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Neanderthal mobility over very long distances: The case of El Castillo cave (northern Spain) and the 'Vasconian' Mousterian

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ABSTRACT

This study explores the mobility and raw material circulation of Neanderthals at the El Castillo cave, located in the northern part of the Iberian Peninsula, with a particular focus on flint. The levels analyzed (XXab—XXf1.1) date between 45 and 70 ka BP, corresponding to the Mousterian period and, in some cases, to the Vasconian facies. Most of the flint varieties are of local origin (<10—30 km), but six additional sources have been identified, both regionally (30—120 km) and tracer (120—250 km), as well as a variety that would fall under the supertracer range (>250 km). These findings provide insights into patterns of lithic resource acquisition. Based on these data, together with the technotypological data and the quantitative representation of the different varieties of raw materials, it is proposed that the territory of these Neanderthals was larger than expected. Beyond their home range, they may have had an even larger 'social territory,' covering more than 600 km in length, from the Oviedo basin (Piedramuelle flint) to the Adour River (Tercis flint), including the Upper Ebro Basin (Treviño flint). Furthermore, this broad geographical region and the dates from the levels at El Castillo align with the spatial distribution of the Mousterian with cleavers or the Vasconian. The technotypological analysis of these assemblages suggests that the Vasconian may be more closely related to a broad view of the group and the sharing of ideas, rather than representing a strictly defined technological tradition.

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1. Introduction

The study of siliceous raw material sources during the Paleolithic is a valuable tool for analyzing and identifying the geographical areas that different groups may have been shared during this period (Geneste, 1992). Traditionally, research to identify the origins of raw materials and the possible territories used by Neanderthal groups during the Middle Paleolithic has shown that they tended to move within relatively small territories, typically within a 50-km radius of their sites, with most raw materials being sourced from even shorter distances. This aligns with the *Human Revolution* hypothesis (Mellars, 1996), which argued that Neanderthals were not highly advanced, either cognitively or socially. Additionally, the pattern of sourcing materials from short to medium distances has been confirmed at numerous European sites (for example, Geneste, 1992; Turq et al., 2017; Romagnoli et al., 2022).

However, current data on Neanderthal societies reveal more complex intergroup and regional behaviors. These conclusions are supported by wide technological variability, group mobility patterns, and varied territorial management strategies (Eixea et al., 2020; Romagnoli et al., 2022). In the Franco-Cantabrian region, when combining research on raw material sourcing with other cultural aspects, such as artistic and symbolic expressions or technical processes, it has been possible to identify potential territories indicating very long-distance contacts, both in the Upper (for example, Cazals et al., 2007; Arrizabalaga et al., 2014; Sauvet, 2019; Martín-Jarque et al., 2024) and the Middle Paleolithic (for example, Turq et al., 2017; Minet et al., 2021), at sites like Arlanpe and Axlor (Ríos-Garaizar, 2008, 2013). Moreover, the movement of raw materials over distances of up to 100 km has been documented in other parts of the Iberian Peninsula and Central Europe (Frahm et al., 2016; Turq et al., 2017; Eixea, 2018; Valde-Nowak and Cieśla, 2020; Malinsky-Buller et al., 2021). In some instances, these distances extend even further, reaching 200 km at exCasino in Italy (Porraz, 2005), 254 km at Champ Grand (Slimak and Giraud, 2007), and 300 km at Mezmaiskaya and Matuzka (Armenia) (Doronicheva and Kulkova, 2017).

Another aspect to consider is the proportion of these ‘exotic’ raw materials within the overall assemblage, which generally decreases as the distance from the source increases (Geneste, 1992). While this premise is important when studying *débitage*, it is less critical when investigating the extent of traveled space, social territories, or intergroup social networks given that the mere presence of these nonlocal raw materials is already a clear indicator of such contacts (Kuhn, 2020).

In recent years, various studies have been conducted to define the territory occupied by the Neanderthals at the El Castillo cave within the broader research on prehistoric group mobility during the Middle Paleolithic. A key aspect of this research involves characterizing the lithic raw materials to identify the sourcing areas for different types of flint. This research, combined with data from other sites and types of archaeological evidence, has focused on the early part of marine isotope stage 3 (MIS3) and the end of MIS4 (levels XXa/b, XXc, XXd, XXe, and XXf1.1).

In the geographic area and period under discussion, between 70 and 40 ka BP, covering the end of MIS4 and the early MIS3, some Neanderthal occupations have been linked to the Vasconian facies of the Mousterian. This Vasconian was first identified in the early 20th century as a Middle Paleolithic with cleavers with African influences (Vega del Sella de la, 1921; Carballo, 1923; Obermaier, 1924) or simply Middle Paleolithic with cleavers (Passemard, 1936). Bordes (1953) finally defined it as Vasconian, interpreting it as a Charentian Quina-type facies with cleavers. However, he always pointed out that these assemblages did not fit well into his broader Mousterian framework. Because of this, some researchers questioned the need to classify it as a distinct facies as aside from the presence of cleavers, there did not seem to be many other unifying features across the collections (Freeman, 1966; Cabrera-Valdés, 1983). More recent studies, however, have argued that Vasconian assemblages share both cleavers and Discoid *débitage* (Deschamps and Mourre, 2012; Deschamps, 2017; Ríos-Garaizar, 2017; Ríos-Garaizar et al., 2024).

The Vasconian has been identified across the Franco-Cantabrian region, stretching from Asturias in Spain to the French Basque Country. It spans from La Viña in Asturias in the west to Noisetier in the east, Latrote in the north, and Abauntz in the south. The technotypological data from these sites are quite varied, making it difficult to compare them all with the same level of certainty.

Thus, in this paper, we aim to characterize the different types of flint and radiolarite found in levels XXab–XXf1.1 of the El Castillo cave and put these findings into a regional context. We especially want to relate them to the Vasconian Mousterian type with which these archaeological levels have traditionally been associated and to evaluate, prospectively, the entity of the Vasconian itself.

2. El Castillo

The El Castillo cave is a crucial site for understanding the Paleolithic period in Europe. Located in Puente Viesgo, Cantabria, in northern Iberia (Fig. 1A), it was discovered by H. Alcalde del Río in 1903 and excavated by H. Obermaier between 1910 and 1914. The cave features one of the world's most important rock art assemblages, with over 3000 graphic units from all periods of the Upper Paleolithic (Groenen and Groenen, 2015). Additionally, it contains an extraordinary site comprising between 23 and 25 m of stratigraphy with layers spanning from the beginning of the Middle Paleolithic to the Azilian (Fig. 1B), with a brief occupation during the Bronze Age (Cabrera-Valdés, 1984; Maíllo-Fernández et al., 2023).

Alcalde del Río conducted the first excavation at El Castillo in the interior part of the site's debris cone. In this test pit, just over 2 m deep, he confirmed the significance of the site and the need for a more extensive excavation (Alcalde del Río, 1906). Comprehensive excavations were carried out between 1910 and 1914, sponsored by H.S.H. Albert I of Monaco and led by H. Obermaier, H. Breuil, and H. Alcalde del Río. In practice, however, the excavation was directed by Obermaier alongside P. Wernet. These efforts revealed the site's extensive stratigraphy and archaeological potential (Breuil and Obermaier, 1912, 1913). The archaeological materials from these early excavations were studied much later: the lithics by Cabrera-Valdés (1978, 1984) and the fauna by Castaños (2018).

In 1980, a new excavation project began, initially led by Victoria Cabrera-Valdés (until her passing in 2004) and then by F. Bernaldo de Quirós (2004–2017). Since 2020, two of us (J.M.M.F. and J.M.) have continued the work. The focus has been on the Mousterian period, with excavations in a larger main area, as well as a smaller, lateral one, 3 m^2 in size. Both areas are located outside the cave's vestibule (Cabrera-Valdés et al., 2006; Bernaldo de Quirós et al., 2010a; Maíllo-Fernández et al., 2023) (Fig. 1C).

After 120 years of excavations at the site, the stratigraphy can be summarized as follows (Fig. 1B): level 1: stalagmitic crust; level 2: Eneolithic; level 3: stalagmitic crust; level 4: Azilian; level 5: stalagmitic crust; level 6: Upper Magdalenian (alpha for Obermaier); level 7: silt between the Magdalenian; level 8: Lower Magdalenian (beta for Obermaier); level 9: sterile; level 10: Solutrean; level 11: sterile; level 12: Gravettian (Alpha Aurignacian for Obermaier); level 13: sterile silt; level 14: Gravettian (Beta Aurignacian for Obermaier); level 17: sterile; level 18: Transitional? (Delta Aurignacian for Obermaier); level 19: sterile; level XX: Mousterian

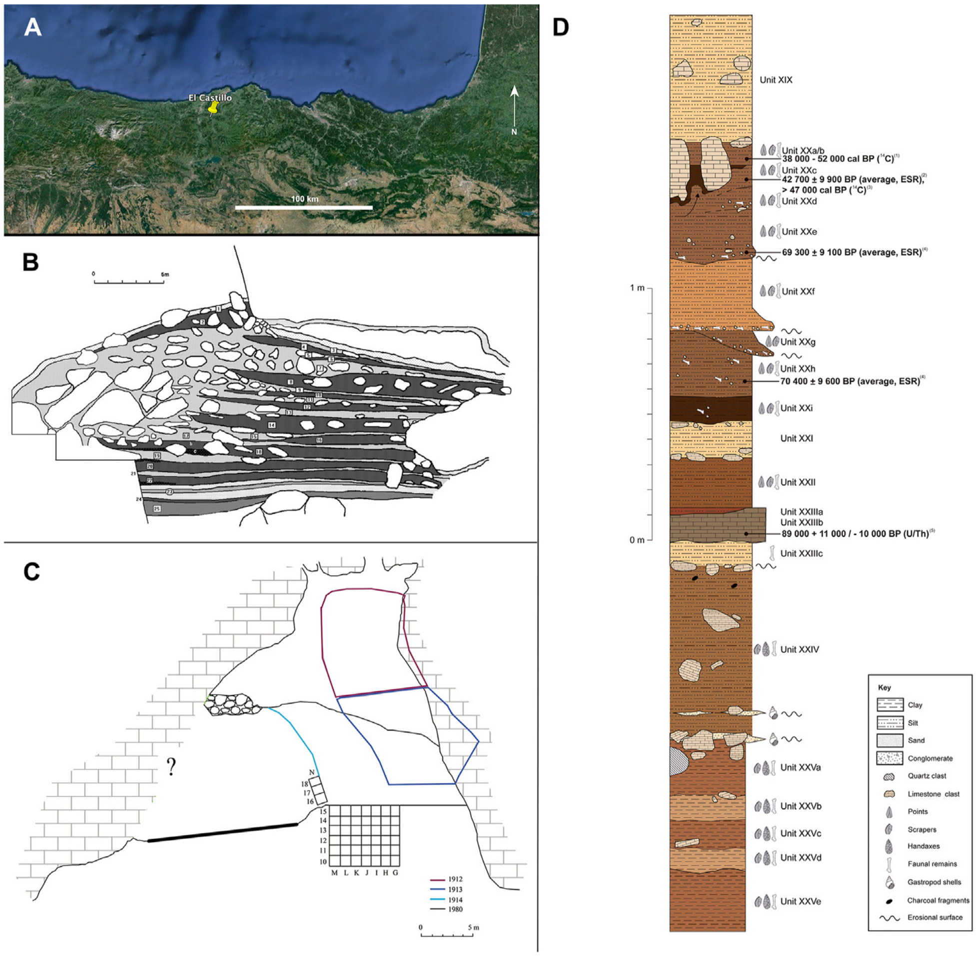


Figure 1. A) Location map of El Castillo in northern Iberia. B) N-S profile of the stratigraphy of El Castillo (after Cabrera-Valdés, 1984). C) Plan of the vestibule of El Castillo. D) Synthetic stratigraphic column of the Middle Paleolithic levels (after Martín-Perea et al., 2023). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

(Alpha for Obermaier); level XXI: sterile; level XXII: Mousterian (Beta for Obermaier); level XXIII: stalagmitic crust; level XIV: Early Middle Paleolithic (Acheulean and '*sous*' Acheulean for Obermaier); and level XXV: Early Middle Paleolithic (Cabrera-Valdés, 1984; Martín-Perea et al., 2023).

3. The Mousterian at El Castillo

The Mousterian at El Castillo is represented by two levels: XXII, the oldest, and XX, separated by a sterile level (XXI). The Mousterian from level XXII is known only from H. Obermaier's excavations, where the archaeological material is like that of level XX, except for the absence of large cutting tools, particularly cleavers.

Level XX corresponds to Obermaier's Mousterian alpha, which was re-excavated by Cabrera-Valdés and Bernaldo de Quirós in the site's lateral test pit (Fig. 1C). Still under excavation in its lower part, this unit has been subdivided into eight slightly clayey sand silt units (XXa/b to XXi). The five most recent ones (XXab, XXc, XXd, XXe, and XXf1.1) are analyzed here (Fig. 1D and Supplementary Online Material [SOM] 1). Colors range from brown (10YR 5/3; units: XXa/b, XXd–e, and XXg–i) to light brown (7.5YR 5/4; unit: XXf), with unit XXc being very dark brown to very dark gray (5YR 3/1) due to the presence of abundant hearths (Martín-Perea et al., 2023). Due to these archaeosedimentary subdivisions, our conclusions cannot be related to the Obermaier collection.

The most used raw materials are fine-grained and coarse-grained quartzite, sandstone, quartz, and flint. Although flint is very scarce, it has significant paleoethnographic implications, which will be discussed later.

The lithic industry in these levels is characterized by *débitage* from unifacial discoid (Table 1) and, to a much lesser extent, Levallois methods (Cabrera-Valdés et al., 2006; Sánchez and Bernaldo de Quirós, 2008; Bernaldo de Quirós et al., 2010b; González-Molina et al., 2024). The most represented retouched pieces are denticulates (levels XXab, XXc, and XXf1.1) and side-scrapers in levels XXd and XXe (Table 1; Fig. 2). These levels were classified as Vasconian-type Mousterian because of the cleavers found in the Mousterian *alpha* of Obermaier (e.g., Bordes, 1953; Deschamps, 2014). In the analyzed collection, cleavers are only found in levels XXd, XXe, and XXf1.1 (Table 1).

These levels also provide clear evidence of microlithization within the industry, primarily resulting from discoid methods. However, it occasionally manifests in the production of bladelets and blades obtained from Levallois, unipolar, and prismatic/unidirectional cores (Fig. 2), some of which show retouch and use wear (Cabrera-Valdés et al., 2000; Maíllo-Fernández et al., 2004; Gutiérrez, 2006). This laminar *débitage* strategy has also been documented at other Cantabrian sites, such as Cueva Morín, El Cuco, and Covalejos (Maíllo-Fernández et al., 2004; Ríos-Garaizar, 2020; Martín Blanco, 2021), as well as at French sites like Combe

Table 1
Technological and typological information of the Mousterian levels analyzed.

Level	Raw material	Flint/radiolarite (%)	Main lithic production	Retouched	Main retouched blank	Cleaver	Points	Sidescraper	Denticulate/notches	Upper Palaeolithic	Others
XXab	FGQ (53.6%)	4.2	Discoid	51 (6.5)	Denticulate	No	0	11 (21.5)	20 (39.2)	5 (9.8)	15 (29.4)
XXc	FGQ (54.5%)	3.4	Discoid	87 (4.5)	Denticulate	No	1 (1.1)	21 (24.1)	39 (44.8)	9 (10.3)	17 (19.5)
XXd	FGQ (37.8%); CGQ (34.3%)	3.8	Discoid	73 (8.2)	Sidescraper	Yes	1 (1.3)	28 (38.3)	19 (26)	7 (9.5)	5 (6.8)
XXe	FGQ (47.6%)	9.8	Discoid	145 (14.6)	Sidescraper	Yes	2 (1.3)	53 (36.5)	49 (33.7)	11 (7.5)	25 (17.2)
XXf1.1	FGQ (60.5%)	9.8	Discoid	172 (12)	Denticulate	Yes	0	39 (22.6)	45 (26.1)	30 (17.4)	54 (31.3)

Excluded from typological data: 1, 2, 3–8 from the list of Bordes (1961). Points (3–8 without 5). In brackets are percentages. Raw materials: FGQ = fine-grained quartzite, CGQ = coarse-grained quartzite.

Grenal, Olha II, and Gatzarria (Deschamps, 2009-2010; Faivre, 2012).

The fauna in these Mousterian levels is dominated by *Cervus elaphus*, representing around 80% of remains in level XXa/b and 50% in level XXd, complemented by smaller proportions of other species such as *Equus caballus*, *Bos/Bison* and *Dicerorhinus* sp., among others (Luret et al., 2020). The analysis of the animal's age at death for level XX shows that adult *C. elaphus* individuals were predominantly hunted. The number of individuals for other species is very small, with no more than two individuals for any species (Pike-Tay et al., 1999). The seasonality study for the Mousterian levels, based on a dental annulus analysis (Pike-Tay et al., 1999) and the examination of young individuals' teeth (Luret et al., 2020), indicates that while hunting occurred year-round, there was a seasonal trend, particularly toward late autumn, during spring, and up to early summer (levels XXa/b, XXc, and XXe).

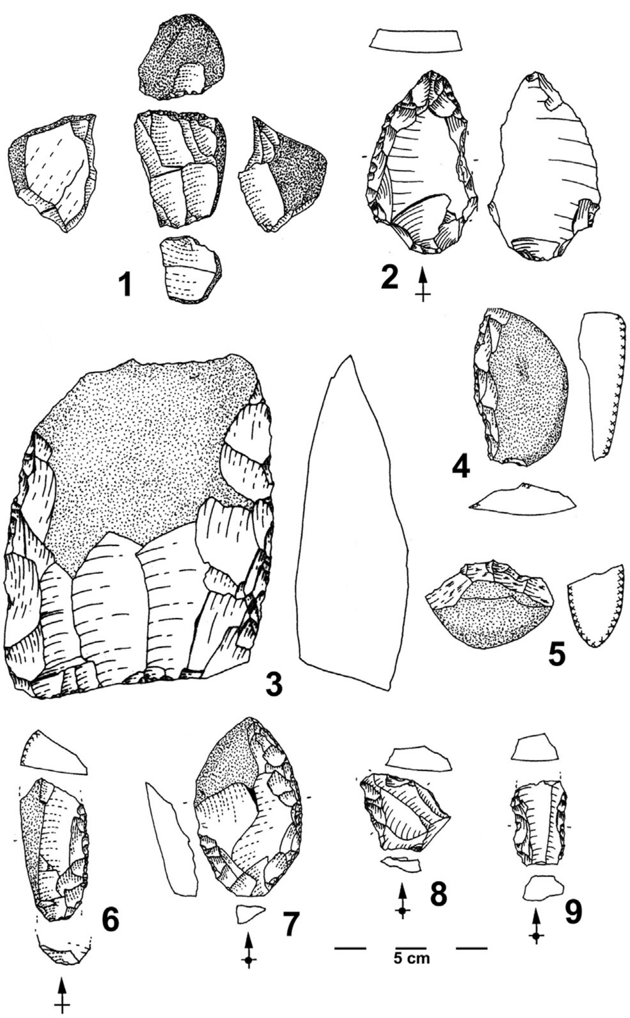


Figure 2. Lithic material from the Mousterian levels analyzed in this study. 1: Laminar bidirectional core in quartzite. 2: Mousterian point on flint. 3: Cleaver on ophite. 4 and 5: Denticulates on quartzite and quartz. 6–8: Fine-grained quartzite sidescrapers. 9: Notches on flint.

From an anthropological standpoint, a premolar was found in level XXd and a fragment of a phalanx in level XXf, both from adult Neanderthals, along with a femur head from a young Neanderthal, also found in level XXf (Garralda et al., 2023).

Chronologically, these levels fall within the time frame of 38–52 ka cal BP for level XXab, dated using C14, and 70 ka BP for level XXh, dated using electro spin resonance (ESR) (Cabrera-Valdés et al., 1996; Rink et al., 1996). Therefore, the levels analyzed here correspond to the first half of MIS3 (XXab–e) and the MIS4/3 transition (level XXf1.1). The study of the microfauna also supports this chronology (Álvarez-Vena, 2024).

4. Materials and methods

The material analyzed here comes from the excavations led by V. Cabrera-Valdés between 1995 and 2004 in the lateral test pit. Levels XXa/b, XXc, XXd, XXe, and XXf1.1 have been examined (Fig. 1). A substantial number of lithic pieces and faunal remains were recovered from these levels, totaling 7382 lithic remains (XXa/b = 863; XXc = 2762; XXd = 988; XXe = 1044; XXf1.1 = 1725). For this study, the analysis focused specifically on the lithic industries made from flint and radiolarite.

4.1. Raw material analysis

The identification of raw material provenance has been conducted exclusively on flint sensu lato as it has the longest research tradition and has yielded the most promising results. In the case of quartzite, although significant studies are currently underway (Prieto et al., 2020, 2021; Prieto, 2022), its provenance has not been considered in this study. The raw materials were identified using the methodology proposed by Tarriño and Terradas (2013). The study took place in two phases. The first involved a microscopic analysis using a stereomicroscope on all the flint pieces from the studied levels. Based on the textural characteristics of each piece (such as matrix, impurities, and inclusions) (Herrero-Alonso, 2018), the pieces were assigned to a known variety of flint, where possible. In cases where clear diagnostic elements were not observed and thin sections could be made, a textural analysis was conducted using a polarized-light microscope (a total of eight samples). These samples were prepared at the *Servicio de Lámina Prima* ('Thin Section Service') at the University of Barcelona, with a thickness of 30 μm. Their analysis was based on the description of orthochemical and allochemical elements, along with authigenic and relict minerals, following the method proposed by Folk (1980) and in other previous studies (Tarriño and Terradas, 2013; Herrero-Alonso, 2018; Herrero-Alonso et al., 2021b). Using these attributes, it was possible to determine the origin of most of the varieties, using the LegioLit knappable material lithotheque at the University of León as a comparative collection (Herrero-Alonso et al., 2018). The different varieties of raw materials have been classified according to their distance from the site. Their designation follows the terminology proposed by Tarriño et al. (2016): local (<30 km), regional (60–120 km), tracer (120–250 km), and supertracer (>250 km). The study of alterations and cortical characteristics has been conducted using a stereomicroscope, acknowledging the limitations of this technique. The cortex has been classified into primary and secondary types, with the latter further divided into those bearing marks associated with high-energy environments (such as mountain river courses) and low-energy environments (including polishing and abrasions). So far, no further analysis has been conducted on the provenance of secondary contexts, considering that outcrops in the Cantabrian region are located very close to marine sedimentary basins. As a result, the transport distance of the flints is very short, making them less susceptible to multiple postdepositional processes than other regions of Europe.

In some cases, the varieties described in this study were grouped based on the flint outcrops (nodular) morphology vs. that of radiolarite (bedded) for comparison. This includes the 'Las Portillas chert' in the first group, disregarding the geological chronology to which this term refers (Herrero-Alonso, 2016).

4.2. Lithic material

We have conducted a technological analysis of the *débitage* raw material economy (Perlès, 1991) using the concept of the *chaîne opératoire* (Karlin, 1992; Inizan et al., 1995; Audouze and Karlin, 2017). In this study, we place particular emphasis on the technological process, specifically the sourcing of raw materials, the knapping techniques and methods, the goals of lithic production, and the final products, both retouched and unretouched (sensu Maíllo-Fernández and Carrión, 2023). Special attention has been given to the management of flint within the assemblage based on its origin, following the patterns on exogenous rocks proposed by Geneste (1985).

The typological study of the retouched pieces follows the Lower and Middle Paleolithic typology developed by Bordes (1961), with an adapted approach from G. Laplace's proposal for the analytical study of retouch (Laplace, 1966). In the latter case, parameters such as angle, extent, position, or localization of retouch have been considered.

4.3. Geographic information system analysis

The maps illustrating the routes taken to acquire raw materials were generated using ArcGIS Pro designed for the analysis and visualization of geospatial data. They incorporate digital terrain model (DTMs) from the French *Institut national de l'nformation géographique et forestière* (http://geoservices.ign.fr/telechargement-api) and the Spanish *Instituto Geografico Nacional* (https://centrodedescargas.cnig.es/CentroDescargas/index.jsp), with a resolution of 25 m.

The 'Optimal Path As Raster' tool was used to predict and replicate movement routes across the terrain from a starting to a destination point. To use this tool, a series of layers were generated to serve as variables for the model.

First, it is essential to understand the accessibility of the terrain using a 'costmap.' Mobility studies have enabled us to calibrate how difficult it was for people to move through the environment (Prieto et al., 2016; Sánchez et al., 2016; Herrero-Alonso et al., 2020; Vaissié, 2021). This involved establishing cost surfaces, which meant generating maps where the terrain was represented through quantified effort values. Using this map instead of a DTM directly makes it possible to replace Cartesian spatial properties with much more complex surfaces. However, it is important to remember that, despite being a determining factor in the cost of movement, it is not the only one that can influence the choice or tracing of a route (García Sanjuan et al., 2009). The slope was taken as a key value in generating the cost surface since it plays a crucial role in establishing impedance. This layer is obtained through the 'Slope' tool, derived from a DTM. The 'Distance Accumulation' tool was also used to create two additional layers needed for the 'Optimal Path' tool.

4.4. Statistical analysis

As we have already seen above, our analysis of flint/radiolarite provenance at El Castillo is historiographically linked to the Vasconian. Therefore, from a statistical point of view, we have analyzed the consistency of this industry to check if it has an internal identity and to assess the relationship of the cleavers/hand axes with the acquisition of raw materials. For this purpose, we conducted a statistical analysis of several collections with cleavers and others without, but roughly from the same chronology, to determine if any correlations or 'statistical identities' exist between them. This involved performing various exploratory data analyses.

Using a database of 31 Mousterian levels from Franco-Cantabrian sites, we compared those with cleavers (El Castillo, Abauntz, Olha II, Gatzarria, etc.) to others without cleavers (Cuco, Covalejos, Axlor, Hornos de la Peña, etc.) (SOM 2.1).

The initial approach was to perform a principal component analysis (PCA) to reduce the dimensionality of our assemblage by projecting the data using least squares. For this, we used only the quantitative variables of the parameters (sidescraper, denticulate/notch, points, Upper Paleolithic tools, main *débitage*, bladelet, hand axe, and cleaver), all expressed as percentages of the total. All numerical variables were included to observe the results regardless of their correlation.

The second analysis was a k-means cluster analysis. For this method, the number of groups or clusters to divide the data into must be preselected. We used the 'mclust' library with the mclust( ) function in R (version 4.3.2) to determine the optimal number of groups to divide our sample. The test indicated that our data's ideal number of clusters is $k = 4$ (see SOM 3 for other combinations).

Additionally, a multiple correspondence analysis was performed, which allows us to examine the relationship between more than two categorical variables. For this analysis, only categorical variables were used (see SOM 2.2).

Finally, a cluster-dendrogram analysis was conducted, generating a hierarchical tree that groups the different cases from our database based on a distance matrix. Like the PCA and k-means analyses, this was done using only the variables 'Points,' 'Hand axes,' and 'Cleavers' as these were the most suitable and explained the most variance. We again used the mclust( ) function to determine the optimal number of groups, which resulted in $k = 4$.

5. Results

5.1. Petrographic analysis

The number of pieces in the lithic assemblage from the Mousterian levels at El Castillo varies (Table 2). Flint is quite rare, but from a diachronic perspective, its percentages range from 3% to 4% in levels XXa/b, XXc, and XXd (MIS3) to 9.5% in XXe and XXf1.1 (MIS4/3).

In this study, a total of 262 blanks were analyzed, 251 of which are flint and 11 are radiolarite (Table 3). This analysis identified seven varieties of flint and one variety of radiolarite.

Table 2
Inventory of pieces from the different levels analyzed indicating the percentage of flint and radioralite.

Level	All raw materials	Which silex	Which radiolarite
XXa/b	777	32 (4.1%)	1 (0.1%)
XXc	1943	61 (3.1%)	7 (0.4%)
XXd	885	32 (3.6%)	2 (0.2%)
XXe	987	94 (9.5%)	3 (0.3%)
XXf1.1	1431	137 (9.5%)	4 (0.3%)

Chips are excluded from the data.

Table 3
Flint and radiolarite analyzed in this study.

Flint-radiolarite type/level	XXa/b	XXc	XXd	XXe	XXf1.1	Total
Radiolarite Alba		5	2	3	1	11
Flint Flysch		9	3	14	7	33
Flint Las Portillas		1			5	6
Flint Monte Picota	5	18	5	54	36	118
Flint Piedramuelle					1	1
Flint Tercis		2		2	3	7
Flint Treviño				2		2
Flint Urgoniano	11				1	12
Flint Indet.	5	24	15	8	20	72
Total	**21**	**59**	**25**	**83**	**74**	**262**

Monte Picota flint The Monte Picota flint is named after its type locality (Tarriño and Terradas, 2013; Tarriño et al., 2013, 2015, 2016) and is one of the most important lithic resources found in the central sector of the Cantabrian region. Given its distribution and identification at numerous prehistoric sites, it can be considered a regional variety (Sarabia Rogina, 1999; Tarriño, 2016; Martín-Jarque et al., 2019, 2022; Fano et al., 2020; Herrero-Alonso et al., 2020, 2021a; Ríos-Garaizar, 2020; Ríos-Garaizar et al., 2020; García Rojas, 2021). Outcrops of siliceous nodules from this formation have been known since the work of Jesús Carballo, who noted their presence in the limestones of Cabo Mayor (Sarabia Rogina, 1983).

Geographically, it is located between the mouth of the Pas River and Cabo Mayor, north of modern-day Santander. Geologically, it is found exclusively in the Santillana-San Román syncline in Cantabria. The flint appears in the glauconitic layers of the Cabo de Lata Formation, which was created on neritic platforms dating back to the Upper Campanian (Ramírez del Pozo and Portero García, 1976).

The Monte Picota flint is macroscopically characterized by its highly uniform and translucent matrix, which displays bluish and violet hues (SOM 4). The grain size ranges from coarse to very fine, with coarse grains being the most common. Orange geodes are frequently found, some cemented, but still retain their color (Fig. 3A). Lastly, the archaeological pieces often have a patinated surface, appearing white. In such cases, the defining features are the piece's translucent edge and the presence of geodes and fibrous quartz growths (Fig. 4A–C). Occasionally, areas with a more detrital texture can be observed, including some foraminifera and echinoderm remains, though these never exceed 1 cm in size (Herrero-Alonso, 2018).

In the thin section, the flint from Monte Picota displays a matrix composed of heteromeric growths of fibrous quartz (chalcedonite). Microgeodes formed by these fibrous quartz growths are relatively common. When these microgeodes are filled, which is in most instances, they contain both fibrous quartz crystals (chalcedonite and, less commonly, quartzine). These microgeodes can reach up to 5 mm in size and have orange hues. Cementation with megaquartz is much less frequent. Allochemicals are only found in areas associated with intraclasts or bioturbations, where various bioclasts and detrital quartz can be noted (Herrero-Alonso, 2018).

The Monte Picota flint is the nearest source to El Castillo, located approximately 23 km away. It is the most common variety among the materials studied at the site, with 118 pieces in total, making up 45.04% of the assemblage and 61.78% of all identified flint pieces. This flint is the most common in all levels, with its highest concentration in level XXe, accounting for 72% of the total. It only becomes the second most frequent flint type in level XXab (31.25%), which is only surpassed by the Urgonian flint.

The Monte Picota flint was sourced in two different ways. On the one hand, nodules were collected in their primary position directly from the outcrops, as evidenced by the primary, rough, and unweathered cortex. This accounts for 10–30% of the flint and is present in all levels except level XXab, where the collection is very limited. On the other hand, the flint was obtained from secondary positions in both riverine and maritime contexts, with a higher percentage range (10–40% depending on the levels), and is absent from level XXd.

Alba radiolarite Alba radiolarite is the most important Paleozoic variety in the Cantabrian region. It was among the first materials in the Cantabrian zone to be described in terms of its texture (Fuertes-Prieto et al., 2010). In recent years, further studies have been published on its characteristics, including its texture, mineralogy, geochemistry, and thermal properties (Arias et al., 2009; Herrero-Alonso, 2018; Herrero-Alonso et al., 2021b).

It has been found at numerous sites in the northern part of the peninsula, establishing Alba radiolarite as a regional resource (Gutiérrez Vuelta, 2000; Santamaría, 2012). This type of radiolarite has a relatively wide distribution, appearing in all geological units of the Cantabrian zone (Sánchez de Posada et al., 2002).

It originates from pelagic environments and appears in two different members of the formation: the middle member (Lavandera) and the upper member (Canalón). Both silifications differ in terms of their matrix characteristics, impurities, and inclusions, but they both share the presence of radiolarians as a common feature (SOM 4).

The primary outcrops of this raw material are about 102 km west of El Castillo, and the findings at the site are not very numerous: only 11 pieces, accounting for 4.2% of the total assemblage and 5.76% of the identified varieties.

However, based on textural characteristics, two distinct subvarieties have been identified. On the one hand, there is a single piece without the cortex found in level XXc, displaying the typical features of radiolarite: parallel lamination, a reddish color, the presence of radiolarians, and evidence of leaching. On the other hand, there are nine other pieces (XXc: 4; XXd: 1; XXe: 3, and XXf1.1: 1) showing parallel lamination, radiolarians, an intense black color, and numerous cemented fractures by quartz (Figs. 3B and 4D). This specific combination of features has only been identified in one very particular variety of Alba radiolarite, which has so far only been found in Paleozoic secondary contexts of a conglomerate kind. Notably, many pieces in the assemblage have a secondary cortex (seven in total). They all share the same features: slightly rounded, but not subspherical, with a light greyish color. This suggests that the Alba radiolarite found at El Castillo was mainly collected as nodules from secondary contexts (nine pieces) as opposed to other, undetermined contexts (one radiolarite from the middle members and one indeterminate radiolarite).

Urgonian flint This variety of flint is perhaps one of the least well-known varieties in the Cantabria region, mainly due to the relatively limited number of studies on its characteristics (Tarriño et al., 2015; Bustillo et al., 2017). It is found in association with Urgonian-age limestones in the Basque-Cantabrian Basin. Its outcrop area is quite large, covering a significant part of modern-day Cantabria. While it is a primarily local resource, it has also been found at some more distant sites (Martín-Jarque et al., 2022).

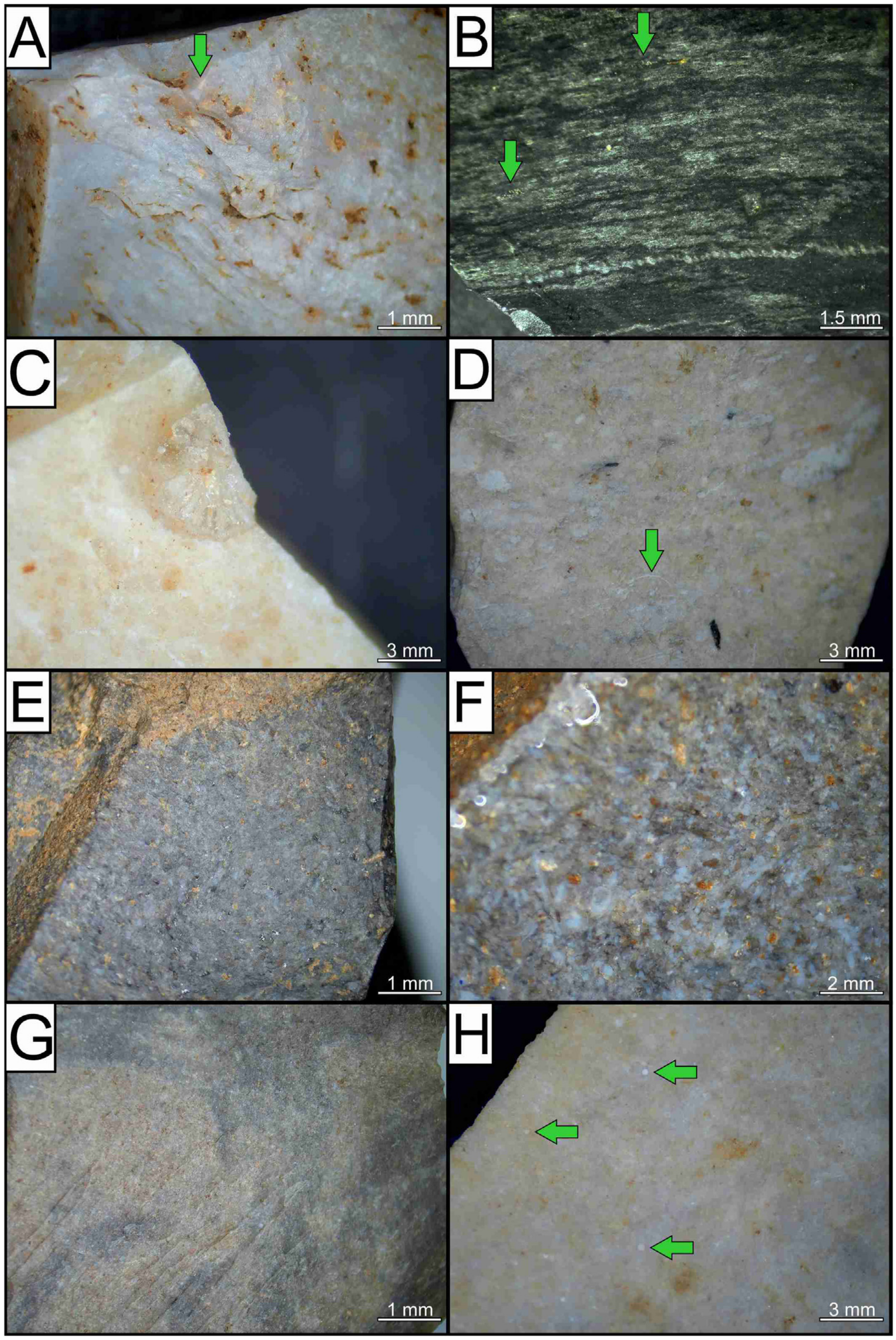


Figure 3. A) Monte Picota flint. Arrows point to orange impurities. B) Alba radiolarite. Parallel lamination and deformed radiolarite phantoms are visible. C) Coral fragment of the Urgonian flint. D) Treviño flint. The arrow points to an ostracod. E and F) Flysch flint, with sands (left), sponge spicules, organic matter, and dolomite (right). G) Gaintxurizketa flint. Matrix with bioturbation. H) Tercis flint. The arrows point to some of the globigerinids. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

The limited studies on this reef formation describe two types of silicifications: one of diagenetic origin and the other of hydrothermal origin associated with mineralizations (Aramburu, 1998). A recent paper links some of these silicifications with bioturbations caused by Thalassinoides (Bustillo et al., 2017). Due to the difficulty in identifying this variety and the lack of available information, only pieces with a homogeneous matrix showing coral remains have been classified as Urgonian flints (Fig. 3C). These bioclasts are one of the most characteristic of this variety. In the future, it is possible that some of the unidentified pieces may be attributed to this variety.

Due to the limited number of studies, the Urgonian flint outcrops are not well known, but they can be considered local to El Castillo given the regional geology. This flint is present in the levels studied at El Castillo, totaling 12 pieces, representing 4.58% of the total assemblage and 6.28% of all identified pieces. However, its distribution is very uneven across the levels: 11 pieces are found in level XXab, the most recent, and only one in level XXf1.1, the oldest of those analyzed. So far, this variety has not been observed in the other levels. Only two pieces with the cortex have been found, both rounded and showing impact marks, indicating they were likely collected from fluvial and/or maritime contexts.

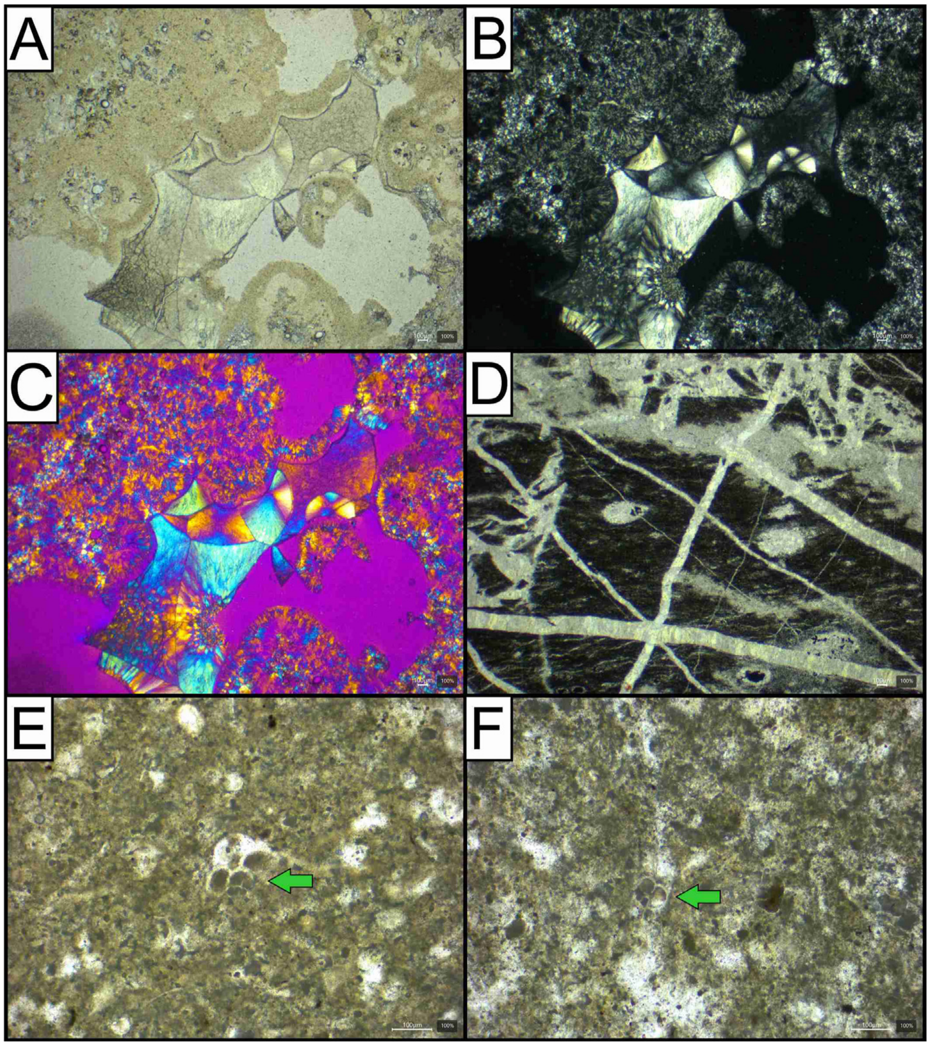


Figure 4. A) Monte Picota flint. Partially cemented pocket (ppl). B) Monte Picota flint. Geode partially cemented by fibrous quartz (xpl). C) Monte Picota flint. Geode partially cemented, in this case, by quartzite (xpl + gypsum wedge). D) Alba radiolarite with lamination and high percentage of cemented fractures. Slightly ellipsoidal radiolarite phantoms parallel to the lamination (ppl) can be seen. E and F) General texture of the Tercis flint, with details of globigerinids (green arrows) (ppl). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Treviño flint The Treviño flint was first formally identified by Tarriño (2006) and is considered one of the most important raw materials of the northern Iberian Peninsula, along with the Flysch flint. It has a wide geographical distribution and has been identified at numerous Paleolithic sites. The outcrops are found exclusively in the Araico-Cucho mountain range, located in the County of Treviño, in the upper reaches of the Ebro River.

Several textures of the Treviño flint have been identified, all linked to lake/marsh environments. At El Castillo, the variety present is known as 'algal banded.' This type is distinguished by subparallel laminations and the presence of ostracods. Additionally, there may be organic matter spots and fragments of algae (Fig. 3D; Tarriño, 2006).

The primary outcrops are about 169 km from the site, where two pieces were found in level XXe, both lacking a cortex. These represent a very small percentage, 0.76% of the total assemblage and 1.05% of the identified flint.

Flysch flint The Flysch flint refers to a group of varieties with shared characteristics formed in turbiditic environments, though with some internal differences (Tarriño et al., 2015). These variations can sometimes make it difficult to distinguish between specific types of Flysch flint such as Kurtzia, Barrika, Gaintxurizketa, and Bidache. This is one of the most well-known flint types in the Cantabria region, thanks to its description by Tarriño (2006).

For this study, we will consider the Flysch flint in a broad sense as only a few pieces can be attributed to a specific variety. Nonetheless, the Flysch flint is a tracer flint, with a wide geographical distribution across the Cantabrian region, appearing at many Middle Paleolithic sites (Thiébaut et al., 2012; Colonge et al., 2015; Ríos-Garaizar, 2016, 2017, 2020; Gutiérrez-Zugasti et al., 2018; de la Rasilla et al., 2020; Minet et al., 2021).

Geographically, Flysch flint outcrops are found along the coastal areas of the Bay of Biscay and at the mouth of the Adur River. The Kurtzia variety, located on the beaches of Barrika, is the westernmost type. Moving east, near the border between France and Spain, we find the Gaintxurizketa variety. Lastly, in the French territory, the Bidache, Behobia, and Mouguerre varieties can be found (Tarriño et al., 2015). The Flysch flint is typically characterized by the presence of abundant sponge spicules and detrital quartz (Fig. 3E, F and SOM 4). Additionally, depending on the specific variety, it may contain spots of organic matter and idiomorphic dolomites (Tarriño, 2006).

The nearest outcrops of Flysch flint are about 161 km from El Castillo. A total of 34 pieces have been identified, representing 12.98% of the total assemblage and 17.80% of the identified flint. It is present in nearly all levels, with its representation ranging from 12.96% in level XXf1.1 to 30% in level XXd. Interestingly, Flysch flint is more abundant in the older levels, with a gradual decrease in the more recent ones. However, it is important to consider the relatively low number of pieces on some levels. In terms of the internal varieties, a 'Kurtzia' and a possible 'Bidache' were identified in level XXe, while a 'Gaintxurizketa' variety was found in level XXc (Fig. 3E–G). Notably, no Flysch flint was found in the most recent level, XXab.

Most of the Flysch flint was gathered from secondary contexts (66.7%). Some pieces show signs of marine abrasion, which indicates collection from coastal areas, which is consistent with the location of many outcrops. Only one piece with the primary cortex has been identified, surprisingly from the only piece linked to the 'Bidache' variety. Lastly, it is also worth noting that the presence of a cortex in level XXe is relatively high, with five out of 14 pieces retaining some cortex, including the only evidence of sourcing from a primary position.

Tercis flint The Tercis flint is a well-known variety that outcrops near the Adour river in the Landes region of France. Its description is closely tied to studies conducted at the quarry where the different layers are exposed (Odin, 2001). This type of flint has also been found at other sites in the Cantabrian region, such as El Mazo (unpublished results).

The Tercis flint was formed in deep marine environments, with very little continental input. Its most distinctive features are its fine-grained texture and the presence of globigerinids (Molina, 2004; Odin, 2010), a type of planktonic foraminifera that typically has spherical shapes, making them easily recognizable (SOM 4). Occasionally, other foraminifera and sponge spicules can also be found, though these are much less common. At El Castillo, the presence of globigerinids was the key factor in identifying Tercis flint as these organisms do not appear in any other known Cantabrian marine formation (Figs. 3H and 4E, F).

Tercis flint is the furthest flint source identified at El Castillo, with its primary sources found 427 km away. A total of seven Tercis flint pieces have been identified at El Castillo, accounting for 2.67% of the total assemblage and 3.66% of all the flint identified. Two pieces were found in levels XXc and XXe and three pieces in level XXf1.1. Of the four pieces that still have a cortex, three exhibit a rounded cortex of a secondary origin, showing ring cracks, while the cortex on the fourth piece could not be clearly identified.

Portillas chert The Las Portillas chert is a variety that was recently characterized (Herrero-Alonso, 2018; Herrero-Alonso et al., 2021b), although its presence was recognized several years earlier (Fuertes-Prieto et al., 2010). Despite this recent description, its use has been documented at Upper Paleolithic sites such as Tito Bustillo and Cova Rosa, as well as at Mesolithic sites like El Mazo, La Uña, and El Espertín (Herrero-Alonso, 2018; Martín-Jarque et al., 2022, 2024). It is possible that future discoveries at other Cantabrian sites may reveal remains of this chert variety, with a local distribution rather than regional, unlike Alba radiolarite.

One of the most striking features of the Las Portillas chert is its very limited geographic distribution as it only occurs in primary outcrops at the headwaters of the Cares and Deva rivers. Numerous pebbles of this raw material can be found along the river course, which are carried downstream to their mount in the Cantabrian Sea.

This marine platform chert, formed in shallow waters with continental input, can be identified by two distinctive elements: the presence of detrital quartz and intense black vitreous luster. Under thin section, a high concentration of detrital minerals such as tourmaline and zircon can be seen in addition to quartz. Occasionally, sponge spicules or dolomite idiomorphs may also appear, though both in very small numbers.

The primary Portillas outcrops are located about 133 km from El Castillo, where six pieces have been identified, representing 2.29% of the total and 3.14% of the identified materials. However, their distribution across different layers is uneven: only one piece, lacking a cortex, was found in level XXc, whereas the other five, all with a rounded cortex, including one fully covered in cortex, were found in layer XXf1.1. The presence of this type of cortex suggests that these pieces were collected in a secondary position.

Piedramuelle flint This variety of flint is the most distinctive raw material from the Cenozoic basin of Oviedo. While interest in this type of flint dates back to the 20th century (de la Rasilla, 1984a, 1984b; Corchón Rodríguez, 1993), it was not until more recent years that its textural and mineralogical features were thoroughly described (Herrero-Alonso, 2018). So far, its distribution has remained regional, reaching archaeological sites located over 60 km away.

This flint is known for its brecciated texture, formed by clusters of carbonate intraclast. It usually appears in brownish tones, turning yellowish when patinated. However, no diagnostic bioclastic elements have been identified yet.

Outcrops of this type of flint are found about 246 km from El Castillo, where a single piece without cortex has been identified in layer XXf1.1. Because of this, it has not been possible to determine how this raw material might have been sourced.

Indeterminates In this study, 72 pieces could not be assigned to any specific variety of flint. This usually happens for one of two reasons: either the pieces have been altered, through heat damage or white patina, making it difficult to observe their texture, or they lack clear diagnostic features.

In summary, most of the flint analyzed in the sample indicates that the closest flint, the Monte Picota variety, is the most abundant. Beyond that, the other sourcing locations are relatively rare, all of which located more than 100 km away from El Castillo. The farthest, Tercis, is located 427 km away. While of limited technological significance, this information opens up interesting interpretive possibilities on how Neanderthal groups used of the landscape. It also allows for hypotheses to be put forward on intergroup relations at the regional level, defining the 'region' as the Cantabrian area as well as the Basque region on both sides of the Pyrenees.

5.2. Lithic analysis

Fine-grained quartzite is the most used raw material for unretouched *débitage* in these levels, followed, to a lesser extent, by coarse-grained quartzite (Table 1). Flint was used sparingly, almost marginally, in some of the levels analyzed, with overall percentages ranging from 3.1% in level XXc to nearly 9.5% in level XXe or XXf1.1 (Table 4).

However, compared to other retouched raw materials, flint shows almost double the percentage of use compared to general raw materials. For example, in level XXab, it increases from 4% in the general category to 5.9% in the retouched category; in level XXc, from 2.8% to 10.2%; and in level XXd, from 3.2% to 6.8%. In contrast, in older levels, the percentages of raw and retouched flint are similar (Tables 4 and 5).

Radiolarite is even scarcer than flint. The level with the largest amount of this raw material is XXc, where it accounts for just 0.4%. As for the retouched pieces, only levels XXe and XXf1.1 contain retouched radiolarite. Notably, level XXe stands out with 2.1% of its retouched pieces made from this material compared to the 0.2% it represents in the overall assemblage for that level (Tables 4 and 5).

Table 4
Distribution of the raw materials used by levels, divided between retouched and unretouched pieces.

	XXab		XXc		XXd		XXe		XXf1.1	
	Unretouched %	Retouched %	Unretouched %	Retouched %	Unretouched %	Retouched %	Unretouched %	Retouched %	Unretouched %	Retouched %
Sandstone	29 (4)		91 (4.9)		66 (8.1)		33 (3.9)		57 (4.5)	2 (1.1)
Fine quartzite	381 (52.4)	36 (70.6)	1002 (54)	58 (65.9)	304 (37.4)	31 (42.5)	391 (46.4)	79 (54.5)	732 (58.1)	134 (78)
Coarse quartzite	153 (21)	8 (15.7)	481 (26)	13 (14.7)	280 (34.5)	24 (33)	154 (18.3)	32 (22.1)	57 (4.5)	9 (5.2)
Hyaline quartz					1 (0.1)		8 (1)	1 (0.7)	49 (3.9)	1 (0.6)
Limonite	20 (2.8)		25 (1.3)	2 (2.2)	10 (1.2)	1 (1.3)			4 (0.3)	1 (0.6)
Ophite	46 (6.4)	1 (1.9)	91 (4.9)	3 (3.5)	64 (8)	11 (15)	70 (8.3)	9 (6.2)	14 (1.1)	1 (0.6)
Quartz	33 (4.5)	3 (5.9)	41 (2.2)	3 (3.5)	32 (4)	1 (1.4)	69 (8.2)	6 (4.1)	167 (13.3)	4 (2.3)
Radiolarite	1 (0.1)		7 (0.4)		2 (0.2)			3 (2.1)	3 (0.2)	1 (0.6)
Flint	29 (4)	3 (5.9)	52 (2.8)	9 (10.2)	27 (3.2)	5 (6.8)	79 (9.4)	15 (10.3)	123 (9.8)	14 (8.1)
Limestone	34 (4.7)		64 (3.4)		23 (2.9)		36 (4.3)		48 (3.8)	1 (0.6)
Other			1 (0.1)		3 (0.3)		2 (0.2)		5 (0.4)	4 (2.3)
Total (n)	726 (99.9%)	51 (100%)	1855 (100%)	88 (100%)	812 (99.9%)	73 (100%)	842 (100%)	145 (100%)	1259 (99.9%)	172 (100%)

Chips are excluded from the data.

Table 5
Retouched and unretouched flint (all flints).

	Unretouched		Unretouched %	Retouched		Retouched %	Total (n)
	Flint	Radiolarite		Flint	Radiolarite		
XXab	29	1	90.9	3	0	9.01	33
XXc	52	7	86.8	9	0	13.2	68
XXd	27	2	85.3	5	0	14.7	34
XXe	79	0	81.4	15	3	18.6	97
XXf1.1	123	3	89.4	14	1	10.6	141

Cortex is rarely found on flint and radiolarite as either most pieces have none or, if present, it covers less than a third of the surface (Table 6 and SOM 5).

From a technological standpoint, flint and radiolarite offer valuable insights. Most of the pieces consist of ordinary flakes (with or without cortex), debris, and flake fragments. Based on the identifiable flint pieces, we can infer patterns in the distinctive use of flint at the site (Table 7 and SOM 6). First, the low number of discoid flakes is notable, appearing in only three levels (XXab, XXe, and XXf1.1), representing the main *débitage* scheme in all analyzed levels. Second, pieces associated with Levallois *débitage*, such as Levallois flakes sensu stricto and débordant flakes, are present in all levels, although specific methods are not detailed due to the small sample size (Figs. 5 and 6 and SOM 6). We have also included chordal flakes and pseudolevallois points, which, while also common in discoid methods, may indicate Levallois exploitation when made on flint (Figs. 5 and 6 and SOM 6). When combining all the pieces associated with Levallois methods, the percentages per level would be as follows: 24.2% for level XXab, 18.9% for XXc, 16.2% for XXd, 18.5% for XXe, and only 8.6% for XXf1.1. There is just one centripetal recurrent Levallois core made on radiolarite in level XXc (Fig. 6).

When we compare the percentages of Levallois *débitage* on flint with the entire lithic collection from levels XXe and XXf1.1, which have been thoroughly analyzed, we find that in level XXe, the Levallois method represents 6.3% of the total assemblage, while flint accounts for 18.5%. In level XXf1.1, general Levallois *débitage* is 4% compared to 8.6% for flint (Sánchez and Bernaldo de Quirós, 2008; González-Molina et al., 2024).

It is worth noting the high number of flint retouched flakes across all levels (Fig. 5). These pieces point to extensive use of flint at the site, with intense rejuvenation of the flint pieces brought in.

On the other hand, there does not appear to be any specific selection of flint based on size. When analyzing the lengths across different levels, flint emerges as the shortest material in three levels (XXd, XXe, and XXf1.1) or similar in size to the fine-grained quartzite in levels XXab and XXc (Fig. 7). Several factors could account for this: the original size of the raw material, the distance it was sourced from, the extent of modification, or the high number of retouch flakes and chips.

Among the retouched blanks from all levels, flint-retouched pieces are distributed across all tools following a similar pattern to that of the overall collection (see Table 1). However, they are especially retouched in sidescrapers, compared to other retouched tools like denticulates, notches, or Upper Paleolithic–type pieces (Table 8).

5.3. Geographic information system

As explained in the Materials and methods section, we mapped out a route that follows the path requiring the least energy expenditure and the easiest mountain passes for travel between El

Table 6
General cortex (flint and radiolarite).

	I (%)	IIa (%)	IIb (%)	IIc (%)	III (%)	Total data	n/a (chips)	Total
XXab	1 (3)	1 (3)	1 (3)	5 (15.1)	25 (75.7)	33		33
XXc	3 (4.8)	4 (6.4)	5 (8)	13 (21)	37 (59.7)	62	6	68
XXd	2 (5.9)	3 (8.8)		7 (20.6)	22 (64.7)	34	1	34
XXe	2 (2.1)	2 (2.1)	6 (6.1)	12 (12.4)	75 (77.3)	97		97
XXf1.1	2 (1.8)	2 (1.8)	11 (10)	6 (5.5)	89 (80.9)	110	31	141

Data do not include chips.

Table 7
Technological classification of flint pieces. Radiolarite is in brackets.

	XXab	XXc	XXd	XXe	XXf1.1
Cobble fragment.					(1)
Tested cobble.		(1)			
Entame flake			1		
Cortical flake with noncortical platform				1	3
Cortical blade with noncortical platform					1
Initiation Cortical flake		2	1 (1)		
Janus or Kombewa flake	1			(2)	1
Cortical knife	1	3 (1)	1	1	
Demi-tablette					
Desbordant flake	2	7 (1)	1	6	
Tangential discoid flake				1	
Bifacial flake					1
Shaping flake	1		1	4	2
Shaping blade					1
Pseudolevallois Point	1	3	1	2 (1)	3
Core's crest				1	
Chordal flake	2	6	2	5	7
Ordinary flake	5	11 (1)	9	20	25
Ordinary flake (cortex)	1 (1)	5 (1)	3 (1)	9	7
Discoid flake	1			1	3
Discoid flake (cortex)					1
Levallois flake (indet).	1				2
Recurrent Unipolar Levallois flake	1		1	3	
Recurrent centripetal Levallois flake	1	1		1	1
Blade Levallois			1		
Blade					1 (1)
Bladelet				5	1
Flake/blade indet. fragment		1	1	1	25
Reshapening/retouch flake	7	6	4	22	39
Core's reshapening					1
Burin spall	1				
Core		1 (1)			2 (1)
Chunk	2	10 (1)	3 (1)	6	8
Flake chip	3	19	2 (1)	3	10
Angular chip	1	5	1	1	
Thermal chip		7		1	1
Indet.		1			
Tectoclast					1 (1)
Total	33	95	37	97	151

The chips are included in the data.

Castillo and the various primary sourcing areas. As shown, most of the routes follow the current coastline, which provides a relatively easy corridor to navigate (Fig. 8A).

For the Monte Picota flint, which is the most abundant and is found in all levels, the route connecting the two sites follows the Pas River. Both Monte Picota and El Castillo are situated along the river, just 29 km apart. Additionally, in level XXab, along with the Urgonian flint of a still unknown but likely local origin, these are the only types of flint found in that level (Table 3).

To acquire Alba radiolarite (about 102 km west of El Castillo) and Flysch flint (161 km east of the site), the easiest route follows the coastline as both outcrops are located near the sea (Fig. 8A). Both types of raw materials are found in all levels analyzed, except for XXab, the most recent level studied.

The Portillas chert, located 133 km west of El Castillo, and the Piedramuelle flint, 246 km further west, both require a coastal route with an inland detour. For the Portillas chert, the easiest route follows the Deva River and its tributary, the Cares. For Piedramuelle, the route would head west along the Villaviciosa Estuary (Fig. 8A).

Access to the Ebro River Basin and to Treviño flint, 169 km from El Castillo, could follow the proposed model by traveling up the Pas River and then its tributary, the Year River, to their headwaters. From there, the Estacas de Trueba pass, located close to the Ebro River, would provide easy access to La Meseta, the interior plateau of the Iberian Peninsula (Fig. 8A).

Lastly, 2the coastal route is also the most efficient way to reach the Tercis flint outcrops in the Landes, about 427 km from El Castillo (Fig. 8A).

From a long-term perspective, it is worth noting that all the analyzed levels were supplied with flint from Monte Picota in the mouth of the Pas River (23 km away). Together with the Urgonian flint, this could define the home-range territory of Neanderthals at El Castillo. However, the nonlocal flint offers an insight into how the regional space was used and the possible sociocultural territory. We can see that the oldest level analyzed, XXf1.1, has the largest catchment area, stretching over 650 km from Piedramuelle in the west to Tercis in the east. This level also contains the greatest variety of flint types, except for Treviño flint (Fig. 8F). The presence of cleavers in the lithic assemblage and the broad catchment area connects it to other sites that feature these kind of pieces, such as La Viña, which also has the Piedramuelle flint (Santamaría, 2012) or the level Cjgr at Gatzarria with the Tercis flint (Minet et al., 2021). Both sites also contain cleavers, and Gatzarria has been classified as Vasconian (Deschamps, 2009).

Level XXe points to a smaller area along the west-east axis but includes some Treviño flint artefacts, in the Ebro Basin (Fig. 8E). This extends the area southward and, based on the modeled routes, close to Mousterian sites in northern Burgos, such as Prado Vargas in Ojo Guareña complex. The presence of Treviño flint also links El Castillo with Gatzarria Cjgr (Minet et al., 2021).

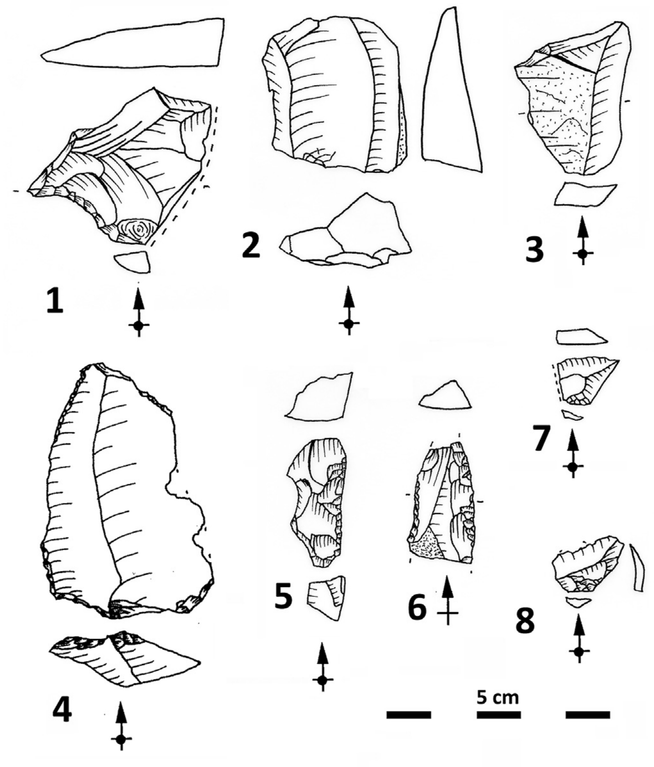


Figure 5. Example of lithic pieces analyzed. 1: Chordal flake; 2: unipolar Levallois flake; 3: ordinary flake; 4: centripetal recurrent Levallois flake; 5: flake from resharpening; 6: straight double-sharpening; 7–8: flake from retouch resharpening. Raw materials: 1, 7: Urgonian flint; 2–4: Monte Picota flint; 6: Alba Radiolarite; 5, 8: Flysch flint. Levels: XXab: 1, 2, and 7; XXc: 3 and 8; XXd: 5 and 6; XXe: 13.

In level XXd, the catchment area appears to shrink and takes on a more coastal orientation. The flints identified at this level include the Monte Picota flint and Alba radiolarite to the west and Flysch to the east (Fig. 8D). During level XXc, the catchment area expands again, stretching west to Portillas and east to Tercis (Fig. 8C).

However, during level XXab, flint comes from more restricted catchment areas, from the immediate home range, from the Monte Picota and the Urgonian flint catchment areas (Fig. 8B).

While there are significant differences in the flint catchment areas, we cannot confidently say whether these differences reflect variations in human behavior. There are two reasons for this: First, the sample comes from only 3 m^2 of excavation, and second, we must take into account the entire area excavated by Hugo Obermaier between 1910 and 1914. As a result, the picture we have outlined may be influenced by the inherent limitations of Obermaier's collection, which have already been discussed.

Overall, our analysis reveals the presence of flint from very distant sources, a phenomenon not previously documented in the Mousterian period of the Cantabrian region. This suggests that the Neanderthal groups at El Castillo had a much broader and more complex network of intersite connections than was previously known (Ríos-Garaizar, 2008, 2013). This network of connections encompasses Mousterian levels classified as Vasconian and non-Vasconian.

5.4. Statistical analysis

Many 'Vasconian' sites had the same sources of raw materials. To check if there is technotypological coherence between them and if they differ from the rest of the contemporary Mousterian levels, we have the statistical results.

The PCA, as expected, shows no significant distribution as the model only accounts for around 50% of the variance (Fig. 9A). As a result, we conducted a Kaiser-Meyer-Olkin test to assess the adequacy of each variable for the model. We then ran a second PCA using only the variables 'Points, 'Hand axes,' and 'Cleavers' as these were the only ones with acceptable (though not excellent) Kaiser-Meyer-Olkin values. This time, the explained variance increases to 83%, but there is still no clear grouping of the Vasconian levels that sets them apart from the other assemblages analyzed (Fig. 9B).

Like PCA, the k-means cluster analysis can only be done with numerical variables, and thus we selected the three that explained the most variance in the PCA, leaving out the others as they introduced noise and reduced the explained variance percentage. The distribution of the 31 levels into the four groups shows no clear connection to the Vasconian (Fig. 10 and SOM 3).

Once again, the challenge we encountered with the multiple correspondence analysis is that it explains only 50% of the variance. However, it does confirm that the studied levels are grouped more by their main operational schemes than by other elements typically linked to the Vasconian, such as the presence of cleavers or hand axes (Fig. 10C). An interesting observation is the distribution along the x-axis, where most of the western assemblages are clustered in the negative range and the eastern ones in the positive range, regardless of whether they are classified as Vasconian or not (Fig. 10B).

The results of cluster-dendogram analysis were expected since the same data were used in the k-means analysis, with only the representation method differing. The results show that most collections cluster into the largest group and that there is still no clear distinction between Vasconian and non-Vasconian assemblages (Fig. 11).

6. Discussion

Overall, it is important to remember that conclusions drawn from materials excavated using modern methods should be approached with caution when comparing them to those from Obermaier's excavations. A direct comparison between the two cannot be made for several reasons:

- Obermaier treated unit XX as a single archaeological unit, whereas today, more than half a dozen distinct layers and sublayers have been identified in just the excavated portion (which is only half of the unit).
- During the 1910–1914 excavation, the archaeological materials were heavily curated, which makes direct comparisons challenging. For instance, in Obermaier's collection, flint was the most abundant raw material, comprising 60% of the total assemblage (Cabrera-Valdés, 1984:167), whereas in our study, it ranges between 3.1% and 9.5% (Table 2).
- Obermaier did not collect the smaller pieces, as indicated by the drawings and notes from the excavators at the time.

Although we do not know the exact extent of flint use at the site, our analysis seems to offer a closer reflection of the actual situation than offered by Obermaier's data despite the difference in the excavation surface areas.

6.1. Raw material procurement

But how do distant raw materials come to El Castillo? Undoubtedly, the provisioning of raw materials is an essential activity for hunter-gatherer groups in what is called 'provisioning territory' (Haas and Kuhn, 2019) in which two factors come together:

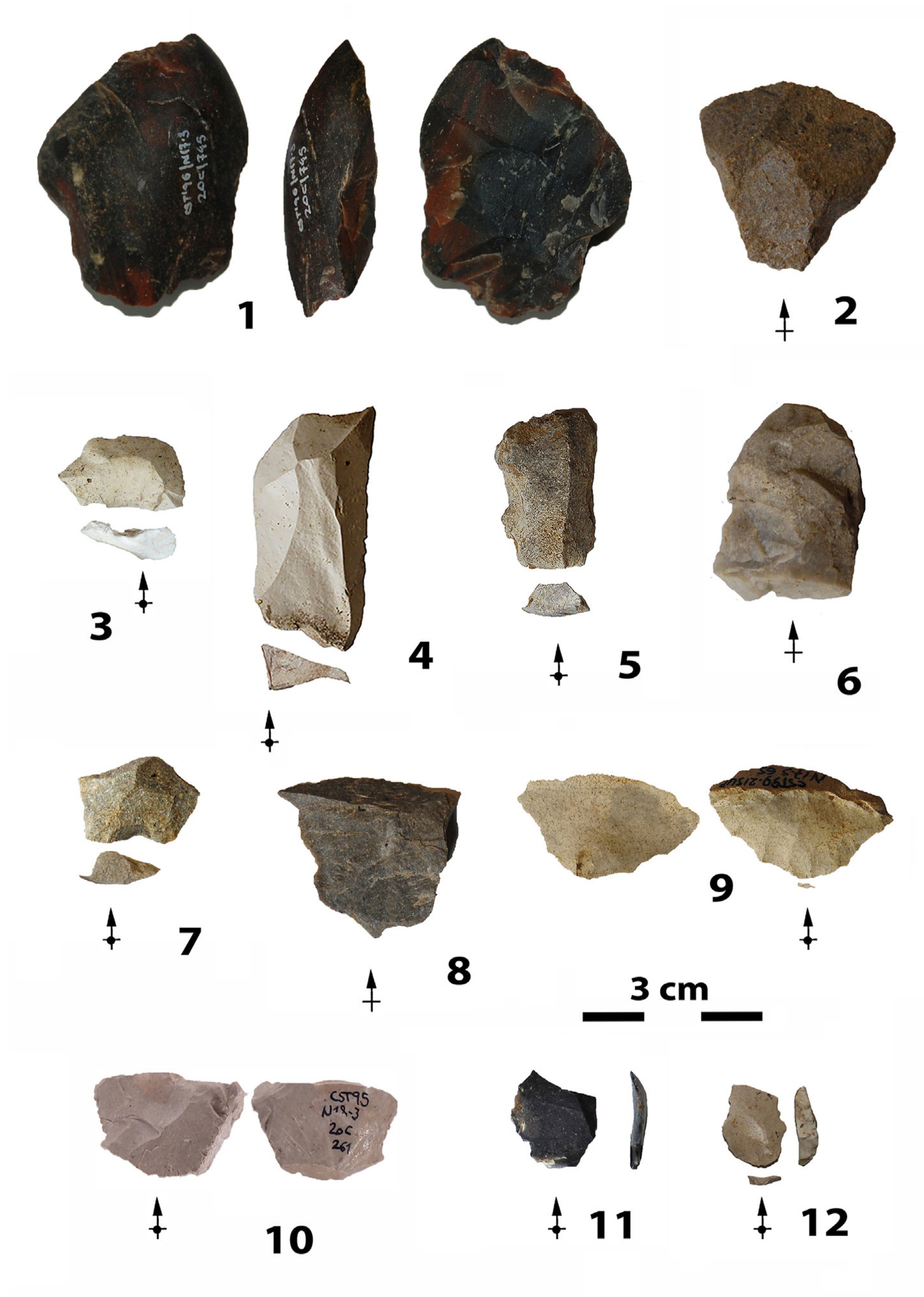
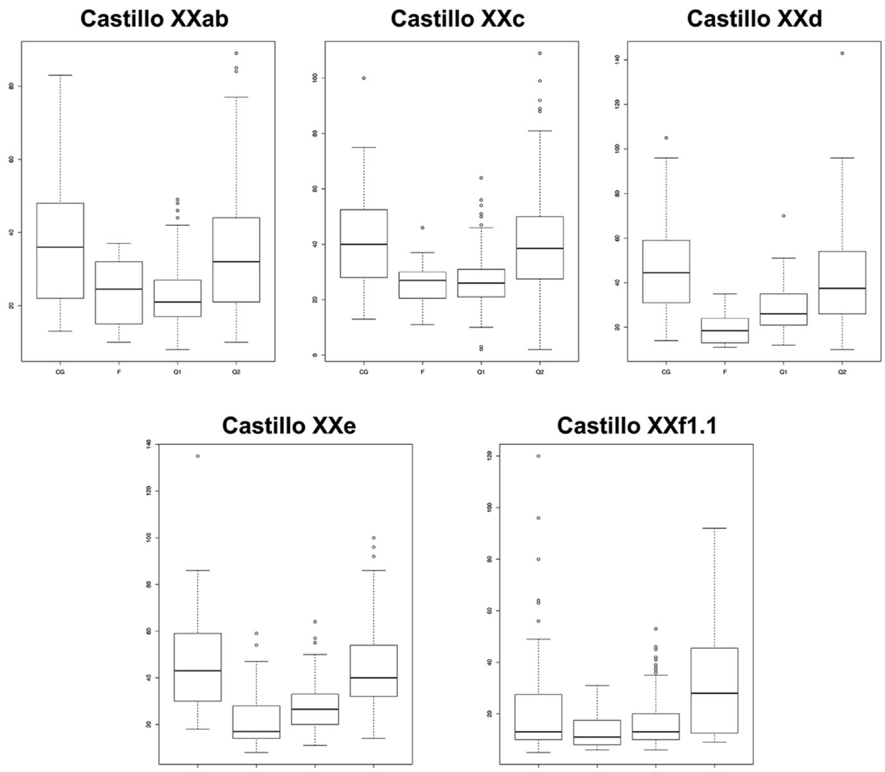


Figure 6. Example of lithic pieces analyzed. 1: Centripetal Recurrent Levallois Core; 2, 4, 5, 6, 8, 10–11: ordinary flake; 3, 7: resharpening flake; 9: shaping flake; 12: desbordant flake. Raw materials: 1: Radiolarite; 2: Urgonian; 3–6: Picota; 7–9: Flysch; 10: Tercis: 11: Chert Portillas; 12: Treviño. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

acquisition and transport. The latter integrates all the raw materials that move through the territory transported either by all or by a part of the group or individually (tool kits sensu Kuhn, 1994, 2020).

From a general point of view, the acquisition of raw materials can be of two types: direct acquisition, either by going *ex-professo* to primary/secondary sources of raw materials or by integrating these actions into the group's annual movements. But they can also be from previous reservoirs or by reusing (recycling) pieces previously abandoned in archaeological sites or other places by themselves or by previous occupations of preceding groups (Binford, 1978; Kuhn, 1994; Tomasso, 2018). Indirect acquisition, on the other hand, requires the concept of 'technical transfer,' which assumes the movement of raw materials and ideas from one human group to another (Beaune, 2018; Vaissié and Faivre, 2023). This technical transfer can be direct (one-to-one exchange) or indirect, where at least one intermediary is needed between the source and destination group (Renfrew, 1977) in any of its variants: reciprocity, redistribution, or exchange sensu stricto (Testart, 1997; Perlès, 2007). Many researchers recognize the complexity of discerning this process during the Paleolithic (e.g. Renfrew, 1977; Perlès, 2007; Beaune, 2018; Haas and Kuhn, 2019; Vaissié and Faivre, 2023).

The presence of flint and radiolarite in the analyzed sequence from the Mousterian levels at El Castillo is minimal but carries significant implications. A specific raw material strategy was



	Min	Q1	Median	Mean	Q3	Max
XXa	8.00	18.00	23.00	27.36	34.00	89.00
XXc	2.00	22.00	29.00	31.59	37.25	109.00
XXd	10.00	23.00	32.00	37.21	47.00	143.00
XXe	8.00	22.00	30.00	34.25	40.00	135.00
XXf1.1	5.00	10.00	13.00	17.89	22.00	120.00

Figure 7. Typometries of the lengths of the different raw materials in the levels analyzed in this study.

applied to the flint. The scarce presence of a cortex in the blanks analyzed indicates that almost all the pieces brought to the site were already knapped (Table 6, SOM 5), most of them using Levallois methods (SOM 6). There is also evidence of intensive retouching and resharpening, as shown by the high percentage of retouch or retouch rejuvenation flakes (Table 7). This behavior aligns with the treatment of distant or high-quality raw materials (Geneste, 1985; Meignen, 1988; Andrefsky, 2009; Turq et al., 2013; Kuhn, 2020). At El Castillo, this pattern is confirmed for the Monte Picota flint and the indeterminate flint in this study, which are the most abundant. However, due to the small sample size, we cannot be certain about the treatment of distant flint and radiolarite (Table 7 and SOM 6).

This pattern, however, contrasts with the use of other raw materials in the analyzed levels, where fine-grained quartzite is the most used, and the discoid method, both unifacial and bifacial, predominates. In contrast, Levallois *débitage* is either rare or completely absent in these other raw materials.

Most of the flint identified across all levels is of the Monte Picota type, with known sources located on the mountain of the same name, about 23 km north of the site, on the mouth of the Pas River, along whose banks Monte Castillo is also located. This aligns with the general pattern of local resource procurement by Neanderthals in the Cantabrian area and southwestern France (Geneste, 1989; Turq, 2000; Romagnoli et al., 2022).

However, the other types of flint, though making up only a very small part of the overall lithic assemblage, offer valuable insights into procurement strategies and exchange networks. This information is crucial for understanding intergroup relationships and the territories of Franco-Cantabrian Neanderthals during the end of MIS4 and MIS3. These flints and radiolarites have known sources located over 100 km away: Alba radiolarite at 102 km, Portillas chert at 133 km, the closest Flysch flint at 161 km, Treviño flint at 169 km, Piedramuelle flint at 246 km, and Tercis flint in the Landes at 427 km (Fig. 8).

On the other hand, the small number of pieces of very distant origin in the levels analyzed does not allow us to do more than conjecture about the acquisition model. However, due to the short distance from the source, we can be sure that the flint from Monte Picota, and possibly the Urgonian, was acquired directly. As the distance is less than 30 km, we can consider an acquisition within the usual circuits in the territory of these Neanderthal groups plausible. For the rest of the raw materials, at distances over 100 km, it is plausible to consider technical transfer as the optimal option (sensu Porraz, 2010: 302), possibly with intermediaries, at least for the most distant ones, such as the Tercis flint.

It is more complex to discern whether distant flint was part of toolkits. These toolkits are usually recognized by their prolonged use and reworking (Kuhn, 1994, 2020). Among the pieces analyzed, only the Flysch flint could be part of this type of kit as it has retouched material, although not very intensively, and presents abundant resharpening flakes in levels XXe and XXf1.1.

Therefore, the flint procurement map for El Castillo reveals a much broader range of sourcing, either direct or indirect, than

Table 8
Retouched flint pieces by levels and technological classification.

XXab	Picota	Flysch	Tercis	Radiolarite	Portillas	Urgonian	Flint indet.	Flint n/a	Total
10. Convex simple sidescraper								1	1
35. Atypical borer						1			1
54. End-notched flake						1			1
Total XXab						**2**		**1**	**3**
XXc	Picota	Flysch	Tercis	Radiolarite	Portillas	Urgonian	Flint indet.	Flint n/a	Total
10. Convex simple sidescraper		1							1
18. Straight convergent sidescraper		1							1
42. Notch							3		3
43. Denticulate			1						1
46. Deep abrupt retouched piece	1								1
47. Thin abrupt retouched piece	1								1
62. Divers							1		1
Total XXc	**2**	**2**	**1**				**4**		**9**
XXd	Picota	Flysch	Tercis	Radiolarite	Portillas	Urgonian	Flint indet.	Flint n/a	Total
12. Double straight sidescraper		1							1
15. Double biconvex sidescraper							1		1
29. Alternate sidescraper		1							1
42. Notch								1	1
43. Denticulate.							1		1
Total XXd		**2**					**2**	**1**	**5**
XXe	Picota	Flysch	Tercis	Radiolarite	Portillas	Urgonian	Flint indet.	Flint n/a	Total
6. Mousterian Point								1	1
9. Straight simple sidescraper				1				1	2
10. Convex simple sidescraper								1	1
11. Concave simple sidescraper	1								1
12. Double straight sidescraper	1								1
17. Double convex-concave sidescraper	1								1
21. *Dejété* sidescraper								1	1
29. Alternate sidescraper		1							1
42. Notch	1								1
43. Denticulate		1		1					2
44. Alternate burinant bec							1		1
46. Deep abrupt retouched piece	1								1
49. Thin alternate retouch				1					1
62. Divers	2	1							3
Total XXe	**7**	**3**		**3**			**1**	**4**	**18**
XXf1.1	Picota	Flysch	Tercis	Radiolarite	Portillas	Urgonian	Flint indet.	Flint n/a	Total
9. Straight simple sidescraper	1			1					2
15. Double biconvex sidescraper	1								1
23. Convexe transversal sidescraper	1								1
30. Endscraper								1	1
34. Borer							1	1	2
40. Truncated flake								1	1
42. Notch	2				1				3
43. Denticulate								1	1
62. Divers	1	1					1		3
Total XXf1.1	**6**	**1**		**1**	**1**		**2**	**4**	**15**

was previously known for Neanderthals in the Cantabrian region and western Europe. It also sheds light on the territories they occupied and their intergroup exchange networks. The sourcing area covers over 600 km in length, stretching from Piedramuelle in Asturias, 246 km west of El Castillo to Tercis, about 427 km to the east.

6.2. The Vasconian

As we have already mentioned earlier, the presence of cleavers and hand axes in Middle Paleolithic assemblages from the Basque-Cantabrian region has been a subject of study since the beginning of the 20th century (e.g., Vega del Sella de la, 1921; Obermaier, 1924; Passemard, 1936). The first systematization was carried out by Bordes (1953), who called these assemblages Vasconian. In essence, it was a Charentian Quina–type facies with cleavers and/or hand axes (Bordes, 1953), although already in that paper he called it 'the Vasconian problem.' Later revisions concluded that it had no technotypological entity (Freeman, 1966; Cabrera-Valdés, 1983; Baena et al., 2004). However, it has been claimed again in recent decades from a more technological perspective and has been defined as a discoid debitage industry with cleavers/hand axes (Deschamps, 2017; Ríos-Garaizar, 2017; Deschamps and Mourre, 2012; Ríos-Garaizar et al., 2024).

After several statistical analyses using some of the Vasconian and non-Vasconian assemblages from the Franco-Cantabrian region (Fig. 12), we align ourselves with the hypothesis that the Vasconian does not have its own entity as a facies or group, at least, as we are identifying it (sensu Freeman, 1966; Cabrera-Valdés, 1983; Baena et al., 2004). In conclusion, our statistical analysis does not provide any clear answers about the structure of the Vasconian. Instead, it seems that the assemblages are more defined by their main operational schemes than by the presence of large cutting tools.

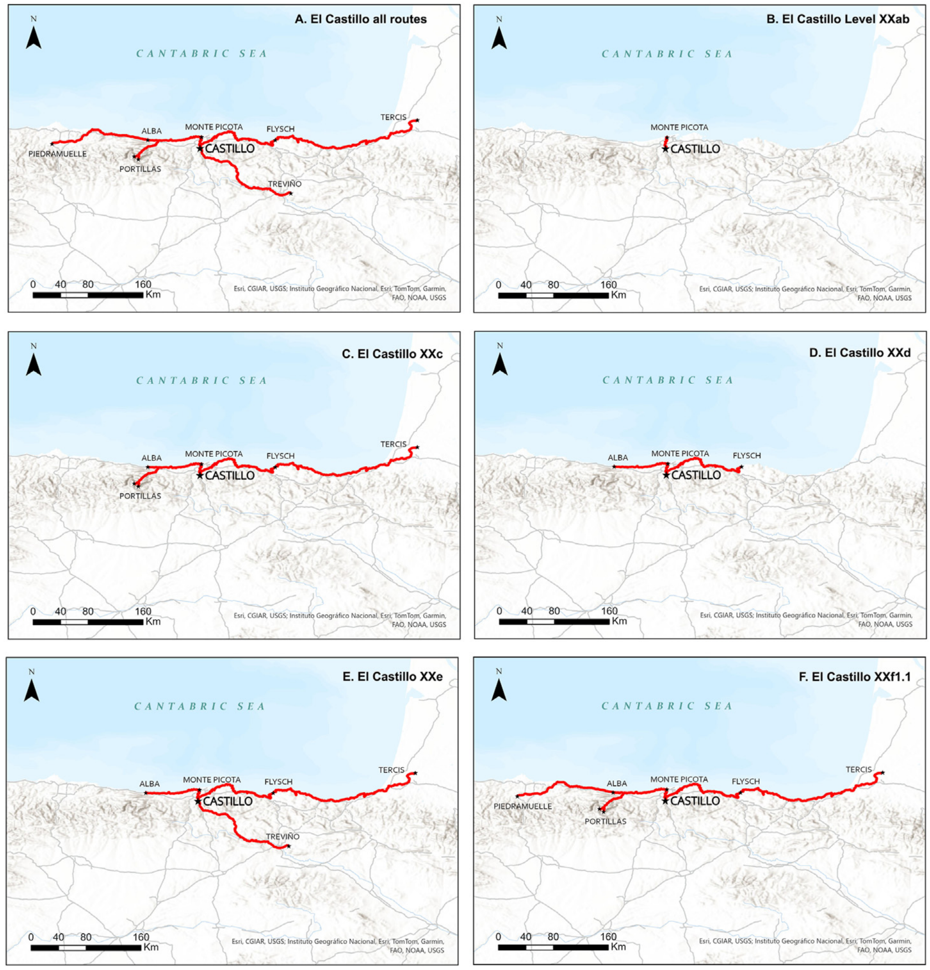


Figure 8. Maps showing the optimal routes between El Castillo and the different flint/radiolarite sources. A) General. B) Level XXab. C) Level XXc. D) Level XXd. E) Level XXe. F) Level XXf1.1. Source: Esri, USGS, Instituto Geográfico Nacional. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

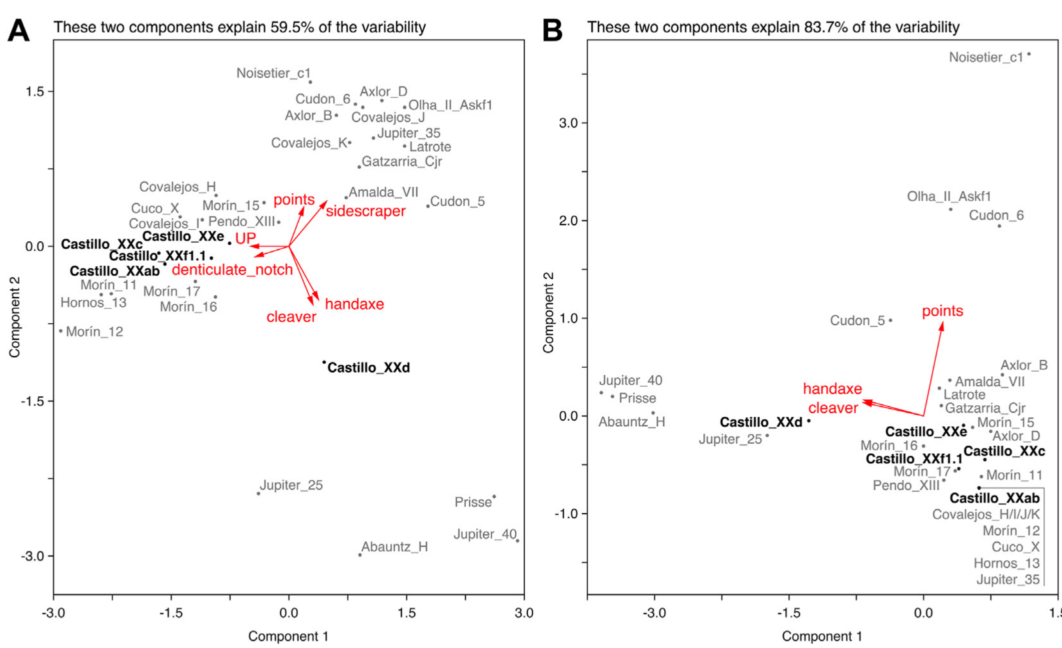


Figure 9. A) Principal component analysis carried out with all numerical variables explains 59.5% of the variance. B) Principal component analysis performed with only the variables 'Points,' 'Hand axes,' and 'Cleavers' explains 83.7% of the variance. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

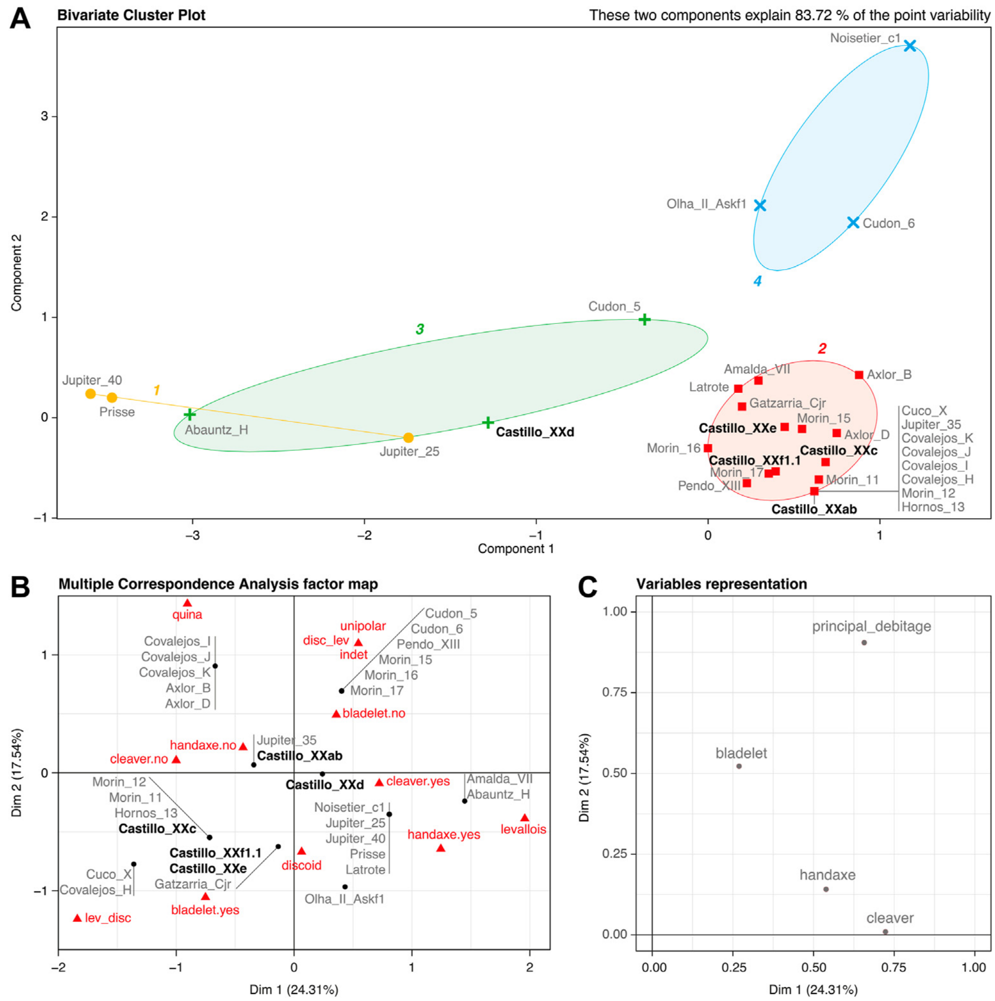


Figure 10. A) k-means cluster analysis, performed only with the variables 'Points', 'Hand axes' and 'Cleavers', $k = 4$; B) multiple correspondence analysis (MCA), performed with the categorical variables; C) contribution of each of the variables used for the MCA in the two main dimensions. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

6.3. The territory of El Castillo and the cleavers question

Understanding how these groups related to their 'territory' is a much more complex challenge. The relationship between hunter-gatherer groups and the territory varies significantly, making it difficult to draw precise correlations between ethnographic studies and archaeological findings (Kelly, 2013). This is further complicated by the inherent challenges of applying modern concepts to past groups (Wobst, 1978; Warren, 2021). In this paper, we are going to work on two concepts that affect territoriality: on the one hand, home range and on the other hand, social territory. We consider the home range as the total area within which the groups who occupied the site had access to determinate resources (Kelly, 1983). On the other hand, social territory refers to the space that is socially integrated into the territory of a group through networks of socioeconomic relations (Vaissié and Faivre, 2023).

The territorial map drawn from the study of the raw materials in the analyzed levels can be further enriched by the research on the seasonality and duration of Neanderthal occupations at El Castillo. Considering the distribution of species, with the dominance of red deer in the assemblage (Luret et al., 2020), a species with a low rate of annual movement, the home range for chasing and capturing this species could be considered local. Studies of seasonality at the death of the animals in levels XXa/b, XXc, and XXe indicate a year-around occupation with a peak from fall to spring (Pike-Tay et al., 1999). Finally, the isotopic analysis indicated that the hunting ranges for red deer were local for these levels (Jones et al., 2019). Rather than indicating long-term occupation at El Castillo, these results suggest that the levels represent a repeated series of separate occupation events, occurring at various times throughout the year, with a small hunting home range for Neanderthal groups who occupied the site. As a result, it is not yet possible to directly link the foraging territory with the type of mobility these groups may have had based on animal resource acquisition.

The size of a hunter-gatherer group's home range depends on various factors, such as the availability and abundance of resources, how they are spread across the landscape, their predictability, and more (Kelly, 2013). Hunter-gatherer groups that rely primarily on hunting tend to use larger territories than those that mainly gather plants or fish for food (Binford, 2001; Hamilton et al., 2007; Kelly, 2013). Studies of the faunal remains and isotopic analyses of Neanderthal remains have demonstrated the significance of ungulate meat in their diet (Gaudzinski and Roebroeks, 2000; Costamagno et al., 2006; Bocherens, 2011; Bocherens et al., 2016; Castel et al., 2017). This is evident in the levels studied here, where the fauna is predominated by medium and large ungulates, and the faunal assemblages are the result of systematic hunting, transport, and consumption by the Neanderthals who occupied the El Castillo cave (Luret et al., 2020).

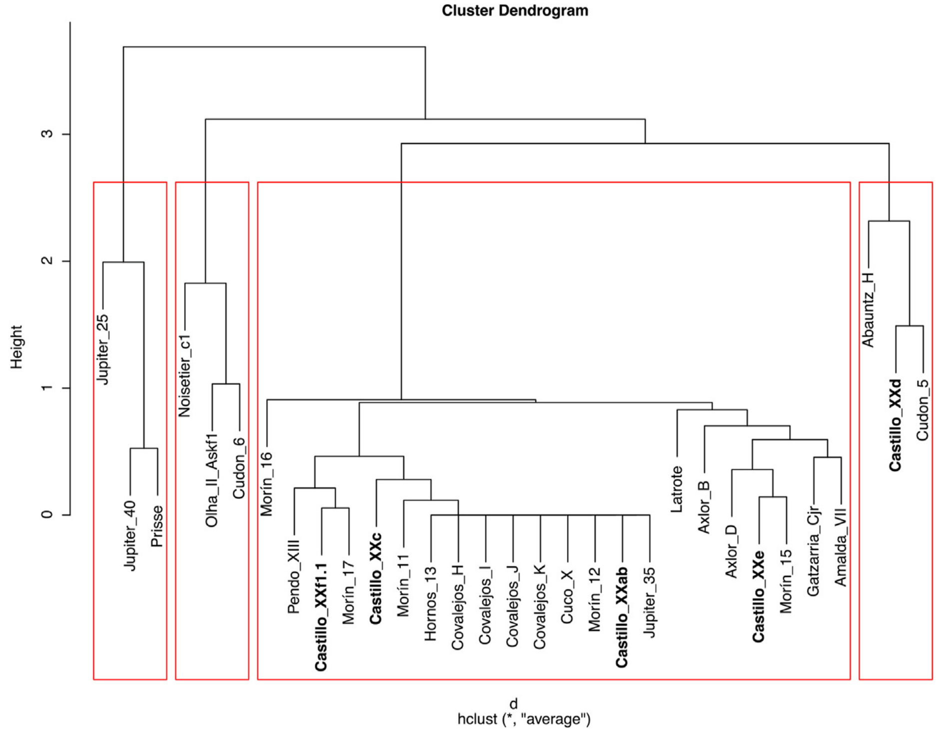


Figure 11. Cluster-dendogram analysis, performed only with the variables 'Points,' 'Hand axes,' and 'Cleavers' $k = 4$. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

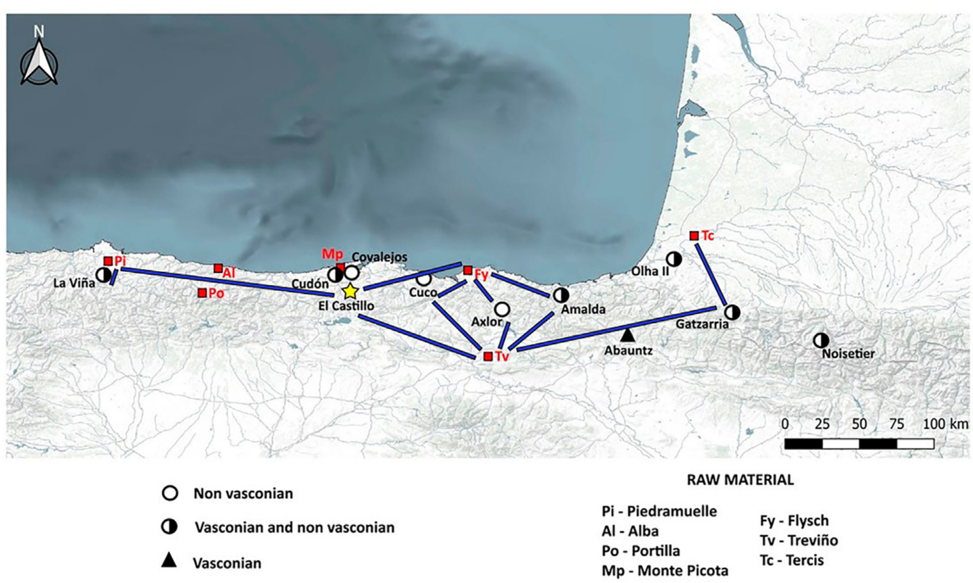


Figure 12. Map showing the main deposits cited in the text. The common sources of raw materials used between these sites and El Castillo are marked. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

When studying foraging territories and the home range in Paleolithic assemblages, caution is needed as many aspects of behavioral variability and decision-making constraints in these groups are not visible in the archaeological record. Nevertheless, territories or spaces have been identified where groups may have shared cultural, genetic, and possibly ethnolinguistic connections (Tryon, 2019), revealing similarities, correlations, or parallels in their material culture.

In the Franco-Cantabrian region, such parallels have been readily identified in the Upper Paleolithic (Cazals et al., 2007; Sauvet, 2019; Martín-Jarque et al., 2022), but not as much in earlier periods. For Neanderthal groups, many studies have explored mobility and territory through the analysis of lithic technology and raw materials (Delagnes and Rendu, 2011; Turq et al., 2017), along with faunal studies (Patou-Mathis, 2000; Daujeard and Moncel, 2010) and through the application of home-range models (Walker and Churchill, 2014; Churchill et al., 2016).

So why do cleavers (and hand axes) appear in a specific region during the same period? Is this the result of a convergence process, or is it influenced by some factor we have yet to identify?

It is well understood that hunter-gatherer groups are mobile to varying degrees (Kelly, 2013) and that they organize themselves within territories, whether or not they display clear territoriality. In the case of El Castillo, and likely for the Mousterian during MIS4/MIS3 in the Cantabrian region, we cannot confidently assert the existence of clearly defined group territories, as has been used for decades to map territories (Geneste, 1985, 1992; Kuhn, 2020). Monte Picota and Urgonian flint, both sourced locally (<30 km), may mark the foraging territory or food procurement area as other studies have stated that acquiring lithic raw materials was an integral part of Neanderthal (and other humans) subsistence mobility (i.e., Binford, 1979; Kuhn, 1992). However, the procurement area for the other siliceous raw materials found at El Castillo should not be considered as an exact marker of the territory inhabited by these groups as many studies on mobility and raw material sourcing have noted (Aubry et al., 2012; Browne and Wilson, 2013). Instead, we believe this wider area likely represents a 'social territory,' more closely tied to intergroup social networks than to the directly exploited territory of a basic group unit, which Whallon (2006) refers to as 'nonutilitarian' mobility.

These kinds of relationships act as a lifeline for hunter-gatherer groups, ensuring access to resources, new members, and, as S. Kuhn emphasizes, crucially, information (Kuhn, 2020). They also allow individuals and groups to access resources or territories outside their own. This helps groups adapt to medium-term changes, as well as unexpected and/or sudden challenges (Kuhn, 2020) acting as safety nets (Whallon, 2006).

The distant flint pieces found at El Castillo reflect what is often described in the literature as a raw material economy (sensu Perlès, 1991): specific operational schemes, in this case the Levallois, rarely seen on other raw materials at the site, along with retouched pieces and resharpening (for example, Meignen, 1988; Geneste, 1992; Kuhn, 2020). Although the proportion of distant flint is small, its presence may indicate both individual and intergroup contacts, suggesting that Neanderthals maintained expansive territories. On an individual level, some of the flint pieces at El Castillo may have been obtained through exchanges during visits or interactions similar to the *Xharo* system practiced by some Kung groups (Wiessner, 2002). From an archaeological perspective, these could represent a 'personal tool kit' (sensu Kuhn, 1992, 1994), including retouched pieces, resharpening or a higher-than-average number of Levallois tools, though the sample size from El Castillo makes it hard to confirm this. Intergroup contacts and indirect acquisition of raw materials could also explain the presence of these high-quality, well-preserved pieces (Meignen, 1988; Geneste, 1992; Beaune, 2018; Kuhn, 2020; Vaissié and Faivre, 2023). In our view, these interactions and social networks could also account for the appearance of cleavers in some assemblages.

As several authors have noted, social networks are essential for studying cultural transmission as they are how ideas are spread and shared (Whallon, 2006; Beaune, 2018; Kuhn, 2020). In Paleolithic research, these networks are identified through archaeological objects, parietal art, and portable art (Cazals et al., 2007; Sauvet, 2019; Mevel et al., 2021). In the Middle Paleolithic, they are recognized through lithic objects (Geneste, 1992; Turq, 2000), marine shells (Arrizabalaga, 2006), fossils (Peresani et al., 2013), or the use of bird of prey claws as indicators of cultural territories (Rodríguez-Hidalgo et al., 2019). Numerous ethnographic examples show how the exchange of 'gifts' strengthens personal and intergroup relationships. For instance, the spread of obsidian from southern Kenya to Lake Nyanza and northern Tanzania (Tryon, 2019) is a classic example of how artefacts can help forge and expand social and cultural ties between distant groups.

The movement of siliceous raw materials and the presence of cleavers in the analyzed levels at El Castillo suggest the existence of long-distance exchange networks (ranging from 100 to over 400 km), linking El Castillo to other significant sites from the same period and which also feature cleavers. To the west, there is Piedramuelle flint, although in small quantities, at La Viña (level XIII base), where there are also cleavers (Santamaría, 2012). To the east, Treviño flint, from the Ebro River Basin, appears at Gatzarria site, along with Tercis flint from the Landes region (Minet et al., 2021, 2022) (Fig. 12). These common sources of procurement, coupled with other reasons for contact, could have been central to the spreading of ideas. This process might also explain why cleavers appear in assemblages with different technotypological compositions, even though some share similar features like Discoid *débitage* and blade production (Thiébaut et al., 2012; Deschamps, 2017; Ríos-Garaizar, 2017). It is plausible that this technical solution was adopted to address specific challenges or tasks, such as tree felling (Claud et al., 2015; Ríos-Garaizar et al., 2024), and so may not have been necessary at certain Mousterian sites in the region.

Recent studies have proposed a common territory covering the eastern part of the Franco-Cantabrian region by correlating technological data and raw material procurement (Deschamps, 2017; Minet et al., 2021). Based on the origin of the flint and radiolarite at El Castillo, we suggest expanding this common area to include southwestern France (south of the Garonne River), the Upper Ebro River Basin, and the Cantabrian area, reaching into central Asturias (Fig. 12) for the Neanderthals in the region.

This area of contact, this social territory among Neanderthal groups would encompass the entire historiographical area occupied by the 'Vasconian.'. This supports Deschamps's concept of a Neanderthal 'province' located southwest of the Pyrenees (Deschamps, 2017). Additionally, the presence of Treviño flint in some levels at El Castillo expands the social territory navigated by Neanderthals into the Upper Ebro River Basin. This connection is not new, as evidenced by the Mediterranean marine shell remains found at the base of level III at Lezetxiki (Arrizabalaga, 2006). We propose, as a working hypothesis, that the movements or exchanges of Neanderthal groups in the Ebro Valley and the Cantabrian may have been more common than previously thought.

Despite these observations, our hypothesis faces significant challenges and should be viewed as a working hypothesis. The main issue is whether the Vasconian phenomenon itself has distinct characteristics; we currently lack the certainties to assert this, aside from vague qualitative data (discoid, laminar, and cleavers). Another challenge is the chronological definition. We cannot precisely determine the timeframe of the Vasconian phenomenon, whether it is homogeneous over time, if it truly represents a technological solution (reviving the debate between functional and ethnic classifications), and how Vasconian and non-Vasconian assemblages relate to each other between MIS4 and MIS3 in the Cantabrian region. Furthermore, the absence of dates, even relative dates, for some of the classic Vasconian assemblages, like El Pendo or Cueva Morín, the latter with unipolar operational schemes (Carrión, 2002) more typical of the regional Early Middle Paleolithic, adds to the difficulty. This chronological uncertainty also makes it hard to connect the 'Vasconian' phenomenon or this Franco-Cantabrian social territory to the potential replacement event among Neanderthals in Iberia around 50 ka BP or estimate whether this event predates or may have affected Iberian Neanderthals or only the eastern part of Europe (Hajdinjak et al., 2018; Rosas et al., 2023). Finally, the lack of demographic studies prevents us from determining, at this time, whether a demographic process was a driving force behind acculturation processes (Derex et al., 2018) or not (Vaesen et al., 2016), and it also limits our ability to assess the costs of such interactions (Fitzhugh et al., 2011).

Nonetheless, based on the current data, this hypothesis—that the cleavers in some Mousterian sites represent a specific response to cultural exchange, independent of the broader technocultural composition of the assemblages—offers a plausible framework for furthering research on the complex social and territorial networks of Neanderthals during the Middle Paleolithic in the Franco-Cantabrian region.

7. Conclusions

The lithic analysis of the levels at the El Castillo site provides valuable insights into how Neanderthals used raw materials and produced tools. The various types of flint used at El Castillo were sourced from locations, between 23 and 420 km from the site, that are much further away than previously believed for these groups in western Europe. While it is true that the number of flint and radiolarite remains in the studied levels is quite small comparted to the total assemblage and that the pieces with tracer origin (>120 km) are rare, these pieces indicate the presence of a broad social territory among the Franco-Cantabrian Neanderthals. This territory encompasses the Cantabrian area, the Bay of Biscay, and part of the Upper Ebro River Basin.

From a technological perspective, the Levallois method is in flint *débitage*, with significant percentages across several levels. This contrasts with the Discoid method predominant on quartzite. The small number of discoid flakes, combined with a higher occurrence of Levallois *débitage* pieces, indicates a specific strategy in the exploitation of flint. Additionally, the presence of numerous retouch/resharpening flakes suggests intensive use and maintenance of flint tools. The scarcity of cortex on the flint and the radiolarite and the incomplete *chaîne opératoires* suggest that these raw materials were brought to the site already knapped.

The shared sources of distant raw materials found at other sites with cleavers from a similar period suggest that rich social networks existed among Neanderthals. These networks enabled the transfer of ideas and technical solutions, such as the incorporation of cleavers into the Neanderthal technological tool kit, irrespective of the overall lithic composition of the groups involved.

Thus, we consider that the presence of cleavers is more related to the exchange of ideas than to a Vasconian facies sensu stricto. The Neanderthal groups from the late MIS4 and the first half of MIS3 occupied a much larger social territory than previously thought, as demonstrated by the sources of raw material procurement in the Mousterian levels of El Castillo.

In summary, the analysis of El Castillo highlights the complexity of Neanderthal procurement networks and mobility in western Europe. The specialized use of flint and radiolarite, together with Levallois methods, demonstrates a profound knowledge and advanced adaptation in the exploitation and management of lithic resources. This points to a sophisticated social organization and an ability to adapt that involves the exchange of knowledge and techniques across extensive territories.

Declaration of competing interest

The authors declare no competing interests.

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Supplementary Online Material

Supplementary Online Material related to this article can be found at https://edatos.consorciomadrono.es/dataset.xhtml?persistentId=doi:10.21950/E4CXMG.

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