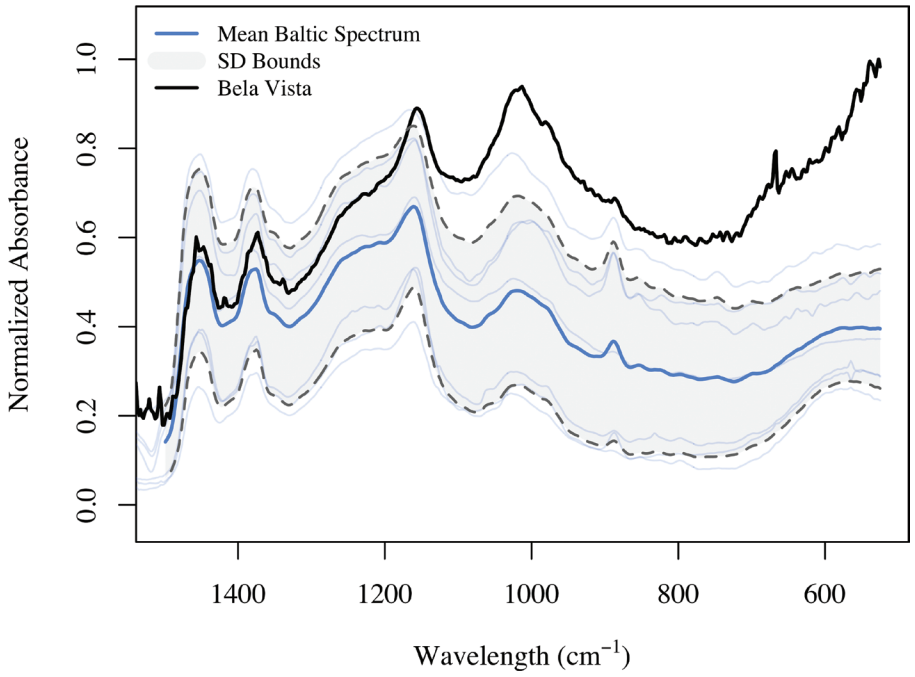

Fig. 4. Mean Baltic amber spectrum (blue line), constructed using reference spectra from the IRUG database (www.irug.org): INR00213, INR00214, INR00215, INR00283, INR00287, and INR00361, representing a range of Baltic amber samples. The shaded area (light grey) indicates the standard deviation (SD), illustrating inter-sample variability. The spectrum from Bela Vista (black line) is overlaid for comparison.

On the Iberian Peninsula, Baltic amber beads are predominantly associated with the Bronze and Iron Ages, based on radiocarbon-dated contexts (Garrido-Cordero *et al.*, 2024). The amber bead from Bela Vista, while undated, has

[4] Each sample was analyzed for approximately 60 seconds, with all chemical elements from magnesium (Mg) to uranium (U) measured and quantified. To ensure accuracy, 32-mm pellets of certified reference materials (BCR-032 #919 and GMB306-12) were analyzed at the beginning and end of each run.

been tentatively linked to Bell Beaker pottery (Leisner, 1965, pp. 85-87; Ferreira, 1966, p. 63). However, the excavators (Mello *et al.*, 1961) reported significant stratigraphic disturbance due to looting, undermining this attribution. Similar issues are present at sites like Larrarte (Beasain, Guipúzcoa) (Mujika and Armendáriz, 1991; Álvarez Fernández *et al.*, 2005), El Bosc I (L'Espunyola, Barcelona) (Serra, 1927; Rovira i Port, 1994, 1996), and Sepulcre de la Pera (Pinós, Lleida) (Castany Llusà and Guerrero Sala, 2010), where amber beads were found near Bell Beaker pottery under ambiguous stratigraphic conditions.

Recent studies indicate that Bell Beaker funerary contexts in inland Iberia frequently include exotic objects, such as amber, marine shells, flint, gold, and variscite. These objects were not necessarily deposited with the same individuals, suggesting complex burial practices and structured spatial associations (Barroso *et al.*, 2015, p. 168). However, Du Gardin (1998, p. 347) emphasizes the limited and highly selective use of amber, primarily in funerary contexts, with only a small fraction of Beaker-associated burials containing it. Alday Ruiz (2018) cautions against assuming a direct link between such materials, noting that the spatial distributions of Bell Beaker pottery, amber, and variscite only partially overlap.

The presence of Baltic amber and Bell Beaker pottery at sites such as Bela Vista may be due to:

1. Different individuals being interred in shared or reused funerary spaces.
2. Stratigraphic disturbances, site reuse, or hoard depositions that displaced materials across layers.

In Larrarte, for example, a Baltic amber bead was found alongside Bell Beaker pottery, but radiocarbon dates from the tomb span 4236-1690 cal BCE[5], with the final burial dated to 2289-1690 cal BCE (Mujika and Edeso, 2011)[6], suggesting the bead belongs to the Early Bronze Age. El Bosc I, another example, included late Bell Beaker pottery, a glass bead, and amber beads, dated to the Middle Bronze Age (Rovira i Port, 1994, p. 82). The Baltic origin of those amber beads was recently confirmed (Garrido-Cordero *et al*., 2024).

At Sepulcre de la Pera, despite stratigraphic issues, the presence of Pyrenean-style Bell Beaker pottery and Baltic amber supports a Bronze Age use (~2000-1500 cal BCE) (Castany Llusà and Guerrero Sala, 2010, p. 29).

These cases suggest that the Bela Vista amber bead could date to the Early Bronze Age (2200-1800 BCE), overlapping with the final phases of Bell Beaker use in Portuguese Estremadura (Cardoso, 2014). However, the presence of Iron Age materials in Level C1, such as wheel-thrown pottery and a Hallstatt-type silver bow fibula (Vilaça and Cardoso, 2017), complicates a straightforward association.

The fibula, described by Vilaça (2006), and Vilaça and Cardoso (2017) as a double-spring fibula, lacks the typical breaks for the pin and pin-holder (Fig. 5), raising doubts about its identification.

Further evidence from Quinta do Marcelo (Setúbal), a site with no Bell Beaker pottery, strengthens an Iron Age connection. There, a Baltic amber bead was found in waste pit 2 (level 1), together with a double-spring bronze fibula and high-end artifacts (Soares and Arruda, 2017, pp. 243-244). Radiocarbon dates for this context (1439-209 cal BCE) (Melo and Senna-Martínez, 2001) and associated materials support a Late Bronze to Early Iron Age attribution.

Silver fibulae are rare in pre-Roman Iberia, though not unprecedented. Examples include one from El Acebuchal (Carmona, Seville, 7th-5th centuries BCE) and another from a cremation at the northeast wall of Ampurias (Girona, late 6th century BCE) (Bonsor, 1899, pp. 24-27; Navarro, 1970, p. 56; Ferrer Albelda, 2014, p. 395). Comparable silver fibulae are also known from Punic necropolises, such as Douïmés (Carthage, 8th-7th centuries BCE) (Delattre, 1897). If the Bela Vista coil is indeed a fibula, the bead may date to the 7th-5th centuries BCE. Alternatively, the coil could have functioned as a bead—an interpretation supported by a silver washer misidentified as a black stone bead by Pina (2019) (Fig. 6). Parallels for such silver bead assemblages come from Phoenician-Punic tombs such as Aïn Dalia Kebira (Tangier), where similar components are recorded (Blaschta *et al.*, 2024, p. 164, fig. 5).

In the Iberian Peninsula, a similar association between Baltic amber objects and Late Bronze/Iron Age bronze wire coil can also be observed, as in the reuse of megalithic structure of Llano de la Sabina 99 (Gorafe, Granada) (Lorrio, 2008, p. 187; Murillo-Barroso *et al.*, 2018).

Compounding the ambiguity are 15 copper-based artifacts[7], including arc-shaped filaments, which could represent fragments of bronze rings, fibulae, or earrings (Mello *et al.*, 1961; Pina, 2019, p. 61, fig. 181), highlighting the disturbed nature of Level C1 and strengthening the association with an Iron Age deposit.

[5] Radiocarbon dating was conducted on only six of the twelve recovered individuals. The most recently dated individual is associated with Bell Beaker pottery and an amber bead.

[6] SPD of 3620 ± 60 BP, GrA-20497, Human bone, intcal20 (Reimer *et al.*, 2020), 2 sigma, on rcarbon (Crema and Bevan, 2021).

[7] In addition to these 15 copper-based items, Mello *et al*. (1961, p. 243) document a Palmela-type arrowhead and a knife point, both of which are confidently dated to the 3rd millennium BCE.

Fig. 5. Silver wire-coil from Bela Vista (Sintra, Portugal). Drawing by Luz Marina Salas.

Fig. 6. Silver washer from Bela Vista's (Sintra, Portugal) level C1: four silver fragments interpreted as components of a washer, and proposed reconstruction. Drawing by Luz Marina Salas.

The co-occurrence of amber and wire-coiled beads is a hallmark of elite Iron Age burials, especially in the Balkans (11th-6th centuries BCE) (Ivanova and Kuleff, 2009, pp. 27-32). One notable example is a female burial near Gradets (Bulgaria), which included amber, bronze and silver spiral beads, and fibulae. A striking parallel from Djurslöv (Sweden) features a young woman buried with alternating amber and silver coiled beads suspended between two bronze fibulae (Lundqvist, 2018, pp. 70-73).

These Mediterranean and European analogies suggest that the Bela Vista assemblage represents a high-status Iron Age burial, possibly influenced by Phoenician or Mediterranean trade networks. A stylistic reconstruction (Fig. 7) illustrates how the materials may have been worn—amber beads alternating with silver spirals, a cloak fastened with fibulae, and bronze earrings.

Fig. 7. Reconstruction of an elite Iron Age woman from Bela Vista (Sintra, Portugal), wearing a cloak fastened with two Acebuchal-type fibulae, bronze earrings, and a necklace alternating amber beads with silver coils, based on material analyses and Phoenician-Punic parallels. Drawing by Luz Marina Salas.

Current research indicates that the large-scale circulation of Baltic amber into Iberia did not begin until after 1200 BCE, in contrast to its earlier presence in Central Europe, the Aegean, and the British Isles (Vandkilde *et al.*, 2024). The unique case of a Baltic amber bead from Cova del Frare (Matadepera, Barcelona) dated to the 4th millennium BCE (Murillo-Barroso *et al.*, 2023) is likely the result of post-depositional movement or contamination, given the implausibility of such an early date (Garrido-Cordero *et al.*, 2024). The site also yielded an Iron Age sword and fusiform glass bead, reinforcing a Late Bronze or Iron Age context (Giró i Romeu and Masachs, 1968; Rafel i Fontanals, 1978).

Therefore, while a tentative association with Bell Beaker contexts cannot be entirely excluded, the cumulative archaeological, stratigraphic, and compositional evidence, together with comparative parallels, strongly supports an Iron Age attribution for the Bela Vista amber bead.

6.2. Greenstone

Analysis via the MACLAS (Sánchez-Gómez *et al.*, 2024) classified three beads as variscite (Group VII – Phosphates, Arsenates, Vanadates of *Dana's New Mineralogy*; Gaines *et al.*, 1997), with a probability score >97 %. One bead was classified as muscovite, a phyllosilicate from Group VIII (Silicates) (Tab. 3).

Bead ID	MACLAS prediction	MACLAS score	VORTEX score	Mello *et al*., 1961	Leisner, 1965
533.6.4_1	Phosphates, Arsenates, Vanadates	Variscite: 0.9702 Talc: 0.0025 Aheylite: 0.0023	Aliste: 0.6966 Garraf: 0.2369 Terena: 0.0665	Callaite	Callaite
533.6.4_2	Phosphates, Arsenates, Vanadates	Variscite: 0.9707 Talc: 0.0025 Aheylite: 0.0022	Aliste: 0.8761 Garraf: 0.1102	Callaite	Callaite
533.6.4_3	Silicates	Muscovite: 0.9506 Variscite: 0.0188 Clinochlore: 0.0031	-	Callaite	Bone
533.6.4_4	-	-	-	Ceramic	Bone
533.6.4_5	Phosphates, Arsenates, Vanadates	Variscite: 0.9703 Talc: 0.0025 Chlorite-serpentine: 0.0023	Aliste: 0.859 Garraf: 0.1321 Terena: 0.0089	Callaite	Callaite
533.6.4_6	-	-	-	Amber	Amber

Tab. 3. MACLAS and VORTEX predictions.

The VORTEX model (Sánchez-Gómez *et al.*, 2025, 2026) suggests that beads 533.6.4_1 and 533.6.4_5 likely originate from the Aliste region (Zamora, Spain), with ~86 % confidence, and bead 533.6.4_2 with ~70 %. This supports a Palazuelo de las Cuevas source (Villalobos García and Odriozola, 2016).

While early classifications (Mello *et al.*, 1961; Leisner, 1965) were mostly correct, one bead previously labeled variscite was identified as muscovite. Such mixed assemblages of phosphate, mica, and silicate beads are common. The dominance of variscite suggests long-distance exchange, underscoring Bela Vista's significance.

The Aliste origin aligns these beads with the Bell Beaker phase (2600-1800 BCE) (Odriozola *et al.*, 2016), supported by variscite's declining availability in the 2nd millennium BCE.

6.3. Amber and variscite in Iberia

Although the available evidence strongly suggests that the Baltic amber bead from Bela Vista is best attributed to the Iron Age, and that the greenstone beads are more likely associated with a late 3rd millennium BCE (Copper Age) context, the possibility of an Early Bronze Age (*ca*. 2200-1800 BCE) attribution for the amber bead cannot be entirely ruled out.

Amber and variscite have been found together in numerous Iberian funerary contexts, including Campo de Hockey tomb E3-C15 (Cádiz; Vijande Vila *et al.*, 2015), Chousa Nova (Pontevedra; Domínguez Bella and Bóveda, 2011), Dolmen de Alberite (Cádiz; Domínguez Bella, 1996; Domínguez Bella *et al.*, 2001), Anta da Capela (Portalegre; Odriozola *et al.*, 2019), Anta Grande do Zambujeiro (Évora; Odriozola *et al.*, 2012, 2019), Anta Grande da Comenda da Igreja (Évora; Leisner, 1965), Anta dos Penedos de São Miguel (Portalegre; Claustre *et al.*, 2005), Alcalar tombs 3 and 4 (Faro; Sousa *et al.*, 2024), São Paulo 2 (Setúbal; Barros and Espíritu Santo, 1997), Las Arnillas (Burgos; Villalobos García, 2016), La Velilla (Palencia; Villalobos García, 2016), Errekatxuetako Atxa (Bizkaia; López Quintana, 2015), Trikuaitzi I (Guipúzcoa; Mujika and Armendáriz, 1991), Cova de la Pastora (Alicante; García-Puchol *et al.*, 2012), Cal Rajolí (Lleida; Serra, 1927), *tholos* de la Pastora (Seville; Almagro, 1962; Murillo-Barroso *et al.*, 2018), Perdigões tomb 1 and tomb 2 (Reguengos de Monsaraz; Odriozola *et al.*, 2010; Valera, 2017), and Valle de las Higueras 1 and 3 (Toledo; Barroso *et al.*, 2021).

While these associations confirm that amber and variscite could form part of the same burial assemblages, analytical studies consistently indicate that the amber found at these sites is not of Baltic origin. This significantly reduces the likelihood that variscite was ever associated with Baltic amber in prehistoric Iberian contexts, making such a combination—like that proposed for Bela Vista—highly improbable.

The Baltic origin of the Bela Vista bead therefore aligns more convincingly with an Iron Age chronology. The absence of variscite in Iberian sites with confirmed Baltic amber further reinforces this interpretation and diminishes the plausibility of an Early Bronze Age context for the Bela Vista bead.

Moreover, the scarcity of Baltic amber in pre-Bronze Age Iberian contexts remains a major challenge to such an attribution. As previously discussed, the large-scale introduction of Baltic amber into the Iberian Peninsula only began after *ca*. 1200 BCE, during the Late Bronze Age (Vandkilde *et al.*, 2024). The exceptional case of a Baltic

amber bead from Cova del Frare, dated to the 4th millennium BCE (Murillo-Barroso *et al.*, 2023), remains an anomaly and is likely the result of post-depositional disturbance or contamination. The same site also yielded Iron Age materials, including a sword and a fusiform glass bead, further supporting a later chronological framework (Giró i Romeu and Masachs, 1968; Rafel i Fontanals, 1978; Murillo-Barroso *et al.*, 2023).

That said, an Early Bronze Age attribution for the Bela Vista bead cannot be categorically ruled out. If the bead was indeed deposited during this period, it would represent a rare—though not unprecedented—instance of Baltic amber reaching western Iberia via long-distance exchange networks linking the Baltic region to Central Europe and, indirectly, to the Iberian Peninsula. This trend can be observed, for instance, in the prestigious burials at Horta do Pinheiro 5 (Torrão do Alentejo), which contain ivory and silver (Monge *et al.*, 2021).

The discovery of a complete amber necklace at Cabecinho da Capitôa (Sousa *et al.*, 2022), located on the northern platform of the Serra de Sintra very close to Bela Vista, is also noteworthy. This find has been radiocarbon dated to the 8th and 6th centuries BCE (Sousa *et al.*, 2022). As with other deposits—such as the Iron Age hoard from Palacio III (Almadén de la Plata, Seville; Murillo-Barroso and Martinón-Torres, 2012)—this assemblage does not appear to have served a funerary purpose.

Based on the current archaeological, stratigraphic, and compositional evidence, we propose that the variscite beads from Bela Vista are most plausibly associated with a Copper Age burial, in keeping with broader Iberian patterns of variscite use and circulation during the 3rd millennium BCE. In contrast, the Baltic amber bead and associated silver wire coil are more credibly linked to an Iron Age burial, most likely dating to the 7th-5th centuries BCE. This interpretation is supported by regional patterns of Baltic amber consumption during the Iron Age, the typological features of the associated artifacts, and the complex stratigraphy of the Bela Vista *tholos*.

While a tentative Early Bronze Age attribution for the amber bead remains theoretically conceivable—especially given that the Beaker horizon extended into the early 2nd millennium BCE and that Baltic amber exchange had already begun in northwestern Europe—we consider this scenario less likely. The presence of Iron Age materials in the same stratigraphic layer, the extreme rarity of pre-Bronze Age Baltic amber in Iberia, and the contextual and typological parallels all favor an Iron Age attribution.

7. CONCLUSIONS

Our examination of personal adornment materials has enabled the reintegration into scholarly discourse of the amber bead from the Bela Vista *tholos*, which had remained unaccounted for over six decades. Through FTIR analysis, we have confirmed its Baltic origin. This, coupled with its association with a silver artifact, provides strong support for an Iron Age chronology (7th-5th centuries BCE).

The Baltic amber bead from Bela Vista must be understood within two key contextual frameworks: the near-total absence of Baltic amber in pre-Bronze Age Iberia, and its association with silver, a material rarely found in prehistoric funerary contexts in Portugal. While amber is present in Copper Age and Bell Beaker contexts, it is exclusively of Sicilian origin (Murillo-Barroso *et al.*, 2018; Odriozola *et al.*, 2019). Notably, no association exists between Baltic amber and either Bell Beaker vessels or variscite beads in Iberian archaeological contexts. In all documented cases where variscite co-occurs with amber, the latter is Sicilian—never Baltic.

The analytical results presented here, particularly the FTIR identification of Baltic amber and the associated silver coil, further support an Iron Age attribution. This aligns with the emergence of Baltic amber in Iberian contexts *ca*. 1200 BCE (Vandkilde *et al.*, 2024) and with parallels from Iron Age votive deposits, such as those documented at Palacio III (Murillo-Barroso and Martinón-Torres, 2012), Llano de la Sabina 99 (Murillo-Barroso *et al.*, 2018), Cova del Llidoner (Alicante) and Correio-Mor cave (Lisboa; Garrido-Cordero *et al.*, 2024), where later materials were introduced into earlier megalithic contexts.

We propose that the Bela Vista megalithic tomb was reused during the Iron Age for a high-status funerary deposit, which included a Baltic amber bead, a silver wire-coil, and other bronze objects—likely personal adornments. This secondary use is consistent with a broader pattern of monument reuse in Iberia, where prehistoric tombs were reappropriated for elite burials or ritual depositions in later periods (Lorrio, 2008).

At the same time, the presence of Bell Beaker pottery, Palmela points, and V-perforated buttons, in the primary assemblage confirms the site's main use during the second half of the 3rd millennium BCE. An earlier Copper Age phase may also be inferred from the presence of *copos canelados*, which were identified by Pina (2019) but largely overlooked in earlier publications. These objects suggest a funerary phase, potentially linked to long-distance exchange networks that brought exotic materials such as variscite into the region. However, the limited contextual information in excavation records and museum catalogues hinders a full reconstruction of the original burial sequence.

One of the most significant outcomes of this research is the reidentification of a set of silver disc-shaped beads, previously interpreted as part of a fibula coil. Their morphology, contextual association, and typological features strongly suggest their use as independent ornamental elements. This finding represents a novel contribution to the archaeological record of Portugal, as such items had not been previously documented in Iron Age contexts within the region. Their presence reinforces the interpretation of the Bela Vista *tholos* as a site of high-status reuse during the Orientalizing period.

Ultimately, this study highlights the value of applying modern analytical techniques to legacy collections. The rediscovery and reclassification of the amber bead—previously thought lost and misidentified—demonstrate the potential of reexamining museum holdings to yield new archaeological insights. The integration of archaeometry with contextual and typological data has clarified the multi-period use of the Bela Vista monument and refined our understanding of long-distance exchange and symbolic practices in prehistoric Iberia.

SUPPLEMENTARY FILES

The following supplementary material is available on the journal's website: SF1. Coordinates and details of the sites mentioned in the text.

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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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AUTHORSHIP CONTRIBUTION STATEMENT

José Ángel Garrido-Cordero: conceptualization, data curation, formal analysis, investigation, writing – original draft, writing – review & editing.

Rita Loureiro: investigation.

José María Martínez-Blanes: formal analysis, investigation, methodology, validation, writing – review & editing.

Ana C. Sousa: writing – review & editing.

María Dolores Zambrana-Vega: investigation.

Luz Marina Salas Acosta: visualization.

Daniel Sánchez-Gómez: investigation.

Carlos P. Odriozola: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, validation, writing – original draft, writing – review & editing.

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