Journal of Archaeological Science 150 (2023) 105708

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: www.elsevier.com/locate/jas

New insights into the use and circulation of reindeer antler in northern Iberia during the Magdalenian (ca. 21-13 cal ka BP)

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ARTICLE INFO

Keywords:
Osseous technology
Hunter-gatherers
Ecological niche modelling
Raw material circulation
Iberian Peninsula

ABSTRACT

Interactions between prehistoric foragers and reindeer at the end of the Pleistocene are still poorly documented in northern Iberia, particularly the reasons and means by which their antlers were collected, processed and circulated. Here we review the main osseous industries dated to between 21 and 13 cal ka BP, focusing on the use and circulation of reindeer antler as a raw material for the production of weapons and tools by Magdalenian foragers. Thirty-six reindeer antler artefacts were identified from 11 Iberian sites that are located at either end of the Pyrenees: the Cantabrian region to the west, and to a lesser extent, in Catalonia to the east. Despite biases in the identification of production objectives (end-products), a detailed techno-typological, chronological and geographical analysis of these assemblages reveals both the existence of a consistent reindeer antler industry in northern Iberia and long-distance connections between the Cantabrian region and the Pyrenees. The integration of contemporary macrofaunal data makes it possible to explore the extension of the reindeer's ecological niche in northern Iberia, as well as strategies for the acquisition and circulation of reindeer antler in the peninsula. Assuming that some reindeer assemblages result from the import of raw materials to supply manufacturing activities, we propose a scenario where the acquisition of reindeer antlers may have been organised at a local scale in the Basque region, and potentially in the neighbouring territories of Navarre, Cantabria and Asturias. On the other hand, in Catalonia, the combination of both faunal and technological data supports the hypothesis that reindeer antlers were imported (along with pelts) over longer distances, probably from the northern Pyrenees.

1. Introduction

Due to their abilities to adapt to cold environments and their gregarious nature, reindeer (*Rangifer tarandus*) were heavily exploited by humans in periglacial contexts, including modern arctic herders and prehistoric hunter-gatherers (e.g., Beyries and Vaté, 2007). In some regions of Europe, reindeer were a key prey species for Palaeolithic foragers, to such an extent that the Magdalenian (ca. 21-13 cal ka BP) in southwestern France was described by early prehistorians as "the Reindeer Age" (Lartet, 1861). Reindeer antlers were also an essential raw material for the manufacture of weapons, domestic tools and even personal ornaments (e.g., Albrecht, 1977; Averbouh, 2000, 2005; Pétillon, 2006; Costamagno et al., 2016; Lefebvre, 2016; Langley, 2018; Pastoors et al., 2019). Due to differing ecological conditions across Iberia, a similar pattern is observed with red deer (*Cervus elaphus*), which was the main large cervid species during the Late Pleistocene (Meiri et al., 2013) and one of the main prey species for hunter-gatherer groups (e.g., Altuna, 1972, 1995; Yravedra Sainz de los Terreros, 2001; Costamagno and Mateos Cachorro, 2007; Marín-Arroyo, 2010; Portero Hernández, 2022). Red deer were central to both the subsistence and technical needs, and its antlers were used for the production of a significant portion of osseous industries in Iberia (e.g., Mújica, 1983; González Sainz, 1989; Adán Álvarez, 1997; Almeida Évora, 2016; Lefebvre, 2016; Villaverde et al., 2016; Straus et al., 2018; Tapia et al.,

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https://doi.org/10.1016/j.jas.2022.105708
Received 21 August 2022; Received in revised form 6 December 2022; Accepted 12 December 2022
Available online 26 December 2022

2018; Erostarbe-Tome et al., 2022).

However, in the last decade, a growing body of evidence has demonstrated that European reindeer populations tracked suitable tundra-steppe-like environments southwards into Iberia during Late Pleistocene (Berganza et al., 2012; Gómez-Olivencia et al., 2014; Castaños et al., 2014a), thus questioning the Pyrenees being a natural ecological barrier (Costamagno and Mateos Cachorro, 2007). Although numerous paleontological studies, sometimes very early, traced the past distribution of reindeer populations on the peninsula (Harlé, 1908; Altuna, 1971; García and Arsuaga, 2003; Álvarez-Lao and García, 2010, 2011; Gómez-Olivencia et al., 2014), the exact extent of this species' ecological niche remains to be determined. As a result, interactions between humans and reindeer are poorly understood in this area, particularly why and how antlers were collected, processed and circulated. To overcome these shortcomings, we reassessed osseous industries made on reindeer antler and focused on northern Iberian sites dated to the Magdalenian period. With numerous and varied assemblages of worked bone and antler, a precise chronological framework and marked climatic and ecological variations, the Magdalenian (ca. 21-13 cal ka BP) of northern Iberia is an ideal case study for documenting human-animal interactions during the Late Pleistocene.

2. Paleoenvironmental context: the north of Iberia between 21 and 13 cal ka BP

The north of Iberia (excluding the most western region of Galicia) is marked by contrasting reliefs that can be divided into three main ecological zones, from west to east: the Cantabrian region, the southern slopes of the Pyrenees and the northeast of Catalonia (Fig. 1).

The Cantabrian region comprises, from west to east, the current provinces of Asturias (Fig. 1, A), Cantabria (Fig. 1, B), Biscay and Gipuzkoa (Fig. 1, C). For this study, we focused on a 25 to 50-km-wide littoral band, extending west to east over approximately 350 km, from the Nalón River in the centre of Asturias to its eastern limits in the Pyrenees. The region is bordered to the north by the Gulf of Biscay (also referred to as the Cantabrian Sea in this area), and to the south by the Cantabrian Cordillera, with altitudes ranging between 1,500 and 2,000 m a.s.l., and a maximum altitude of 2,700 m a.s.l. (Picos de Europa). The region is drained by relatively deep, narrow valleys essentially oriented south-north and forming an independent catchment area. Punctuated by what are at times steep foothills, giving way to the limited coastal valleys and plains, the region also contains a well-developed karstic system and is one of the main areas occupied by Magdalenian foragers in Iberia.

The Pyrenees Mountain range is generally oriented east-west, forming an isthmus that stretches some 440 km from the Bay of Biscay to the Gulf of Lion. The highest peaks (around 3,500 m a.s.l.) are located in its axial part. The southern slope, which is twice the area of the northern slope (Montés and Domingo, 2013), opens onto the Ebro Valley which is currently characterised by dry, continental conditions. Among the different provinces included in this area (i.e., Navarre, Zaragoza, Huesca, etc.), the southern part of Navarre (Fig. 1, D) represents the western limit. The chain is cut into deep and sinuous valleys that are generally oriented north-south and represent the only trans-Pyrenean communication routes between the two sides of the mountain chain (Lacombe, 1998). Bypass zones can be found at either end of the mountain range. To the west, where landscapes are more varied and include medium mountains incised by numerous rivers, the highest peaks gradually decrease to 2,500 m a.s.l., until they drop to sea level in the area of Bas Adour and the Atlantic coast. In the east, on the other hand, mountainous zones abruptly disappear around 50 km from the coast. As a result, the landscape is more contrasted with high reliefs (up to 2,921 m a.s.l. for the Carlit) meeting the large coastal plain of Roussillon.

The northeast part of Catalonia (Fig. 1, E) is an approximately 40 km wide natural corridor that runs along the eastern Pyrenees to the west and the Mediterranean Sea to the east. Its relief is made up of the lowlands of the Catalan coastal chains that are drained by the different river basins that flow towards the Mediterranean Sea (e.g., the basins of Fluvià, Ter or Llobregat) or the Ebro River (Segre Basin).

Climatic reconstructions built from terrestrial, marine and Greenland ice records show that the Late Glacial period, between 21 and 13 cal ka BP, was marked by a progressive global warming, punctuated by more or less rapid cold events leading to the post-glacial conditions of the Holocene (Naughton et al., 2007, 2016, 2023; Stanford et al., 2011; Rasmussen et al., 2014; Osman et al., 2021). Following the end of the Late Pleniglacial, characterised by very cold and dry climatic conditions (GS-2.1 b), the following deglaciation displays substantial instability that sets in from ca. 17 to 14.8 cal ka BP (GS-2.1a), corresponding to the Dryas I in the continental record. Despite still cold climatic conditions, ice-rafted debris is recorded in the North Atlantic Ocean, leading to

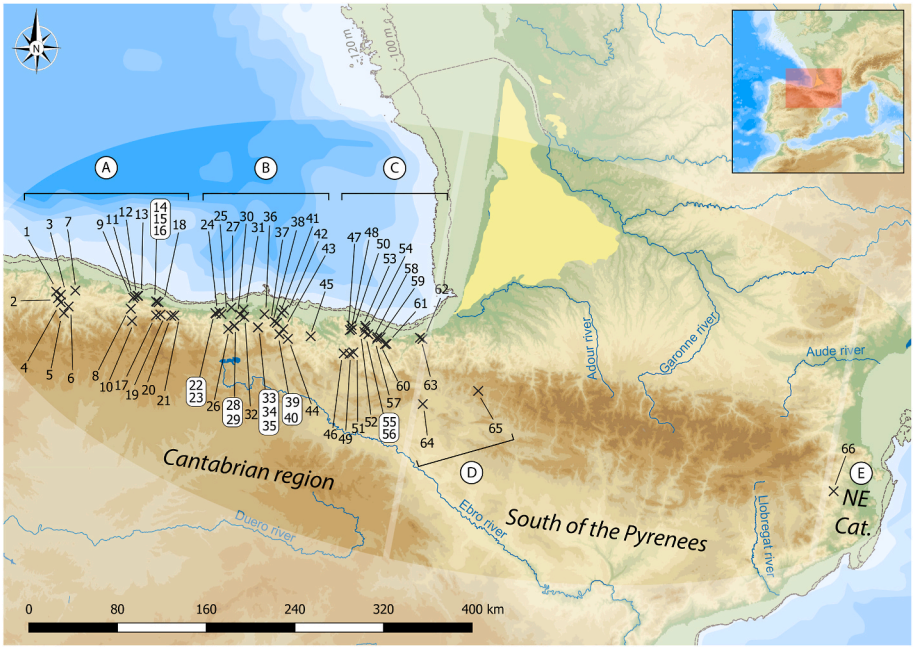

Fig. 1. Distribution of Iberian Magdalenian sites examined in this study. The Cantabrian region includes: A: Asturias, B: Cantabria, C: Iberian Basque region; D: Navarre; E: North East of Catalonia. The marine levels −120 m and −100 m correspond, respectively, to the LGM and the following Late Glacial (Benjamin et al., 2017). Relief is derived from altimetric data available in Reuter et al. (2007) and Jarvis et al. (2008), and bathymetric data are from Natural Earth (www.naturalearthdata.com). The "Sables des Landes" region appears in yellow (data from Sitzia, 2014). See Table 1 for site names. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

cooler sea surface waters (Heinrich Event 1 – HE1). The following Greenland Interstadial 1 is characterised by a sharp rise in temperatures between broadly 15 to 13 cal ka BP.

3. Material and methods

3.1. Osseous artefact assemblages

We carried out a systematic examination of the main Magdalenian osseous industries from northern Iberia (Table 1; Fig. 1) that included antler artefacts, as well as worked bone and ivory. Assemblages from 66 sites attributed to the Magdalenian by the excavators or following subsequent revisions were examined. As several assemblages derived from early excavations (before the 1960s) with poor stratigraphic control by modern standards, available contextual information varies. An additional bias in the studied assemblages is linked to the fact that the worked osseous artefacts were not systematically isolated among the faunal remains. Consequently, still unidentified bone and antler artefacts present in faunal assemblages is impossible to quantify. All reindeer remains come from cave sites, which tend to preserve organic material better than open-air sites, which is tied to soil acidity that varies significantly throughout the region (Gómez-Olivencia et al., 2014; Contreras et al., 2017). No significant biases were identified during our study in terms of the differential preservation of osseous materials between sites or materials (i.e., bone, ivory and antler). Dates associated with the reindeer remains were compiled from the literature and calibrated using the OxCal program (Bronk Ramsey, 2017) and the IntCal20 curve (Reimer et al., 2020) at 2σ (95% confidence interval) to correlate them with climatic data.

3.2. Criteria for identifying reindeer antler

When well-preserved, antler can easily be distinguished from other osseous raw materials (i.e., terrestrial mammal bone, marine mammal bone and ivory) including antlers of different cervid species (e.g., reindeer, red deer, roe deer). However, as osseous remains from Pleistocene deposits are often fragmented and affected by human-induced as well as post-depositional processes, identifying them is not always straightforward. Given the palaeoenvironmental context, the main issue for the present study was distinguishing reindeer from red deer antler, the two main cervid species then exploited by Magdalenian groups. Despite some interspecies variability, these two biomaterials display sufficiently marked anatomical differences to allow them to be reliably separated (see among others Averbouh, 2000; Ashby, 2013; Lefebvre, 2016; Lefebvre et al., 2016): as the presence of a posterior tine in reindeer (instead of a trez tine in red deer), palmate ends (more developed in adult males), flatter cross-sections and smoother surfaces compared to the circular to quadrangular cross-sections in red deer, as well as the presence of a typical pearling, particularly developed around the burr base. These characteristics are fairly well-documented and allow antlers from the two species to be separated with a good degree of certainty. However, when antler is highly fragmented, transformed or affected by post-depositional agents, identifying pieces to species can be difficult. In such cases, only relatively non-destructive physico-chemical methods can reliably differentiate them, such as ancient proteomics (von Holstein et al., 2014; Welker et al., 2016) or micro-CT approaches (Lefebvre et al., 2016) based, respectively, on collagen peptide mass fingerprint and the microstructure of the spongy tissue. For this study, the distinction between reindeer and red deer antlers was made uniquely using traditional anatomical criteria observed with the naked eye and at low magnification (for more details concerning antler anatomy and sizes see Lefebvre et al., 2016).

3.3. The technological analysis of osseous industries

The technological analysis consists in reconstructing the production processes for osseous objects, from the acquisition of the raw material, through tool manufacture, the identification of waste products and working techniques, up to the use, maintenance and discard of tools and weapons (e.g., Lefebvre, 2016; Tapia et al., 2018; Straus et al., 2018; Borao Álvarez, 2019; Erostarbe-Tome et al., 2022 for Magdalenian examples in Iberia). Reconstructing such production sequences sheds light on the technical, economic and even social choices made by foragers in terms of the availability of the raw materials, raw materials productivity and/or the mobility requirements of groups. The analysis of manufacturing traces and use-wear was carried out at low magnification (× 50) and taphonomic traces were identified based on several modern and archaeological reference collections (e.g., Olsen, 1989; Averbouh, 2000).

4. Results

4.1. Worked reindeer antlers

Thirty-six artefacts from 11 Iberian Magdalenian sites were determined to be manufactured from reindeer antlers (Table 2, and more details in Table S1). Among them, 22 are newly discovered, six were already identified and sometimes illustrated, and it is difficult to determine if the eight remaining artefacts (from Santimamiñe-VI/VII, Urtiaga-D and Ekain-VIa) were already identified or not, given that reindeer antler remains were mentioned from these sites but no details were provided concerning whether the artefacts were worked (respectively Castaños, 1984; Altuna, 1971; Altuna and Mariezkurrena, 1984). Eight artefacts previously identified as reindeer antler in the literature (from the sites of Las Caldas, Balmori, El Castillo, El Rascaño and Aitzbitarte IV), or identified only on a photo (from El Castillo and La Garma-Galería Inferior - zone III), were not included in this study, either because we could not locate them in the corresponding archaeological collections (Table S2), or because we did not get access to it (for that of La Garma-GI - zone III). Among the 22 newly recognized elements, only those from zone IV of La Garma-GI come from recent archaeological interventions; the others were identified during the revision of old collections in which the presence of reindeer was already known, except for La Pila which provided the first indication of the presence of reindeer on the site. Given the difficulty in identifying species when the material is highly transformed (see section 3.2), only elements that retained pertinent anatomical landmarks were taken into account.

4.2. Techno-typological characteristics of the assemblage

4.2.1. Waste products

The studied assemblage primarily comprises waste products (n = 23 – Table 3). All basal fragments (n = 6) are shed antlers, with a significant over-representation (n = 5) of medium/large-sized specimens (maximum thickness of compact tissue equal to or greater than 5 mm). However, a few occurrences of smaller-sized antlers have also been reported from La Pila, La Garma-GI, Santa Catalina and Bora Gran, where one small shed antler displays traces of transversal sectioning on the bez tine (Lefebvre, 2016, Figs. 102 and 7). The corresponding sectioning waste products are represented by nine tine elements with uni- or bifacial striations, proximal traces of grooving (Figs. 2, 1–2), or peripheral chopping (Figs. 2 and 3). This sectioning operation usually takes place during the first phase of the debitage sequence, as a trimming operation designed to make the block easier to work (Averbouh, 2000; Lefebvre, 2016). It is interesting to note that the extremity of one of these waste elements has been shaped by scraping and probably reused as an awl (Mújica, 1983, p. 487; here Fig. 2 and).

Eleven other waste products reflect three different methods of debitage, using variations of the groove and splinter technique (GST, after Clark 1953; Clark and Thompson 1953), to produce blanks that were likely used for the manufacture of projectile points and tools.

Table 1
Magdalenian assemblages from northern Iberia (from west to east) reassessed in this study. Institutions where the collections are housed: MN: Museo de Navarra (Pamplona), Gor: Gordailua (Irun), AM: Arkeologi Museoa (Bilbao), MUPAC: Museo de Prehistoria y Arqueología de Cantabria (Santander), MNCIA: Museo Nacional y Centro de Investigación de Altamira (Santillana del Mar), MAN: Museo Arqueológico Nacional (Madrid), MNCN: Museo Nacional de Ciencias Naturales (Madrid), IIIPC-UC: Instituto Internacional de Investigaciones Prehistóricas de Cantabria-Universidad de Cantabria (Santander), MAA: Museo Arqueológico de Asturias (Oviedo), UO: Universidad de Oviedo (Oviedo), UCM: Universidad Complutense de Madrid, USAL: Universidad de Salamanca, MACB: Museo Arqueológico Comarcal de Banyoles, MAC: Museo de Arqueología de Cataluña (Girona). Chrono-cultural periods: Az.: Azilian, ULM: Upper and Late Magdalenian, MM: Middle Magdalenian, CLM: Cantabrian Lower Magdalenian, IM: Initial Magdalenian, Mag.: Magdalenian, Bad.: Badegoulian, Sol.: Solutrean, Ind: Indeterminate. Iberian provinces: Ast.: Asturias, Cant.: Cantabria, Biscay, Gipuz.: Gipuzkoa, Nav.: Navarre, Cat.: Catalonia. See the bibliographical references for the correspondence between the levels and chrono-cultural attributions.

#	Site	Province	Collections	Archaeological levels	Chrono-cul. Attributions	Conservation institutions
1	**La Paloma**	Ast.	E. Hernández Pacheco et al.	8, 6, 4, 3*	CLM, MM, ULM	MAA, MAN, MNCN, MNCIA
2	**Sofoxó I**	Ast.	Conde de la Vega del Sella and H. Obermaier	Ind.	Mag.	MAA
3	**Oscura de Ania**	Ast.	J. M. Gómez Tabanera and M. Pérez Pérez	3, 3a, 3 b	MM, ULM	MAA
4	**Las Caldas-Sala II**	Ast.	M.S. Corchón Rodríguez	XIII to I, –III - II, –I (Sala II)	CLM, MM, ULM	MAA
5	**Entrefoces**	Ast.	M. R. González Morales	A, B, C, D, E	CLM, ULM	MAA, UC
6	**La Viña**	Ast.	F. J. Fortea Pérez	I, III, IV	MM, ULM	MAA + FFL
7	**El Olivo**	Ast.	D. Álvarez-Alonso	2 b	MM	UCM
8	**Los Azules I**	Ast.	J. Fernández-Tresguerres Velasco	6	ULM	MAA
9	**Cova Rosa**	Ast.	F. Jordá Cerdá et al.	Upper level/B6	CLM	MAA
10	**Collubil**	Ast.	Conde de la Vega del Sella and H. Obermaier	Ind.	Mag	MAA
11	**El Cierro**	Ast.	F. Jordá Cerdá et al.	2, 3/F, G, G1	CLM	MAA, USAL
12	**La Lloseta**	Ast.	H. Hernández Pacheco and P. Wernert/F. Jordá Cerdá	1, 2	CLM, ULM	MAA, MAN
13	**Tito Bustillo-Área de estancia**	Ast.	M. A. García Guinea/J. A. Moure Romanillo/R. de Balbín Behrmann et al./Álvarez-Fernández et al.	1,1C1,1C2, 1C3, 1C4 (Área de Estancia) + Área de las Pinturas	Mag.	MAA, MUPAC, USAL
14	**La Riera**	Ast.	Conde de la Vega del Sella/J. M. Gómez Tabanera/L. G. Straus and G. A. Clark	ind/26-19	CLM, ULM	MAA, MNCN
15	**Cueto de la Mina**	Ast.	Conde de la Vega del Sella/F. Jordá Cerdá/M. de la Rasilla Vives	B, C, D/II,III,IV	Sol, CLM, MM, ULM	MAA, MAN, MNCM, MNCIA
16	**Bricia**	Ast.	F. Jordá Cerdá	E, C	CLM, ULM	MAA
17	**Los Canes**	Ast.	P. Arias Cabal	2 B, 2C	CLM, ULM	MAA
18	**Balmori**	Ast.	Conde de la Vega del Sella	"Nivel Magdaleniense" = Magdalenian level	Mag.	MAA, MNCN
19	**Arangas**	Ast.	P. Arias Cabal and C. Pérez Suárez/P. Arias Cabal	F	CLM	USAL
20	**Coimbre**	Ast.	D. Álvarez-Alonso et al.	4, 2, 1 (Zone B)	CLM, MM, ULM	UCM
21	**Llonín**	Ast.	F. J. Fortea Pérez et al.	VIII-X (Cono Anterior), II-III (Vestíbulo), I-II (Galería)	MM, ULM	MAA, FFL
22	**Las Aguas**	Cant.	J. A. Lasheras Gurruchaga	B, C	CLM/MM?	MNCIA
23	**El Linar**	Cant.	J. Sanguino and R. Montes Barquín	"Sondeos A y C" = Test pit A and C	CLM (+MM?)	MUPAC
24	**Cualventi**	Cant.	M. A. García Guinea	5/E	CLM/ULM	MUPAC, MNCIA
25	**Altamira**	Cant.	H. Alcalde del Río et al./H. Breuil and H. Obermaier/L. G. Freeman and J. González Echegaray	Upper levels	CLM	MIUPAC, MNCIA
26	**Hornos de la Peña**	Cant.	H. Alcalde del Río et al.	Ind.	Mag.	MAN
27	**La Pila**	Cant.	C. Gutíerrez Saez and F. Bernaldo de Quirós Guidotti	IV.1 - IV.4	ULM/Az.	MUPAC, MNCIA
28	**La Pasiega**	Cant.	J. Carballo and García Lorenzo/J. González Echegaray and E. Ripoll Perelló	Ind.	Sol./Mag.	MUPAC
29	**El Castillo**	Cant.	H. Obermaier et al./J. Carballo	6–8	Mag.	MUPAC, MNCIA, MAN
30	**El Pendo**	Cant.	J. Carballo et al./J. Martínez Santaolalla et al./ Edgard Camarós	II(b), IV	Sol./Mag.	MUPAC, MNCIA, MAN, MNCN, UC
31	**El Juyo**	Cant.	P. Janssens et al./L. G. Freeman and J. González Echegaray	III-X/4-11	CLM	MUPAC, MNCIA
32	**Morín**	Cant.	Conde de la Vega del Sella/J. Carballo/J. González Echegaray et al.	Mag., 2	ULM	MUPAC, MAN, MNCN
33	**Rascaño**	Cant.	J. González Echegaray and I. Barandiarán Maestu	2, 2 b, 3, 4(b), 5	IM/Bad., CLM, ULM	MNCIA, MNCN
34	**Pielago II**	Cant.	M. A. García Guinea	5, 6	ULM?	MUPAC
35	**Pielago I**	Cant.	A. García Guinea/M. A. García Guinea	5	ULM?	MUPAC
36	**La Garma**	Cant.	P. Arias Cabal and R. Ontañon Peredo	La Garma A - level L; La Garma GI - zones 1-4	MM	MUPAC, IIIPC
37	**El Otero**	Cant.	J. González Echegaray et al.	2–3	ULM	MUPAC
38	**La Chora**	Cant.	J. González Echegaray and M. A. García Guinea	ind	ULM/Az.	MUPAC
39	**El Horno**	Cant.	M. A. Fano Martínez	1–3	ULM	MUPAC, MNCIA
40	**El Mirón**	Cant.	M. González Morales and L. G. Straus	12-17 (Cabaña), 108 (Trinchera), 102.1/108/110–119 (Corral)	IM, CLM, ULM	UC
41	**La Peña del Perro**	Cant.	M. González Morales and Y. Díaz Casado	2c	ULM	MUPAC
42	**La Fragua**	Cant.	M. R. González Morales et al.	4	ULM	MUPAC
43	**El Valle**	Cant.	L. Sierra/H. Breuil and H. Obermaier/M. P. García-Gelabert	ind	ULM	MUPAC, MAN, MNCN

(*continued on next page*)

Table 1 (*continued*)

#	Site	Province	Collections	Archaeological levels	Chrono-cul. Attributions	Conservation institutions
44	**Polvorín**	Biscay	R. Ruiz Idarraga and F. d'Errico	Upper level (Sala interior intermedia)	ULM	AM
45	**Arenaza I**	Biscay	J. M. Apellaniz Castroviejo and J. Altuna Echave/J. A. Fernández Lombera	VI	ULM?	AM
46	**Balzola**	Biscay	J. M. de Barandiarán/L. Zapata Peña	7, 8	ULM	AM
47	**Atxeta**	Biscay	J. M. de Barandiarán	E	ULM	AM
48	**Antoliña**	Biscay	J. M. de Barandiarán/M. Aguirre Ruiz de Gopegui	Lgc	CLM/ULM	AM
49	**Silibranka**	Biscay	J. M. de Barandiarán and T. de Aranzadi	I-IV	ULM?	AM
50	**Santimamiñe**	Biscay	T. de Aranzadi et al./J. M. de Barandiarán/J. C. López Quintana	Csn-Camr/IX, Almp/VIII, Slnc/VI	Mag.	AM
51	**Bolinkoba**	Biscay	J. M. de Barandiarán and T. de Aranzadi/M. J. Iriarte Chiapusso	IV (D), III (C), II (B)	Sol., CLM, ULM/ Az. (+MM?)	AM
52	**Abittaga**	Biscay	J. M. de Barandiarán/J. M. Apellaniz Castroviejo	VI, VII	ULM (+Az?)	AM
53	**Santa Catalina**	Biscay	E. Berganza Gochi	II, III	ULM	AM
54	**Lumentxa**	Biscay	J. M. de Barandiarán and T. de Aranzadi/J. L. Arribas Pastor	IV, V, VI, VII	ULM (+CLM?)	AM
55	**Laminak II**	Biscay	E. Berganza Gochi and J. L. Arribas Pastor	II	ULM	AM
56	**Atxurra**	Biscay	J. M. de Barandiarán and T. de Aranzadi	III	ULM	AM
57	**Preaileaitz I**	Biscay	X. Peñalver	III, IV	CLM/ULM	Gor
58	**Ermittia**	Gipuz.	J. M. de Barandiarán and T. de Aranzadi	III	MM/ULM (+CLM?)	Gor
59	**Urtiaga**	Gipuz.	J. M. de Barandiarán (and T. de Aranzadi)	D, E, F	Mag.	Gor
60	**Ekain**	Gipuz.	J. M. de Barandiarán and J. Altuna Echave	VI a and b/VII	CLM, ULM	Gor
61	**Erralla**	Gipuz.	J. Altuna Echave	II, III, V	CLM/ULM	Gor
62	**Aitzbitarte IV**	Gipuz.	Conde de Lersundi/J. M. de Barandiarán	I inf/I, III	ULM (+ MM ?)	Gor
63	**Torre**	Gipuz.	A. Laburu et al.	ind	ULM?	Gor
64	**Abauntz**	Nav.	P. Utrilla and C. Mazo	e, 2r	MM/ULM	MN
65	**Zatoya**	Nav.	I. Barandiarán Maestu	IIb	ULM	MN
66	**Bora Gran**	Cat.	É. Harlé and P. Alsius/J. Bosoms/J.M. Corominas	Ind.	Mag.	MACB, MAC

Table 2
Reindeer antler artefacts identified in this study are expressed as artefact numbers and percentages within each worked osseous assemblage (bone, ivory and antler). NRAA: Number of Reindeer Antler Artefacts, TNOA: Total Number of Osseous Artefacts, % RAA: Percentage of Reindeer Antler Artefacts in the Osseous Industry. Chrono-cultural periods and sites numbers are the same as in Table 1.

#	Site	Levels/Layers	Chrono-cul. attribution	NRAA	TNOA	% RAA	Main bibliographic references
4	**Las Caldas-Sala II**	VI	MM	1	984 (levels IX-VI)	0.1	Corchón and Ortega (2017); This study
27	**La Pila**	IV-2	ULM	1	48 (levels IV-2, IV-3, IV-4)	2.1	González Sainz, 1989; This study
36	**La Garma**	Galería Inferior (zone IV)	MM	2	14	14.3	Arias et al. (2011); This study
		Sector A - L3	MM	1	n/a	n/a	Arias et al. (2005); This study
50	**Santimamiñe**	VI	ULM	3	63	4.8	Barandiarán, 1962; Utrilla (1981); Castaños (1984); González Sainz (1989); This study
		VII	ULM/CLM	1	30	3.3	
53	**Santa Catalina**	II	ULM	1	142	0.7	Castaños (2014); Lefebvre (2016); This study
		III	ULM	7	697	1	
54	**Lumentxa**	VII	CLM?	1	13 (levels VI and VII)	7.7	Castaños (1986); This study
59	**Urtiaga**	D	ULM?	4	187	2.1	Mújica (1983); Altuna (1971); This study
		E	ULM/MM?	4	12	33.3	
60	**Ekain**	VIa	ULM	1	18	5.5	Altuna and Mariezkurrena (1984); Baldeón (1984); This study
62	**Aitzbitarte IV**	II	ULM	1	37	2.7	Mújica (1983)
64	**Abauntz**	2r	ULM	1	4	25	Altuna et al., 2001–2002; Utrilla et al. (2004); This study
66	**Bora Gran**	Ind.	MM/ULM	7	474	1.7	Rueda i Torres, 1987; Galobart et al. (1996); Nadal et al. (1997); Lefebvre (2016); This study
	Total			**36**			

(1) The first debitage method is represented by five elements connected to the extraction of several parallel splinters of medium calibre (approximately 10 mm wide) employing multiple longitudinal grooves (Fig. 3). Except for two waste products whose original position on the block cannot be precisely deduced (tine or beam?), including a "déchet en triangle" (Averbouh, 2000, Figs. 3 and 1), the three others are from different parts of the A/B beams. One example from Bora Gran comes from the upper part of A2 beam (B beam) and demonstrates the extraction of at least two adjacent splinters from the anterior and lateral sides of the beam (Figs. 3 and 2). The other two waste products from Bora Gran (Fig. 3 and) and Abauntz-2r (Figs. 3 and 4), could theoretically be the corresponding proximal waste-products since they come from the basal part of the antler. These two pieces can be tied to the extraction of splinters from the posterior and lateral sides of the A beam. Finally, these three waste products describe the exploitation of the entire periphery of the A2 beam for the extraction of splinters. Each edge of the splinter is detached via a

Table 3
Techno-typological and chronological attributions of reindeer antler artefacts from the Iberian Magdalenian assemblages. Chrono-cultural periods as in Table 1. CLM: Cantabrian Lower Magdalenian, MM: Middle Magdalenian, ULM: Upper and Late Magdalenian, Mag.: Magdalenian. Long. extrac.: Longitudinal extraction

	Chrono-cultural attribution							
Techno-typology	**CLM?**	**CLM/MM**	**MM**	**MM?**	**MM/ULM**	**ULM**	**Mag.**	**Total**
Waste products								
Transversal tine sectioning		1	2		1	5		**9**
Longitudinal extraction of a single splinter				1		2		**3**
Longitudinal extraction of multiple splinters						1	4	**5**
Oblique extraction of a beam core						2	1	**3**
Indeterminate							3	**3**
Products of debitage								
Perforated batons			1		2	1		**4**
Possible blunt tool on tine			1					**1**
Engraved antler elements						2		**2**
Indeterminate	1	2				3		**6**
Total	**1**	**3**	**4**	**1**	**3**	**16**	**8**	**36**

Fig. 2. Waste products connected to the transversal sectioning of reindeer tine from the Iberian Magdalenian, 1: first/bez tine sectioned by bifacial grooving (Santa Catalina-III), 2: posterior tine sectioned by bifacial grooving and reused as an awl (Urtiaga-D), 3: bez tine sectioned by peripheral chopping (Urtiaga-E), a: close-up of scraping traces. Black arrows show the location of grooving traces while purple arrows indicate chopping. B.B.: Beam B, P.t: Posterior tine. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

longitudinal groove, while the extremities are detached by transverse chopping (Figs. 3 and 4), or simply by flexion (Figs. 3, 2–3). The length of the splinters cannot be determined with precision but may correspond to either the length of A2 (+B) beams or the entirety of A beam, when debitage runs to the burr base, as documented at Bora Gran (157 mm minimum length – Fig. 3 and).

(2) The second debitage method is represented by three artefacts from Santimamiñe-VI/VII, to which could be added one arched base from La Garma-GI-zone III that was not included in this study (Table S2). All of these elements can be connected to the oblique extraction of an entire beam portion (Fig. 4). Two are "arched bases" (Pétillon, 2016), which are characteristic reindeer antler waste-products that have been recovered from 13 sites in southwest France and dated to the transition between the middle and upper phases of the Magdalenian. The A2 beam is removed from the rest of the block via two convergent oblique grooves, leaving adjacent, characteristic concave grooves on both the beam and the bez tine. This trimming method has been linked to the production of a beam portion destined to be transported as reserves for the production of splinters (Pétillon, 2016).

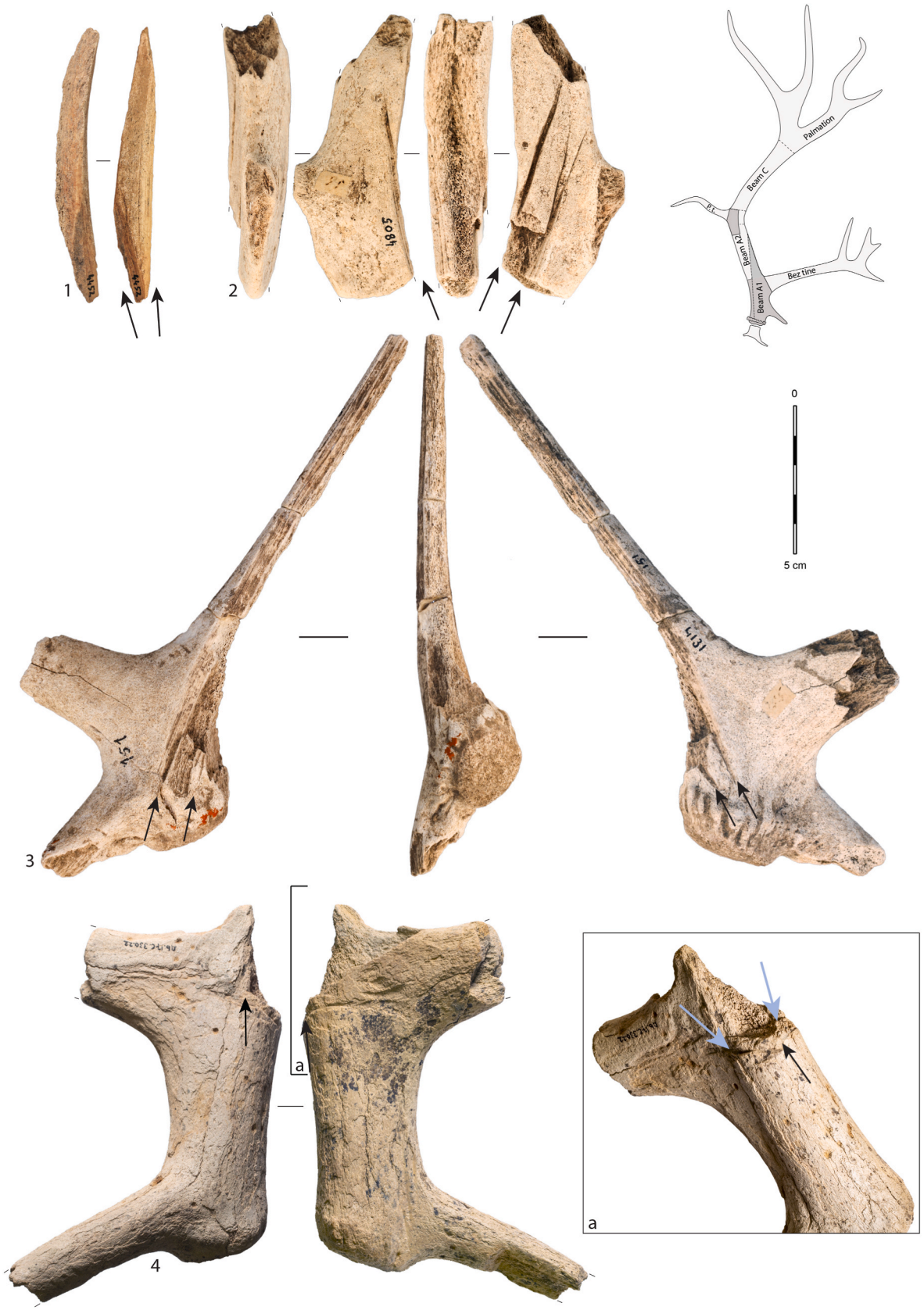

Fig. 3. Reindeer antler waste products from the Iberian Magdalenian showing the longitudinal extraction of several splinters from the A/B beam using multiple longitudinal grooves. 1–3: Bora Gran, 4: Abauntz-2r, a: close-up of manufacturing traces. Black arrows indicate the location of grooving traces while purple arrows indicate chop marks. P.t: Posterior tine. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 4. Reindeer antler waste products (arched bases) from the Iberian Magdalenian with evidence for the oblique extraction of a beam block using the double groove technique. 1: Santimamiñe-VI, 2: Santimamiñe-VII, a–b: close-up of the grooves. Black arrows indicate traces of grooving. B.B.: Beam B, P.t: Posterior tine.

(3) The third debitage method is represented by three waste products linked to the extraction of a single splinter via a longitudinal double grooving from different parts of the block (i.e., the palm, the tine and the A1 beam). The clearest example comes from Urtiaga-E and shows the extraction of a large splinter (22 mm in width) from the posterior side of A1 beam (Fig. 5). Two deep, parallel grooves were installed along the posterior surface of the A1 beam and extending to the burr base for the detachment of a wide splinter.

4.2.2. *Debitage products*

Five debitage products were identified, among which no splinter has been recognized (Table 3). Finished objects all are only minimally worked, made from voluminous parts of generally large antler; amongst

Fig. 5. Reindeer antler waste product from Urtiaga-E showing the longitudinal extraction of one single large splinter from the posterior surface of A1 beam using the double groove technique. Black arrows show the location of grooves while purple arrow indicates traces of chopping. B.B.: Beam B, P.t: Posterior tine. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

which perforated batons are best represented, with four specimens from the sites Las Caldas-VI (n = 1), Urtiaga-D (n = 2) and Aitzbitarte IV-II (n = 1) (Figs. 6, 1–4). Only the latter had already been identified with certainty as made from reindeer antler (Mújica, 1983, p. 463; here Figs. 6 and 2), probably due to its flattened cross-section. The two specimens from Urtiaga may have been among the remains previously identified as reindeer antler by Altuna (1971) but not described in the publication. The specimen from Las Caldas had never been determined as being made from reindeer antler before. Three specimens have a perforation located at the junction between A beam and the bez tine. This characteristic corresponds to the "two branches types" of Peltier's (1992) typology, which is relatively common in southwestern France but rare in Iberia, where perforated batons are usually made from red deer tines (Redondo Sanz, 2016). The Las Caldas-VI specimen (Figs. 6 and 1) is decorated with both schematic engravings and a possible engraved ungulate head (Corchón and Ortega, 2017, Fig. 251B). It also

Fig. 6. Finished reindeer antler objects from the Iberian Magdalenian. 1–4: perforated batons, 5: possible blunt tool on a palmate tine. 1: Las Caldas-VI, 2: Aitzbitarte IV-II, 3–4: Urtiaga-D, 5: La Garma A-L3. Purple arrows indicate peripheral chopping traces. B.B.: Beam B, P.t: Posterior tine. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

displays traces of proximal sectioning via peripheral chopping that is partially covered by traces of crushing of the osseous fibres which could be linked to its use against a hard material. The Urtiaga pieces also bear some of these anthropogenic traces: one is decorated with schematic engravings (Figs. 6 and 3), while the other was transversely sectioned with proximal peripheral chopping (Figs. 6 and 4). Two other perforated batons from Rascaño (Obermaier, 1923, Fig. 2, p. 13) and El Castillo (Breuil and Obermaier, 1913; Cabrera Valdés, 1984, p. 336, 356) were also identified as reindeer antler; however, as the original specimens could not be found, we were unable to confirm the raw material used (more information in Table S2).

The second type of finished object is represented by one artefact from La Garma A-L3 (Figs. 6 and 5). Already identified as a reindeer antler (Arias et al., 2005), this object is manufactured from a voluminous element from the upper part of a large-sized antler, probably a tine from the palm, based both on its naturally wide and pointed morphology and the thinness of the compact tissue (2 mm). Again, it is minimally worked, the only manufacturing marks being longitudinal scraping on one edge associated with geometric engraving on each side. Its distal extremity is not well-conserved but is marked by the crushing of osseous

Fig. 7. Reindeer antler remains with indeterminate traces that could be related to portable art from Santa Catalina-III. a–b: close-up of a possible engraving of the forequarters of an ungulate in profile view. B.B.: Beam B, P.t: Posterior tine.

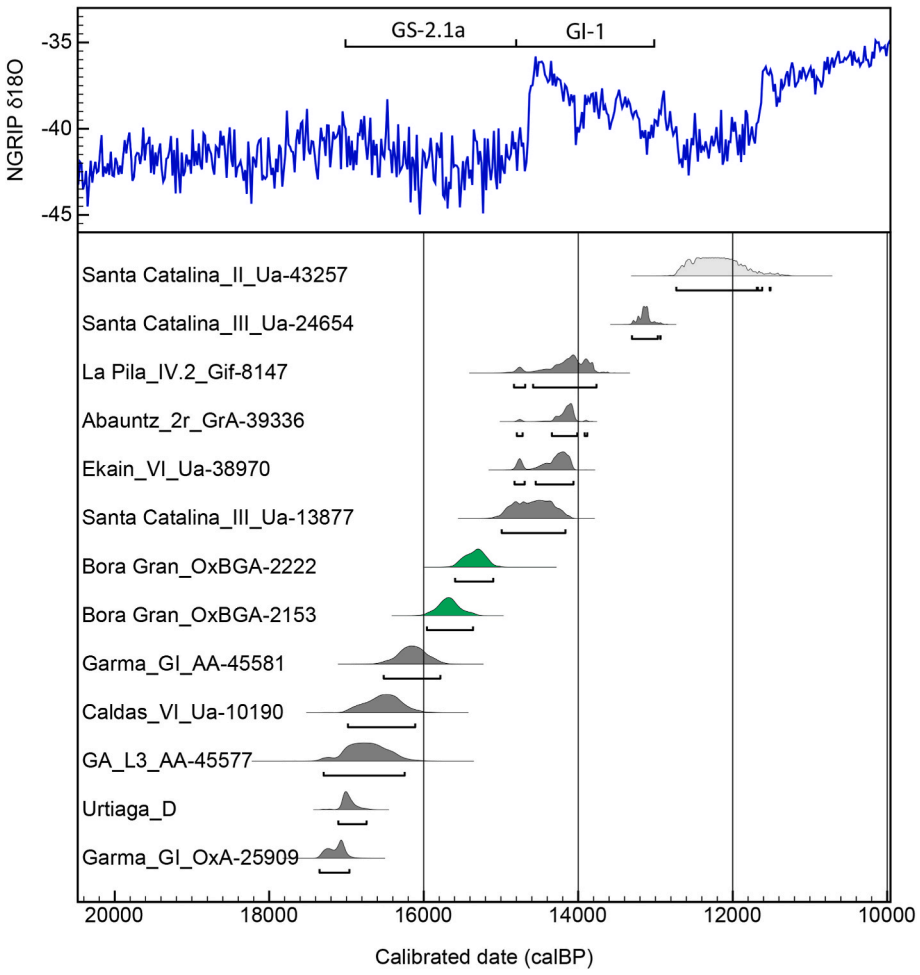

Fig. 8. Calibrated radiocarbon dates (at two sigma) for Magdalenian levels containing reindeer antler objects in northern Iberia. Calibration: OxCal v4.4.4. (Bronk Ramsey, 2017); IntCal20 dataset (Reimer et al., 2020). In green, the dates obtained directly on reindeer bones from Bora Gran (Nadal et al., 2002), in light grey, the excluded date from Santa Catalina (see text), GA: Garma A. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

fibres. All these features are reminiscent of several artefacts made on reindeer tines, most of which have been considered to be blunt tools. These implements have already been identified from several Lower – Saint-Germain-la-Rivière, ensemble inférieur (Langlais et al., 2015, Figs. 19, 3–7) – or Middle – Isturitz-SI/EŬ (Lefebvre, 2016, Figs. 1, 8 and 52), Canecaude I-II (Lefebvre, 2016, Figs. 119, 2), Enlène-SdF (Averbouh, 2000, p. 196), and Saint-Michel d'Arudy (Pujol, 2008, p. 62) – Magdalenian sites in the northern Pyrenees.

Finally, two antler elements (tine or beam fragments?) from Santa Catalina-III display indeterminate engravings that could be related to portable art objects. In one case, an antler fragment bears several oblique striations arranged parallel between them all around the object (Figs. 7 and 1), while a second one shows what could be the engraving of the forequarters of an ungulate in profile view (Figs. 7 and 2). At least two other elements of portable art display some anatomical characteristics reminiscent of reindeer antlers – a possible distal element of an engraved spearthrower from Las Caldas (Corchón and Ortega, 2017, Fig. 212), and a pendant representing an ibex head from Tito Bustillo (Moure Romanillo, 1983). However, as these specimens are too heavily worked to be identified with certainty using traditional anatomical criteria, we excluded them from our study.

4.3. Chronological distribution

We collated available ^{14}C dates for each archaeological level that contained a reindeer antler object, favouring, when possible, AMS dates over conventional radiocarbon determinations (β counting method). When only one artefact was recovered from a site, we retained a single date – the closest in stratigraphy for Las Caldas-VI, La Pila-IV.2, La Garma-A and Santa Catalina-II; or the average for Ekain-VI and Abauntz-2r, where several dates are available for each level – so as not to give additional weight to a single assemblage. When several artefacts were recovered from a single level, we either retained one date if it is the only one considered reliable for the level (i.e., Urtiaga-D) or the *terminus ante* and *post quem* when several dates are available (i.e., Santa Catalina-III and La Garma-GI). For Bora Gran, despite the lack of 3D data for the location of the material, we retained two dates obtained directly on what was reported as contemporary reindeer remains (see Text S1 for more details concerning the selection of the dates).

Based on these criteria, 13 dates were retained from ten assemblages (Table 4), with five assemblages producing no reliable dates (i.e., Santimamiñe-VI, Santimamiñe-VII, Lumentxa-VII, Urtiaga-E, Aitzbitarte IV-2). Once calibrated, the dates are spread over a 5,000-year period between 17,2 and 12,2 cal ka BP (Fig. 8).

However, the retained date from layer II of Santa Catalina appears as an outlier. This is further supported by the incompatibility between the date and the chrono-cultural attribution and the fact that most of the reindeer antler artefacts come from the underlying layer III (n = 7). Once this date is removed, the exploitation of reindeer antlers is further constrained to a 4,000-year period between 17,2 and 13,1 cal ka BP. This chronology corresponds to the Middle/Upper/Late phases of the Magdalenian as they are known in the Cantabrian region (for synthesis of the chronology of the Magdalenian in south-west Europe see Langlais and Pétillon, 2019). While the upper chronological limit lies around 13,000 cal years BP, the lower limit is less clear. At least two artefacts from level 8 of El Castillo, which we have not included in the study (see section 4.1 and Table S2), shed some light on this issue. If their provenance and taxonomic determination were confirmed, they could be

Table 4
Radiocarbon dates from Magdalenian levels in northern Iberia containing reindeer antler objects. In bold, the date obtained directly on reindeer bone remains. Chrono-cultural periods as in Table 1.

#	Site	Level/ Layer	Chrono-cult. attribution	Age in radiocarbon years BP	Calibrated age in years BP (95.4%)	Laboratory code	Nature of the sample dated	Method	Main bibliographic reference
53	Santa Catalina	II	ULM	10,392 ± 179	12,730–11,510	Ua-43257	Bone (*Cervus elaphus*)	AMS	Berganza and Arribas (2014)
53	Santa Catalina	III	ULM	11,225 ± 80	13,304–12,934	Ua-24654	Bone	AMS	Berganza and Arribas (2014)
27	La Pila	IV.2	ULM	12,160 ± 130	14,831–13,763	Gif-8147	Bone	β count	Soto-Barreiro (2003)
64	Abauntz	2r	ULM	12,220 ± 60	14,794–13,883	GrA-39336	Charcoal	AMS	Utrilla and Mazo (2011)
60	Ekain	VI	ULM	12,297 ± 66	14,824–14,061	Ua-38970	n/a	AMS	Altuna, 2012
53	Santa Catalina	III	ULM	12,425 ± 90	14,990–14,165	Ua-13877	Bone	AMS	Berganza and Arribas (2014)
66	**Bora Gran**	**n/a**	**MM/ULM**	**12,830 ± 80**	**15,593–15,099**	**OxBGA-2222**	**Bone (reindeer 3rd phalanx)**	**AMS**	Nadal et al. (2002)
66	**Bora Gran**	**n/a**	**MM/ULM**	**13,080 ± 90**	**15,959–15,361**	**OxBGA-2153**	**Bone (reindeer astragalus)**	**AMS**	Nadal et al. (2002)
36	La Garma - Galería Inferior	Zone IV	MM	13,410 ± 120	16,518–15,785	AA-45581	Bone	AMS	Arias and Ontañón (2008)
4	Las Caldas-Sala II	VI	MM	13,650 ± 140	16,981–16,110	Ua-10190	Bone	AMS	Corchón (1995)
36	La Garma A	L3	MM	13,810 ± 180	17,296–16,247	AA-45577	Charcoal	AMS	Arias and Ontañón (2008)
59	Urtiaga	D	MM/ULM	13,960 ± 50	17,106–16,740	n/a	n/a	n/a	Areso-Barquín et al. (2018)
36	La Garma - Galería Inferior	Zone IV	MM	14,060 ± 65	17,349–16,962	OxA-25909	Bone (Ursus sp.)	AMS	Cueto et al. (2020)

older than the rest of the dates, given that level 8 of El Castillo, attributed to the Initial/Lower Magdalenian (Utrilla, 1981; Cabrera Valdés, 1984), yielded an uncalibrated AMS age of 16,850 ± 220 years BP (Barandiarán, 1988). However, level 8 is about 2 m thick and, in the absence of 3D provenance data, this date would have been excluded from our analysis. With that said, the fact that reindeer antler technology may have had antecedents before the Middle Magdalenian in the region, or even before the Magdalenian period in general, would not be surprising given the early presence of reindeer in Iberia (Álvarez-Lao and García, 2010; Gómez-Olivencia et al., 2014).

Despite the low number of reindeer artefacts and the lack of precise chronological data for a possible evolution of reindeer antler technology for blank production in Iberia, the data presented here are consistent with available contemporary data for the same type of raw material in southwestern France (see among others Pétillon, 2006, 2016): the three debitage methods described, which reflect different variations of the GST (see section 4.2), appear at relatively the same time during the Middle and Upper phases of the Magdalenian (Table 3). In contrast, our results do not provide technological data for the older periods of the Magdalenian (i.e., the lower and initial phases).

4.4. Geographical distribution

The 36 reindeer antler artefacts are distributed across 11 Magdalenian sites in the northern part of Iberia (Fig. 9a). Their geographical distribution shows two discontinuous areas, both in connection with the Pyrenean Mountain range: the Cantabrian region (including Navarre) and Catalonia. This distribution, however, might be biased for two reasons: first, the last marine transgression submerged the paleo-coastlines, especially the ca. 10 km of coastal fringe that connected Iberia to Europe in the Basque region, which was the main area occupied by humans and reindeer in Iberia during this period. Therefore, the number of reindeer remains in this area may have been significantly greater. Second, biases could have been introduced by due to the fact that, except for Abauntz and Zatoya, we did not include Magdalenian sites from the southern part of the Pyrenees in our sample. However, this should not significantly affect the overall picture since (a) this area yielded very few Magdalenian assemblages with worked antler and a very small number of artefacts (Tejero, 2003–04), and (b) except for the two sites mentioned above, no reindeer remains have been discovered in this area.

Most of the reindeer antler artefacts (n = 23) are concentrated in six sites in the Basque region (from west to east: Santimamiñe, Santa Catalina, Lumentxa, Urtiaga, Ekain and Aitzbitarte IV), which is the core area of this industry. Whether in terms of overall artefact numbers or as a percentage of the total osseous industry (Table 2), Basque sites are the best represented. This concentration should be expected given the role this area played as a conduit for the movement of animals (and humans) as they entered/left the peninsula from the north during the Pleistocene (Álvarez-Lao and García, 2011). Four other areas are also concerned by the presence of reindeer antler artefacts but in much smaller proportions, in decreasing order: Catalonia (Bora Gran – n = 7), Cantabria (La Pila, La Garma – n = 4), Navarre (Abauntz – n = 1) and Asturias (Las Caldas – n = 1). The circulation of particular objects (i.e., "two branches", perforated batons and blunt tools made on a tine) and how blanks were produced throughout the entire Pyrenean-Cantabrian region demonstrates a techno-typological continuity at the end of the Upper Palaeolithic between these two neighbouring areas. This connection is further supported by structured communication networks previously demonstrated by the circulation of particular materials and types of objects (see synthesis in Lefebvre et al., 2021).

In the Cantabrian region (*sensu lato*), the distribution of antler artefacts follows two specific patterns already observed for the distribution of all reindeer remains during the Late Pleistocene (Gómez-Olivencia et al., 2014). First, an increasing west/east gradient in terms of the number of artefacts from Asturias to the Basque region and the Pyrenees. This pattern is also observable with the distribution of waste products, which are primarily concentrated in the Basque region (n = 12), followed by Cantabria (n = 3) (Fig. 9b). The distribution of finished objects seems wider, being found throughout the area up to Asturias (Fig. 9c);

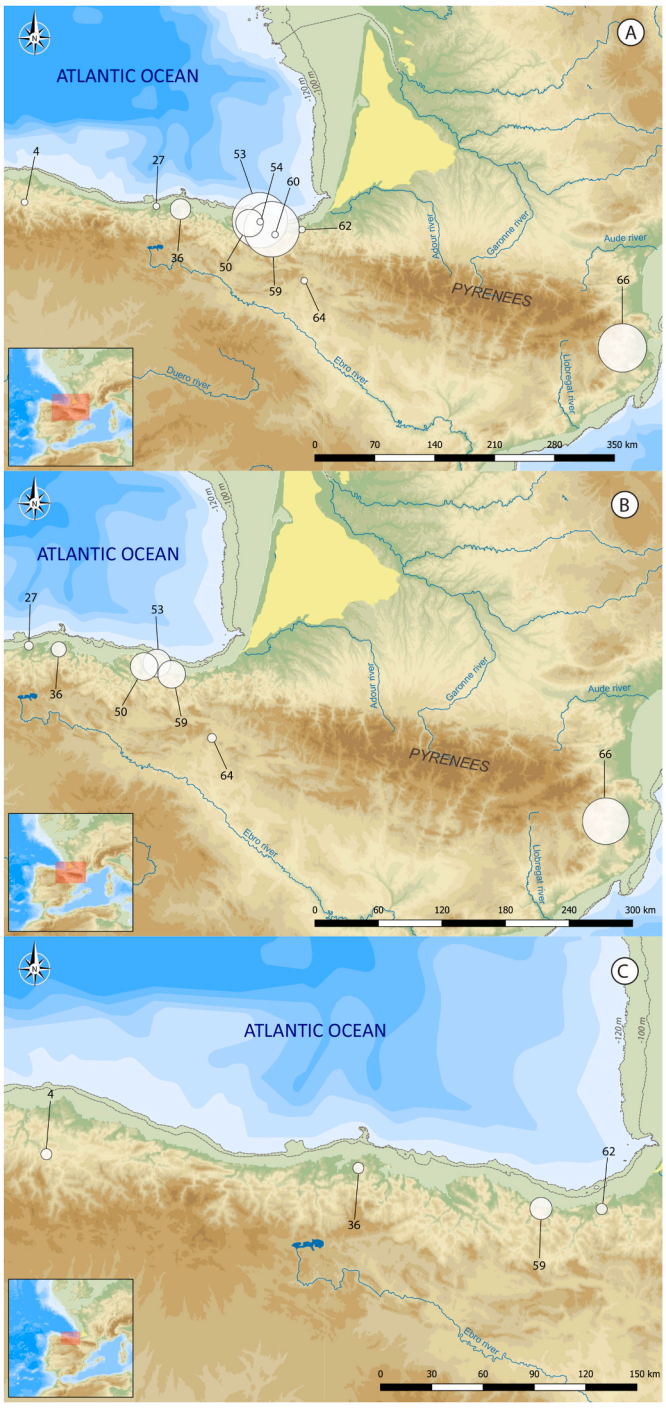

Fig. 9. Distribution of the worked reindeer antler in northern Iberia during the Magdalenian. The size of the circles is proportional to the number of artefacts found per site. A: all worked artefacts including waste products and debitage products, B: only waste products, C: only finished objects (debitage products). 4: Las Caldas-Sala II, 27: La Pila, 36: La Garma, 50: Santimamiñe, 53: Santa Catalina, 54: Lumentxa, 59: Urtiaga, 60: Ekain, 62: Aitzbitarte IV, 64: Abauntz, 66: Bora Gran. See Fig. 1 for map data; site numbers correspond to Table 1.

however, the number of remains is too low (NR = 5) to reveal any particular trends, especially since an artefact from Las Caldas (Corchón and Ortega, 2017, Figs. 20 and 376), which we have not integrated here (Table S2), could also extend the distribution of waste products into Asturias. The second pattern follows a north/south gradient: except for the artefact from Abauntz (Navarre), which comes from the Mediterranean watershed, all the others come from the Atlantic watershed that was in direct geographical continuity with the western Pyrenees through to the Basque coastal plain. This suggests that the Pyrenean-Cantabrian ranges constituted the southern limit of the ecological niche of the species in Europe at that time.

5. Discussion

5.1. Determination biases

Our techno-typological analysis reveals a discrepancy between waste products, represented uniquely by the extraction of splinters (or reserves of splinters), and end-products manufactured from the most voluminous parts of reindeer antlers (i.e., perforated batons made from the junction between the A beam and the tine, as well as blunt tools made on tines). This discrepancy is most likely due to identification biases that hinder the recognition of the finished objects made on (splintered) rods, and probably shaped into projectile points and tools (i.e., wedges) that cannot be distinguished from their red deer antler counterparts. The absence of waste from the production of perforated batons is more unexpected and could be explained by three non-exclusive factors: (a) they have been categorised as sectioning waste (for tine elements – Fig. 2), (b) they were not found during excavations, or (c) the perforated batons were not manufactured locally. In any case, the failure to identify products made on rods undoubtedly affects our perception of both production objectives – was reindeer antler used for the manufacture of specific points and tools made on rods? – and the proportion of reindeer antler within the overall osseous industry at each site. When assemblages with less than 20 artefacts are excluded, reindeer antler represents between 0.1% (for Las Caldas-IX-VI) and 4.8% (for Santimamiñe-VI) of the total osseous industry (Table 2). These percentages should be taken with some caution due to the fact that the numbers of reindeer antler artefacts given here are minimum estimates and because counts of overall osseous industry vary significantly from one specialist to another.

5.2. Characteristics of the reindeer antler technology in Iberia during the Magdalenian

As documented for contemporary reindeer antler technologies from the northern Pyrenees (Pétillon, 2016), medium-to large-sized shed antler was primarily used by Iberian foragers and was not necessarily acquired on a seasonal basis (ibid.). Except for one specimen from Bora Gran, whose protruding section from the anterior side of A2 beam looks like a splinter left attached to the base (Fig. 3 and), reindeer antlers were fully exploited for blank production during the middle and upper phases of the Iberian Magdalenian. In terms of technology, the A2 beam was preferentially used for the extraction of a secondary block (Fig. 4), while the extraction of multiple splinters implies the exploitation of all the periphery of the A2 beam and can descend lower to the base of A1 beam – also true for single extractions (Figs. 4 and 5). These modalities are evident not only in contemporary reindeer antler assemblages from the northern Pyrenees (e.g., Averbouh, 2000; Baumann, 2006/2007; Pétillon, 2006, 2016; Lefebvre, 2016) but also in numerous contemporary Iberian red deer antler assemblages (see González Sainz, 2011; Lefebvre, 2016; Corchón and Ortega, 2017; Straus et al., 2018, among others). Finally, while some reindeer antler waste products attest to the local production of splinters, both the presence of arched bases (possibly resulting from the circulation of secondary blocks – see section 4.2) and the absence of waste products related to the production of perforated batons, could suggest that part of this industry was circulated.

5.3. Strategies for the acquisition and circulation of reindeer antler in the north of Iberia

The question of acquisition strategies and the circulation of reindeer antlers in northern Iberia is directly linked to the geographic extension

of this species' ecological niche in the region. However, it is difficult to reconstruct the niche of Pleistocene species given the scarcity of paleontological sites reflecting the natural distribution of animals in the environment in the absence of anthropogenic activity. The available models, which are primarily built from archaeological data (e.g., Banks et al., 2008), usually do not consider the possibility that some remains could have been transported by humans. Thus, it is commonly accepted that reindeer regularly extended their range southwards into the peninsula during the Pleistocene and that the distribution of both skeletal remains and graphic depictions of this species reliably reflect the extension of the reindeer's ecological niche (among others Harlé, 1908; Altuna, 1971; García and Arsuaga, 2003; Banks et al., 2008; Álvarez-Lao and García, 2011; de Blas Cortina and Briansó, 2017).

A closer look at the geographical distribution of the different categories of reindeer remains (worked and unworked antlers, teeth and bones; Table S3) provides new insights on this issue. As already noted (e.g., Estévez, 1978; Utrilla, 1997; Gómez-Olivencia et al., 2014), elements from the extremities of the skeleton could be imported to sites from distant areas to be integrated into manufacturing activities; for example, antler for the manufacture of hunting implements and tools, teeth for ornaments, as well as hand and foot elements reflecting the transport of pelts used for protection and clothing (see below).

5.3.1. The Cantabrian region

In the Basque region (i.e., Biscay and Gipuzkoa), while reindeer remains have been documented from multiple archaeological sites (Fig. 10; Table S3), whether in terms of the number of remains or in terms of skeletal representation, almost all of them come from two sites, where they were introduced as hunted prey: Santa Catalina (Castaños, 2014) and Urtiaga (Altuna, 1971). Considering that Iberian Basque sites are in direct geographical continuity with Magdalenian sites from the western Pyrenees where reindeer were present during the Magdalenian (see Lefebvre, 2016, Figs. 3 and 5), and because numerous reindeer remains have also been found and directly dated from the contemporary natural accumulation at Kiputz IX (Castaños et al., 2014b; Castaños, 2017), there is no reason to doubt the presence of reindeer in this region.

However, in other parts of the Cantabrian region (i.e., Asturias and Cantabria) and Navarre, the situation is less clear. The small number of reindeer remains in these two areas, combined with the fact that most of them come from the extremities of the skeleton (i.e., antler, cranial elements or the distal part of the leg – Table 5), could be related to their importation as raw materials. However, this assumption is not true for all faunal assemblages. A new unpublished ZooMS faunal analysis of the La Viña material (Asturias) revealed the presence of a handful of reindeer remains, including long bone fragments, a pattern that suggests they were introduced to the site as hunted prey (Torres-Iglesias L., pers. com.). This equally suggests that the overrepresentation of cranial elements (antler, teeth, mandible, etc.) among reindeer remains in Asturias and Cantabria could also be influenced by identification biases: unidentified long bone fragments are more likely to remain among the faunal remains. Thus, the possibility that reindeer were present in Asturias, and by direct geographic continuity, in Cantabria, therefore cannot be ruled out. In Navarre, the situation is still unclear. The only two sites - Abauntz and Zatoya - which yielded reindeer remains are located in the Mediterranean watershed, with difficult access from the north for reindeer as they would have to cross mountain passes with altitudes ranging from 600 to more than 1,000 m a.s.l. (Gómez-Olivencia et al., 2014). Although the reindeer remains from Abauntz could all be linked to manufacturing activities, the presence of a unique reindeer scapula at Zatoya is difficult to interpret. In sum, pending clarification by an additional archaeozoological assessment of the Magdalenian faunal remains from northern Iberia, a local supply of raw material is very likely in the Basque region while the situation must be considered on a case-by-case basis in the other Cantabrian (and Navarre) areas (Fig. 11). The latter is presumably linked to the sporadic presence or even absence of reindeer in the Mediterranean watershed.

5.3.2. The north-eastern part of Iberia

In contrast, reindeer remains are absent from natural traps in Catalonia and are known from only one archaeological site, Bora Gran, which yielded 13 elements from the extremities of the skeleton (Table 5). The pattern of skeletal representation at Bora Gran could suggest a preferential introduction of particular anatomical parts, likely accumulated during off-site carcass processing and to be used in manufacturing activities. Given the absence of unshed reindeer antlers and the fact that seven antler remains display traces of having been worked (Lefebvre, 2016), it is very likely that the four supplementary unworked antler remains (including one base of a shed antler) identified in this study were linked to the production of projectile points and tools. Moreover, a growing body of archaeozoological evidence gathered over

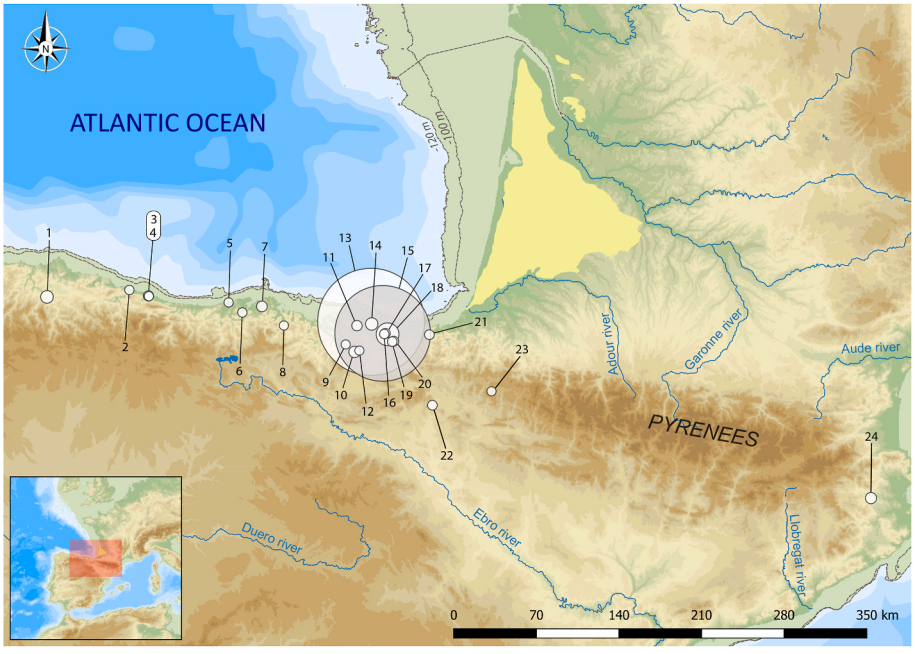

Fig. 10. Geographic distribution of the identified reindeer remains during the Magdalenian period in northern Iberia, including worked and unworked antlers, teeth and bones. The size of the circles is proportional to the number of remains found per site. White circles represent archaeological sites, while the grey light circle is the natural accumulation at Kiputz IX. 1: Las Caldas - Sala II, 2: Tito Bustillo-Área de estancia, 3: La Riera, 4: Cueto de La Mina, 5: La Pila, 6: Morín, 7: La Garma (A + GI), 8: El Valle, 9: Arlanpe, 10: Atxuri, 11: Santimamiñe, 12: Bolinkoba, 13: Santa Catalina, 14: Lumentxa, 15: Kiputz IX, 16: Ermittia, 17: Praileaitz I, 18: Urtiaga, 19: Ekain, 20: Erralla, 21: Aitzbitarte IV, 22: Abauntz, 23: Zatoya, 24: Bora Gran. See Fig. 1 for map data.

Table 5
Skeletal representation of reindeer remains, including worked and unworked specimens, from Asturias, Cantabria, Navarre and Catalonia during the Magdalenian.

Province	Site	Reindeer skeletal representation	Total NR	Bibliographic references
Asturias	Las Caldas	3 antler remains (including one perforated baton), 15 teeth (including 11 serrated incisors), 1 mandible, 1 phalanx and 1 radius (distal)	21	Corchón et al. (2012); Altuna and Mariezkurrena (2017); Mateos (2017); This study
	Tito Bustillo	2 incisors (including 1 perforated), 1 metapodial (distal), 1 possible antler fragment	2	Altuna (1976); Á lvarez-Fernández et al. (2018), 2022; This study
	La Riera	3 teeth and 1 mandible	1	Altuna (1986)
	Cueto de la Mina	1 phalanx (2nd)	1	Castaños (1982)
Cantabria	La Pila	1 worked antler remain	1	This study
	Morin	2 teeth (1M2 + 1M3)	2	Altuna (1971)
	La Garma (A + Galería Inferior)	10 antler remains (including 3 worked elements, 1 unworked bez tine and 1 unworked base from a hunted animal)	10	Arias et al. (2005); This study
	El Valle	1 tooth (1 M sup)	1	Altuna (1971)
Navarre	Abauntz	1 worked antler remain, 2 phalanges (2nd), 1 perforated incisor	4	Utrilla (1982); Altuna et al., 2001-02
	Zatoya	1 scapula	1	Mariezkurrena and Altuna (1989)
Catalonia	Bora Gran	7 worked antler remains (including 2 shed bases), 4 unworked antler remains (including 1 shed base), 1 astragalus and 1 phalanx	13	Galobart et al. (1996); Nadal et al. (1997); Lefebvre (2016); This study

the last two decades has revealed that the under- or overrepresentation of the distal portions of the legs of fur-bearing mammals in faunal assemblages to result from the transport of pelts (among others Persson, 1979; Charles, 1997; Cochard and Brugal, 2004; Cueto et al., 2016; Kirkinen, 2017; Costamagno et al., 2018; Kivikero et al., 2020). During the skinning process, small bones of the hands and feet (i.e., phalanges, astragalus and even metapodial for small species) can remain attached to the pelt for their aesthetic/ritual aspect – for example, the claws of carnivores attached to furs (Persson, 1979; Cueto et al., 2016; Kirkinen, 2017) –, or for technical purposes (e.g., Cochard and Brugal, 2004; Costamagno et al., 2018; Kivikero et al., 2020). In the latter case, these leg elements remain attached to the pelt during transport between the butchery site and the tanning site, where they are removed, demonstrating a spatio-temporal segmentation of skinning activities. With this in mind, the phalanx and the astragalus found at Bora Gran may reflect the transport of reindeer pelts.

In this scenario, (1) the presence of reindeer in this region appears unlikely and (2) the nearest region from which these reindeer remains could have been imported lies north of the Pyrenees. The presence of reindeer is attested in the Ariège and tributary valleys, at sites including La Vache (NR in the Salle Monique = 5,821; Pailhaugue, 1996, 1998), as well as further east in the Montagne Noire, at Canecaude I (NR of the level II = 5,460; Fontana, 1998), Gazel (NR of levels 7–8 = 6,026; Fontana, 1999) and Bize (NR of the level H = 3,184; Magniez, 2010). On the other hand, southeast of these territories, reindeer are significantly less represented, accounting for only 179 elements at Les Conques (Moigne et al., 1998), 18 at La Crouzade (Saos et al., 2020), 2 at Belvis (NR = 2 - Fontana, 1999), while its presence is not guaranteed at Trou Souffleur (Sacchi, 1986). Accordingly, the foothills of the eastern Pyrenees could constitute the south-eastern margin of the ecological niche of reindeer in the Pyrenees at the end of the Pleistocene (Fig. 11). This likelihood is further supported by modelling of this species' ecological niche in southwest Europe that does not include Catalonia as a refuge during the Last Glacial Maximum (Banks et al., 2008, Fig. 1, C). Assuming that the ecological niche of the reindeer in western Europe saw its maximum geographic extension southward during the LGM, it seems unlikely that reindeer occupied this area during the following Late Glacial (Costamagno et al., 2016). Moreover, the LGM model for Catalonia is based on the unique presence of a shed reindeer antler in the Solutrean levels of L'Arbreda that was used as a hammer and potentially transported over relatively long distances (Estévez, 1978). Therefore, in the absence of relay sites between the eastern Pyrenean sites where reindeer have been recorded (i.e., Les Conques) and the northeast part of Catalonia, the three Magdalenian shed reindeer antler bases found at Bora Gran could also have been imported (along with pelts) over at least 75 km (as the bird flies) from the northern part of the chain, before being processed on-site (e.g., Figs. 2 and 3).

5.4. Reindeer antler industry as human mobility marker

Given the difficulty in determining their geographical origin, Palaeolithic osseous industries (including bones, antlers, teeth and excluding shells) are generally not considered relevant markers of human mobility, unlike lithic materials whose diffusion is more easily traceable across landscapes (e.g., Delvigne, 2016). However, in the few cases where the origin of osseous materials can be determined, or assumed, it is possible to trace the transport and or circulation of finished objects and even raw material blocks over sometimes large distances. Thus far, the only known examples from the European Palaeolithic involve the use of bones and teeth of marine mammals of presumably Atlantic origin (e.g., Poplin 1983; Corchón et al., 2008; Langley and Street, 2013; Pétillon, 2013, 2018; Pétillon et al., 2019; Lefebvre et al., 2021). However, when the ecological niche of species can be determined, as demonstrated here for reindeer, non-maritime osseous materials are equally relevant for tracking human mobility, in an extended range of archaeological contexts, including prehistoric hunter-gatherers and medieval craft specialists, as already demonstrated by the circulation of reindeer antlers combs in Early Medieval northern Europe (von Holstein et al., 2014; Ashby et al., 2015).

6. Conclusion

Our study shows the importance of reviewing previously excavated collections of osseous artefacts to explore the selection of raw materials for the manufacture of tools, weapons and personal ornaments. The (re) identification of reindeer antler artefacts in Magdalenian assemblages from northern Iberia demonstrates the use of this particular raw material in the region at the end of the Upper Palaeolithic and a technology designed to maximize the productivity of this relatively rare raw material. The demonstration of shared debitage methods and artefact types also reinforces previously identified connections with the neighbouring northern Pyrenean. Although only minimally-shaped objects made from the voluminous parts of antlers were identified (i.e., perforated batons and a possible blunt tool), waste products suggest that the main goal was to produce rods for the manufacture of projectile points and other tools. Therefore, despite the limited number of artefacts identified, our study nevertheless provides the first extensive database of Magdalenian antler

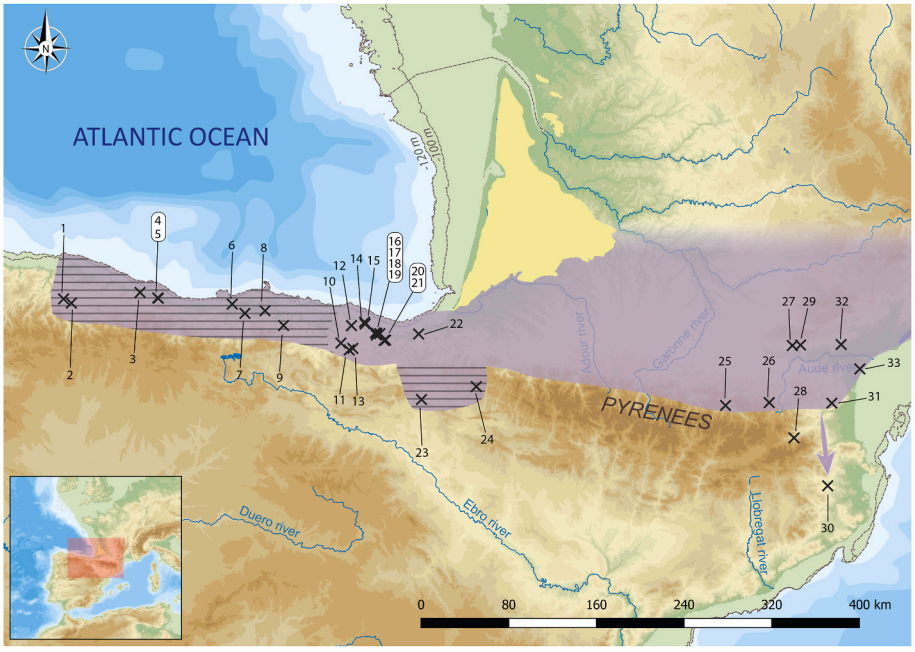

Fig. 11. Hypothetical distribution of the reindeer's ecological niche in southwestern France (the north of the Aquitaine Basin is not considered) and northern Iberia during the Magdalenian between 21 and 13 cal ka BP. In purple, the area where reindeer were probably naturally present in the environment, hatched purple, areas where its presence requires further study (i.e., Asturias, Cantabria and Navarre). The purple arrow represents the importation of reindeer antlers (along with pelt) to the Catalonian site of Bora Gran. 1: Las Caldas, 2: La Viña, 3: Tito Bustillo, 4: La Riera, 5: Cueto de La Mina, 6: La Pila, 7: Morín, 8: La Garma, 9: El Valle, 10: Arlanpe, 11: Atxuri, 12: Santimamiñe, 13: Bolinkoba, 14: Santa Catalina, 15: Lumentxa, 16: Kiputz IX, 17: Ermittia, 18: Praileaitz I, 19: Urtiaga, 20: Ekain, 21: Erralla, 22: Aitzbitarte IV, 23: Abauntz, 24: Zatoya, 25: La Vache, 26: Belvis, 27: Canecaude I, 28: Trou Souffleur, 29: Gazel, 30: Bora Gran, 31: Les Conques, 32: Bize, 33: La Crouzade. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

technology in northern Spain and highlights several aspects that need to be addressed in the future, including more precisely determining the type of objects manufactured on rods and linked to the more widespread red deer antler technology.

As already attested by ethnohistorical evidence from North American Subarctic populations (e.g., Burch, 1991; Kendrick and Lyver, 2005), the circulation of reindeer (and humans) in the Pyreneo-Cantabrian region was likely conditioned by the presence of both mountainous areas and migration corridors. While complementary faunal data suggests a local acquisition of reindeer antlers in the Basque region, the situation in Asturias, Cantabria and Navarre is less clear, likely because reindeer were only occasionally present in these areas. On the other hand, available data shows reindeer not to have been present in Catalonia at the end of the Pleistocene. The reindeer antler objects recovered from this region thus reflect the transport of blocks of raw material (along with pelts) over at least medium distances (ca. 75 km) from the northern part of the Pyrenees, demonstrating a spatio-temporal segmentation of this manufacturing activity and the potential role of reindeer antler industry as human mobility markers.

Author contributions statement

A.L. designed the study, analysed the assemblage of osseous industry, compiled the reindeer faunal data and led the taxonomic identification of antler remains with the help of J.-M.P. A.B.M-A. and J.-M.P. contributed to evaluating the outcomes. A.L. led the writing with edits and critical inputs from A.B.M-A. and J.-M.P. M.C. provided new unworked reindeer antler remains from La Garma. E.A.-F., P.A., R.O. and E. B. provided access to osseous collections still under study.

Acknowledgements

This research was primarily financed by an international collaboration between the Spanish Ministry of Science and Innovation (MCIN/AEI/10.13039/501100011033) and the European Union (NextGenerationEU/PRTR) as part of the HumAntler project (PCI2021-122053-2 B) based at the Grupo I + D + i EvoAdapta (UC). Funding was also provided by the UMR-5608 TRACES laboratory of the University of Toulouse and PID2020-114462 GB-I00 of the Spanish Ministry of Science and Innovation (University of Salamanca). The authors are grateful to all the museum curators and personnel for access to the studied collections: Maria Antonia Pedregal Montes, Sofia Díaz Rodríguez and Beatriz García for the Archaeological Museum of Asturias (Oviedo); Adriana Chauvin and colleagues of the Museum of Prehistory and Archaeology of Cantabria (Santander); Carmen de las Heras Martín, Lucía María Díaz González and Déborah Ordás Pastrana of the National Museum and Research Centre of Altamira (Santillana del Mar); Ruth Maicas Ramos, Eduardo Galán and J. Antonio Martos Romero of the National Museum of Archaeology of Madrid; Susana Fraile Gracia for the National Museum of Natural Sciences of Madrid; Iñaki García Camino and the entire team of the Archaeological Museum of Biscay (Bilbao); Sonia San Jose Santamarta and her colleagues of the archaeological centre of Gordailua (Irun); Mercedes Jover Hernando and Jesús Sesma Sesma of the Museum of Navarra (Pamplona); Ramon Buxó Capdevila and his colleagues of the Archaeological Museum of Catalonia (Girona); Andrea Ferrer Welsch of the Archaeological "Comarcal" Museum of Banyoles. We also thank Maria Soledad Corchón, Marco de la Rasilla, José Maria Fullola, Diego Garate, Olivia Rivero, Sandrine Costamagno and Emmanuel Discamps for helping with several collections, as well as Leire Torres-Iglesias and Rosana Cerezo Fernández for providing us with unpublished data from, respectively, La Viña and Tito Bustillo. Finally, we would like to thank the two reviewers and the editor whose comments and suggestions helped improve the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2022.105708.

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