Palaeoenvironmental and chronological context of human occupations at El Cierro cave (Northern Spain) during the transition from the late Upper Pleistocene to the early Holocene

Esteban Álvarez-Fernández[a,b,*], Julián Bécares[a,b], Jesús F. Jordá Pardo[b,c],
Amaia Agirre-Uribesalgo[d], David Álvarez-Alonso[e,b], Mª Teresa Aparicio[f],
Inmaculada Barrera-Mellado[g,b], Pilar Carral[h], René-Pierre Carriol[i], Miriam Cubas[j,b],
Marián Cueto[k], Katerina Douka[m,n], Mikelo Elorza[l], María-José Fernández-Gómez[b,g],
Sonia Gabriel[o], Naroa García-Ibaibarriaga[p], María-José Iriarte-Chiapusso[p,q], Carlos Llave[a],
Adolfo Maestro[r], Sergio Martín-Jarque[a,b], Rodrigo Portero[a,b], Aitziber Suárez-Bilbao[s],
Andoni Tarriño[t], Luis C. Teira[k], Paloma Uzquiano[u], Pablo Arias[k]

[a] Dpto. de Prehistoria, Hª Antigua y Arqueología, GIR PREHUSAL, Facultad de Geografía e Historia, Universidad de Salamanca, C. Cerrada de Serranos s/n, 37002 Salamanca, Spain
[b] Grupo de Investigación Reconocido PREHUSAL-Universidad de Salamanca, Spain
[c] Laboratorio de Estudios Paleolíticos, Departamento de Prehistoria y Arqueología, Facultad de Geografía e Historia, UNED, Paseo Senda del Rey 7, 28040 Madrid, Spain
[d] Departament de Prehistòria, Universitat Autònoma de Barcelona, Edifici B Facultat de Filosofia i Lletres, 08193 Bellaterra, Barcelona, Spain
[e] Dpto. de Prehistoria, Hª Antigua y Arqueología, Facultad de Geografía e Historia, Universidad Complutense de Madrid, C. Profesor Aranguren s/n, Edificio B, Ciudad Universitaria, 28040 Madrid, Spain
[f] Museo Nacional de Ciencias Naturales, CSIC, C. José Gutiérrez Abascal, 2, 28006 Madrid, Spain
[g] Dpto. de Estadística, Facultad de Medicina, Universidad de Salamanca (Campus Miguel de Unamuno), Av. Alfonso X El Sabio, S/N, 37007 Salamanca, Spain
[h] Dpto. de Geología y Geoquímica. Universidad Autónoma de Madrid. Campus de Cantoblanco, 28049 Madrid, Spain
[i] Muséum National d'Histoire Naturelle, Département Histoire de la Terre, Case Postale 38, 57 rue Cuvier, 75231 Paris Cedex 05, France
[j] University of Oviedo. C. Amparo Pedregal S/N, E-33011 Oviedo, Spain
[k] Instituto Internacional de Investigaciones Prehistóricas de Cantabria (Universidad de Cantabria-Gobierno de Cantabria-Santander) Av. de los Castros S/N, 39005 Santander, Spain
[l] Sociedad de Ciencias Aranzadi. Zorroagagaina 11, 20014 Donostia-San Sebastián, Spain
[m] Oxford Radiocarbon Accelerator Unit, Research Laboratory for Archaeology and the History of Art, University of Oxford, Dyson Perrins Building, South Parks Road Oxford, OX1 3QY, UK
[n] Max Planck Institute for the Science of Human History, Department of Archaeology, Kahlaische Str. 10, 07745, Jena, Germany
[o] Direção Geral do Património Cultural - Laboratório de Arqueociências (DGPC-LARC), CIBIO-InBIO, UNIARQ. Calçada do Mirante à Ajuda, n° 10A, 1300-418, Lisboa, Portugal
[p] Dpto. Geografía, Prehistoria y Arqueología, Facultad de Letras, Universidad del País Vasco UPV/EHU, C. Tomás y Valiente s/n, 01006 Vitoria-Gasteiz, Spain
[q] IKERBASQUE, Basque Foundation for Science. Bilbao Universidad del País Vasco UPV/EHU, C. Tomás y Valiente s/n, 01006 Vitoria-Gasteiz, Spain
[r] Departamento de Investigación y Recursos Geológicos. Instituto Geológico y Minero de España. Calle Calera, 1. E-28760 Tres Cantos, Madrid, Spain
[s] Dpto. Estratigrafía y Paleontología, Facultad de Ciencia y Tecnología, Universidad del País Vasco UPV/EHU, Apartado 644, 48080 Bilbao, Spain
[t] CENIEH. Paseo Sierra de Atapuerca, 3. 09002 Burgos, Spain
[u] Dpto. de Prehistoria, UNED. C/ Mediodia Grande 17, 28005, Madrid, Spain

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ABSTRACT

El Cierro Cave possesses one of the few sequences in SW Europe in which archaeological levels cover the transition from the late Pleistocene to the early Holocene. Information contributed by the palynological and anthracological studies indicates that this transition was marked by a steady expansion of broadleaf woodland and a reduction in herbaceous-shrub communities. Archaeofaunal studies reveal continuity in subsistence strategies throughout the sequence. This was based on specialisation in hunting red deer, fishing, and gathering molluscs, crustaceans and echinoderm species on rocky shores. The difference between the Azilian and Mesolithic occupations lies in the replacement of some marine invertebrate species and the decrease in limpet

* Corresponding author.
E-mail address: epanik@usal.es (E. Álvarez-Fernández).

sizes. The abiotic evidence is characterised by a lithic assemblage with allochthonous flint types, which has been interpreted as continuity of the raw material procurement strategies inherited from the Magdalenian.

1. Introduction

Studies on the upper Pleistocene to early Holocene transition in SW Europe (about 12.9 – 7.5 cal BP) have attracted new attention partly because of the application of new analytical techniques, such as palaeogenetics (e.g. Fu et al., 2016; Villalba-Mouco et al., 2019) and palaeodemographic modelling (Fernández-López de Pablo et al., 2019). In addition, new sites have been excavated and old collections have been re-examined, resulting in the drafting of new regional overviews. One recent example presents the archaeological information available for the Atlantic seaboard of France and the western Pyrenees (Naudinot et al., 2019). In the case of the Iberian Peninsula, although some overviews have been published (e. g. Mcclure and Schmich, 2009), regional studies on a smaller scale have examined areas in Portugal (e. g. Araujo, 2009; Tavares da Silva and Soares, 2016) and Spain (e. g. Alday et al., 2018; Aura et al., 2009). Other research has focused on particular aspects, such as the use of animal resources (e.g. Aura et al., 2016; Chevallier, 2015; Dias et al., 2016; Morales Pérez, 2015) and lithic technology (e.g. Naudinot et al., 2019; Vadillo Conesa, 2018). In the case of Cantabrian Spain, the study by L. G. Straus (2018) reflects a state of the art regarding the environmental changes that occurred in the late glacial period and start of the post-glacial period, and how they affected the last hunter-gatherer groups that lived in the area.

In this context, current interdisciplinary research carried out at El Cierro cave highlights new aspects related with the environmental changes, due to it being one of the few sites in north Spain where the transition from the late Pleistocene to the early Holocene has been documented. The study of archaeological remains, both biotic (charcoal, pollen and fauna) and abiotic objects (lithic artefacts) documented in this cave allows us to specify how human groups adapted to the climate changes that took place in this region of SW Europe during that time of transition.

2. The transition from the Upper Pleistocene to the Holocene in northern Spain: Current state of research

The Late Glacial Interstadial (GI1e-a) occurred between *ca.* 14.7 and 12.9 ky cal BP in northern Spain (Rasmussen et al. 2014). The Upper and/or Final Magdalenian took place in that period (González and González, 2004; Álvarez-Fernández et al., 2019). This relatively temperate phase was followed by the Younger Dryas (GS1, dated *ca.* 12.9–11.7 ky cal BP (Rasmussen et al. 2006), the last cold period in the Pleistocene, during which much of the Azilian took place (*ca.* 12.7/ 11.7–10.8 ky cal BP) (Fernández-Tresguerres, 2007). The Holocene began about 11.5 ky cal BP (Rasmussen et al., 2014). The first industries in that time are attributed to the Mesolithic -including the Asturian facies, located above all in the eastern coast of Asturias Region- (from *ca.* 10.0 to 7.5 ky cal BP) (Fano, 2019; Fano et al., 2015), during a time of a favourable climate only interrupted by the "8.2 ky event" (Rohling and Pälike, 2005).

In north Spain, the climate change that occurred in the Pleistocene-Holocene transition caused a slow rise in sea level and changes to the position of the coastline (e. g. Leorri et al., 2012; Salas, 1995; Galparsoro et al., 2010; Thompson and Goldstein 2006). Several studies have recently determined contour lines marking sea level variations during this transition period, such as at the mouth of the River Deba in the Basque Country (Edeso and Mujika, 2017) and the River Sella in Asturias (Jordá Pardo et al., 2018b), which implies a reconstruction of the coastline near El Cierro Cave. At the start of the Younger Dryas (GS1: 12.9 ky cal BP), sea level was 70 m lower than today and the coast 5 km from El Cierro, whereas at *ca.* 11.7 ky cal BP it would have been 56 m lower with the shore 4 km from the cave. In the early Holocene (*ca.* 10 ka cal BP), sea level was 45 m below the current level and the coastline 3 km away; and at ca. 8.2 ky cal BP it would have been 20 m lower, with the shore about 2 km from El Cierro.

Azilian and Mesolithic periods have been individualised through a large number of deposits mostly located in caves and rock-shelters (Fano, 2007, 2019; Fernández-Tresguerres, 2007) (Fig. 1). These are
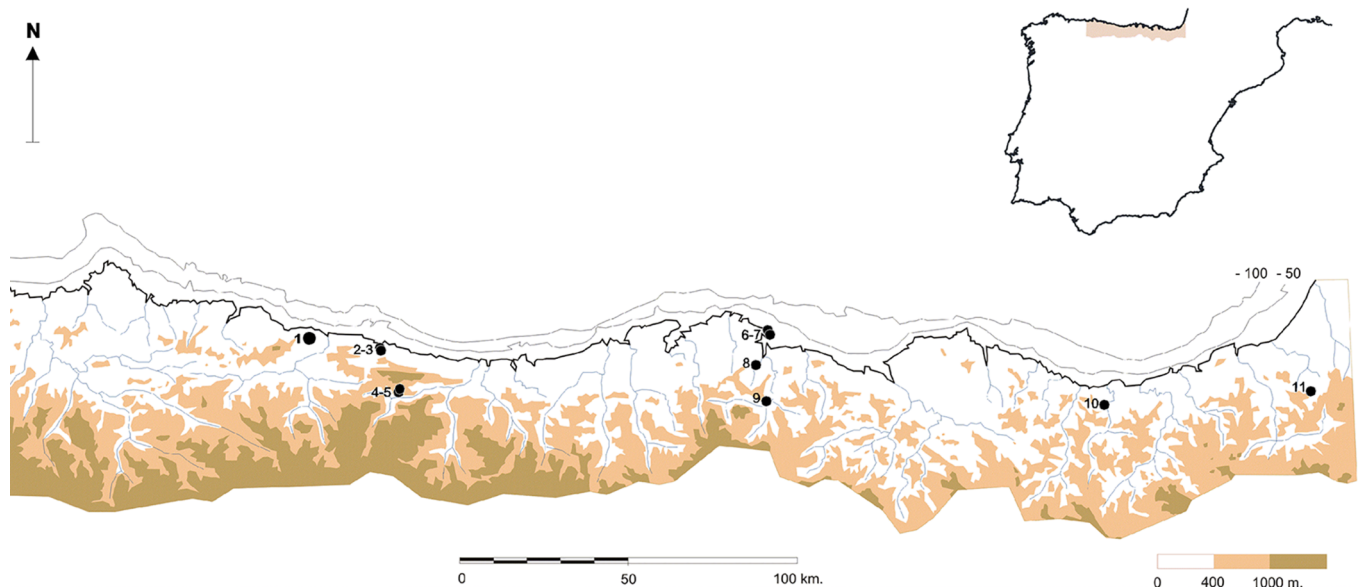

Fig. 1. Location of El Cierro Cave and other sites in Cantabrian Spain cited in this article. 1. El Cierro; 2. La Riera; 3. La Poza ĺEgua; 4. Arangas; 5. Los Canes; 6. La Fragua; 7. El Perro; 8. El Carabión; 9. El Mirón; 10. Ekain; 11. Berroberria.

generally located near the coast, but some are known in inland mountain areas. However, few sites contain stratigraphies where the two cultures are present and changes in subsistence strategies can be observed from a synchronic point of view. Some of these sites that can be mentioned are La Riera (Straus and Clark 1986a) and La Poza ÍEgua (Arias et al., 2007a) near the coast of Asturias, and Los Canes and Arangas (Álvarez-Fernández et al., 2020; Arias, 2013) inland. In Cantabria, El Carabión (Pérez, 2017), La Fragua and El Perro (González, 2000; González and Díaz, 1991–1992) are near the coast and El Mirón (Straus and González 2012; González and Straus 2012) is inland. In the Basque Country, we can cite Ekain (Altuna and Merino 1984) and in Navarre, Berroberria (Barandiarán 1990). However, only La Riera and the excavation at La Poza l'Egua have been published in the form of interdisciplinary studies including all the information about the Upper Pleistocene-Holocene transition.

The subsistence of the groups who lived in the region during the transition to the Holocene was based on hunting and gathering (e.g. Álvarez-Fernández, 2011, 2015, Fano, 2007, 2019, Fano et al., 2013b, 2013a; Fernández-Tresguerres, 2007; Straus, 2018; Marín, 2010). Hunting during the Azilian and Mesolithic continued the patterns established during the Magdalenian. At lowland sites (on the coastal strip and in lower valleys), accumulations formed shell-middens. Large mammal remains are not too abundant in those deposits. In general terms, the best-represented species is red deer, followed by Iberian ibex, wild boar and roe deer. The latter two animals are linked with forest expansion. At sites near steep or rocky terrain, seasonal hunting camps occupied in the warmer months specialised in Iberian ibex and chamois. The consumption of these mammals is attested by taphonomic evidence (butchery marks, fractures, etc.). Remains of birds tend to be scarce. Additionally, most remains reveal no signs of anthropic modifications (breakages, cutmarks or burning) and therefore it is difficult to establish whether they were hunted or caught systematically.

Shell-fishing is well-documented in both periods. The collection of marine invertebrates was an activity inherited from the Magdalenian, like hunting. Continuity between the Azilian and the Mesolithic is seen in the use of molluscs gathered on rocky substrates in the intertidal zone. However, in the latter period, the common periwinkle *Littorina littorea* disappears from the stratigraphies to be replaced by the toothed topshell *Phorcus lineatus*, and the limpet species *Patella depressa* and *Patella ulyssiponensis* in some cases are more abundant than *Patella vulgata*. In the Mesolithic, species were also gathered on sandy or muddy substrates (e. g. the grooved carpet shell, *Ruditapes decussatus*). The limpets decreased in size and this has been explained as due to either environmental factors or overexploitation, or both (see discussion in Álvarez-Fernández et al., 2011).

As well as molluscs, crustaceans and echinoderms complemented a diet that was based on proteins from terrestrial animals. The latter invertebrates were collected opportunistically.

Fishing activity has been extrapolated indirectly by finds of harpoons (but see Fano et al., 2013a,b) and hooks, and directly by fish bones with evidence of anthropic manipulation. These belong not only to freshwater fish like Salmonidae and eels, but also to pelagic and demersal species and fish that live in brackish water with low salinity. The consumption of marine resources has also been demonstrated through isotopic analysis of human remains from Mesolithic sites (e. g. Arias, 2005/2006).

Plants (wild fruits like acorns and hazelnuts, roots, mushrooms, etc.) must have formed an important part of the diet and their availability would have increased as the forests expanded during the transition period. However, evidence of plant macro-remains is not abundant (López-Dóriga, 2016; Zapata, 2000). Their absence is compensated by information provided by pollen studies and the documentation of carbonised wood, in both Azilian and Mesolithic sites (Iriarte-Chiapusso et al., 2016; Uzquiano, 2018).

Recent studies have summarised the characteristics of lithic and osseous industries during the Azilian and Mesolithic (e.g. Fano, 2007,

2019; Fernández-Tresguerres, 2007; Straus, 2018; Álvarez-Fernández, 2006; Álvarez-Fernández, 2018). The varied lithic typology employed in the Magdalenian decreases during the Azilian. Small, wide and short endscrapers on flakes, unguiform or round, are characteristic. Microliths are also common, including large numbers of backed pieces, particularly the Azilian point. In the Mesolithic, however, retouching of flakes produced substrate implements (sidescrapers, denticulates, etc.). The typical Asturian picks were produced; geometric microliths (such as backed bladelets, circle segments and triangles) were also documented . The raw materials employed were mainly obtained locally; mostly quartzite, flint or radiolarite depending on the location of the site in northern Spain.

Artefacts made from antler and bone are much less diversified in Azilian deposits than during earlier periods. The most particular objects are the harpoons with a flat cross-section, a row of several barbs cut in an acute angle and a proximal zone consisting of a protuberance with an oval-shaped hole. Much less frequent are sagaies with different cross-sections, borers, spatulas and small bi-pointed pieces of bone usually classified as hooks. Bone tools in the Mesolithic are even more limited. The most characteristic implements are pierced staffs, as well as some tools from earlier traditions, both pointed (sagaies, awls and hooks) and rounded (spatulas).

Objects of adornment in both the Azilian and the Mesolithic were usually made from marine shells, especially *Trivia* sp., although with two holes in the Azilian and one in the Mesolithic. They would probably have been gathered on the shores of northern Spain. Animal teeth were also used, mostly red deer atrophied canines.

Figurative motifs disappeared from portable graphic activity, contrasting with the Magdalenian (Fernández-Tresguerres, 2007). They were replaced, on the few examples that have been documented, by engraved geometric linear decoration and dots, on some harpoons and awls. Some painted pebbles have also been found. This graphic activity disappears completely in the Mesolithic.

3. El Cierro cave

3.1. Fieldwork

El Cierro Cave (Fresnu, Ribadesella, Asturias) is located in the north-central region of Iberia (43° 27′ 26″ N, 5° 06′ 20″ W, ETRS89), at 83 m above sea level, about 2 km from the coast and 3.5 km from the mouth of the River Sella (Fig. 1).

In 1959 F. Jordá Cerdá excavated a test pit of 2 × 3m where he documented several archaeological layers belonging to the Upper Palaeolithic. On the top of this sequence a "shell-midden" was also documented. It consists of two parts; a lower one calcited with shells and an upper one calcited with stones and bones (Jordá Pardo et al., 2018a). In 1969 G. Clark sampled the "conchero" where he documented over a thousand archaeological remains: shells of marine and continental gastropods, echinoderms and bones of ungulates, small mammals and fish. A charcoal sample situated this shell-midden at the end of the Upper Pleistocene (Clark, 1983), during the Younger Dryas.

Between 1977 and 1979, F. Jordá Cerdá and A. Gómez Fuentes cleaned the sections of the 1959 excavation, took samples (sedimentology, palynology, etc.) from the different layers of the archaeological site and excavated the Magdalenian layers below the shell-midden over a surface area of 2 × 1 m (Álvarez-Fernández et al., 2014a; 2016). Samples and remains from this fieldwork are currently stored in the Department of Prehistory, Ancient History and Archaeology at the University of Salamanca, where they are being studied.

Current research restarted in 2014 to study the remains found in the 1970s, re-sample the "shell-middens" (Levels D, C and B), and excavate the archaeological deposit beneath the Lower Magdalenian levels (Álvarez-Fernández et al., 2016, 2017; Jordá Pardo et al., 2018a).

3.2. Stratigraphy

The stratigraphic sequence currently known includes a total of 14 archaeological layers. This makes it one of the most complete stratigraphies known in the prehistory of Western Europe, as it includes levels belonging to the Middle Palaeolithic, Upper Palaeolithic and Mesolithic. Thus, from bottom to the top, the levels are: level N, over the bedrock, is assigned to the Mousterian; two layers with Aurignacian materials (M and L); two levels attributed to the Gravettian (J2 and J1); two Solutrean levels (H1 and H); three Lower Magdalenian levels (G1, G and F); a semi-barren level (E); two late Upper Palaeolithic levels (C and D) and one Mesolithic shell-midden (Level B) (Álvarez-Fernández et al., 2016; Jordá Pardo et al., 2018a) (Fig. 2).

The levels studied here are Levels D, C and B , corresponding to the shell-midden in the archaeological fieldwork in the 1970 s and since 2014. The sedimentary characteristics of these levels are described in Table 1 (Álvarez-Fernández et al., 2016; Jordá Pardo et al., 2018a).

3.3. AMS radiocarbon dating

A total of eight AMS radiocarbon dates have been obtained from the transitional levels at El Cierro in the course of the new research in the cave: two dates for Level B, both of them on marine shell samples (the gastropod *Phorcus lineatus* and the peppery furrow shell *Scrobicularia plana*); four dates for Level C, two of them from marine shell samples (the limpet *Patella vulgata*) and two more from *Cervus elaphus* bone samples (a fragment of a cranium and a fragment of a humerus, both with cut marks); and one sample for Level D, from a marine shell sample (the gastropod *Littorina littorea*) and one for Levels D/E, from a bone sample (a fragment of a *Cervus elaphus* phalanx). A previous 14C date for charcoal sampled in the "shell-midden" was published in the 1970 s (Clark, 1976) (Tables 2 and 3).

Apart from the latter date, all the other determinations were obtained at the Oxford Radiocarbon Accelerator Unit (University of Oxford, UK), following routine protocols (Brock et al. 2010).

Bayesian analysis of radiocarbon dates (Fig. 3) indicates coherence between chronology and cultural attributions. Azilian occupations took
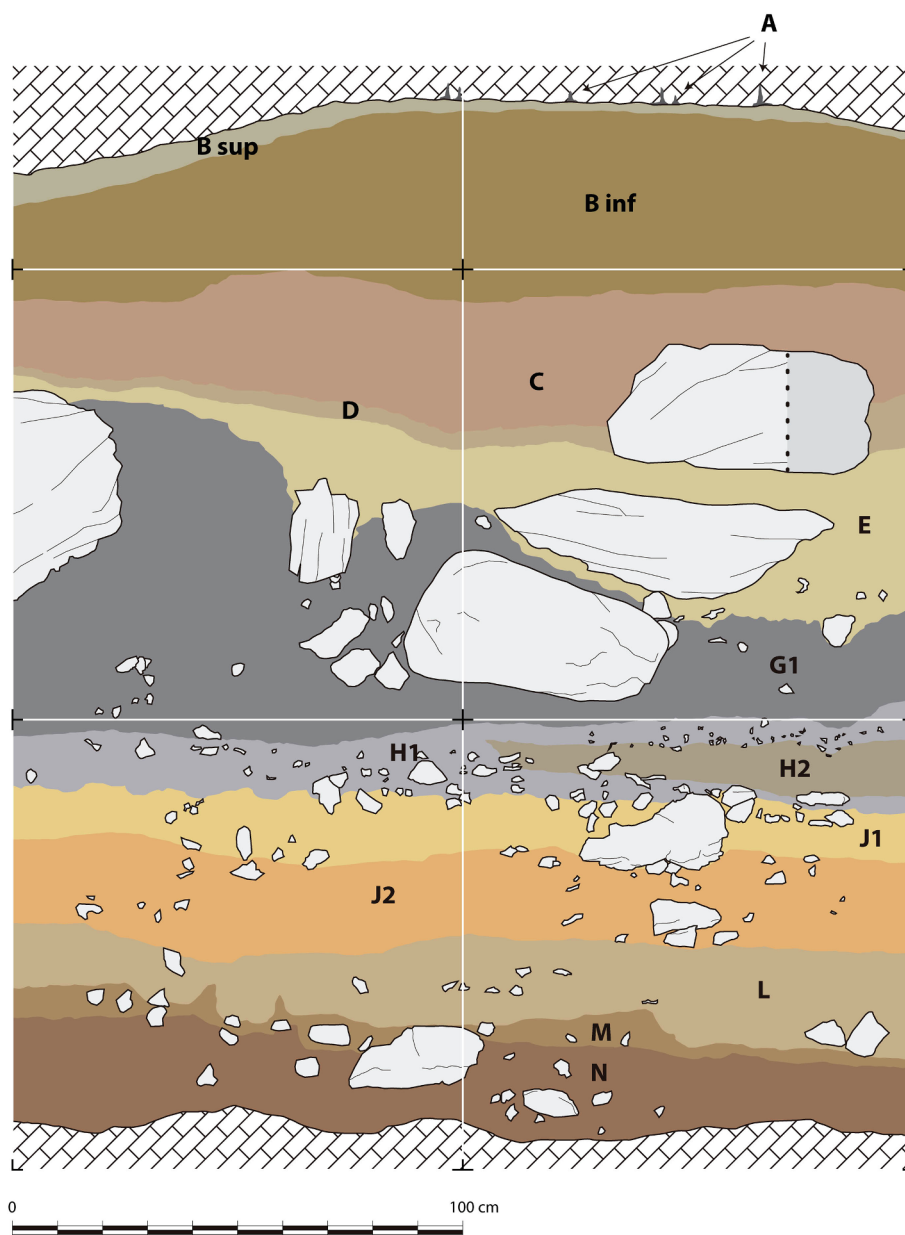

Fig. 2. Stratigraphic section at El Cierro Cave after the 2014 fieldwork campaign.

Table 1

Lithostratigraphic description of the upper sedimentary units at El Cierro.

Level	Thickness	Description (from the bottom to the top)
E	2–15 cm	Sandy silt with clay, orange to yellow in colour. At the top, in the eastern sector, two facies consist of carbonated sediment 15 cm thick with a granular appearance which changes laterally towards the east to a clayish facies with limestone clasts. In the section that is currently visible, this unit appears to be archaeologically semi-barren.
D	5–10 cm	Carbonated deposit which laterally displays dark detritic material cemented with carbonates. It contains remains of invertebrate and vertebrate bones. At the top, in contact with this level and the overlying one (Level C), carbonate concretions with millimetre-size grains is 1 cm thick. The growth of botroidal concretions is also observed around detritus particles.
C	35–40 cm	Whitish shell-midden, with abundant osseous remains of vertebrates and invertebrate shells joined by calcium carbonate with zones containing very little matrix and others where it is more abundant. Some autochthonous limestone clasts also appear (centile 15 cm, mean 2 cm) and some larger boulders (up to 40 cm). The clasts are very angular with fresh edges. At the top of Level C a less calcited area is eroded, causing a notch in the contact with Level B shell-midden.
B	30–35 cm	Whitish shell-midden with abundant animal remains, mainly invertebrate shells and mammal bones. It contains a few small and angular limestone pebbles (centile 3 cm). At the top of the Level B shell-midden and in contact the rock of the ceiling and the wall, 5–10 cm of loose sediment is formed by brownish-black clay that is termed upper Level B. These deposits are in the western sector and form a detached plane of the shell-midden as regards the rock so that the whole midden is separate from the cave rock, which is very smooth and possesses some small parts of the shell-midden adhered to the wall. Very fine stalactites are currently forming on it.
A	1–5 cm	White globular carbonate concretions that connect with Level B and are in contact with the wall and the rock ceiling of the cave.

Table 2

Raw radiocarbon determinations from El Cierro Cave and their isotopic values.

Level	Method	Sample	Laboratory	14C	St. Dev.	δ^{13}C	δ^{15}N	References
B sup	^{14}C AMS	Bone (Ulna) with cut marks (*Capra pyrenaica*)	Low Yield	–	–	–	–	–
B sup	^{14}C AMS	Marine Shell (*Scrobicularia plana*)	OxA-31702	7470	38	−4.77	–	This paper
B sup	^{14}C AMS	Marine Shell (*Phorcus lineatus*)	OxA-31705	8575	40	2.01	–	Álvarez-Fernández et al (2016)
C	^{14}C AMS	Bone (Cranium) with cut marks (*Cervus elaphus*)	OxA-35634	11,000	50	−20.8	3.3	This paper
C	^{14}C AMS	Bone (Humerus) with cut marks (*Cervus elaphus*)	OxA-34810	10,755	50	−20.66	4.7	This paper
C	^{14}C AMS	M. Shell (*Patella vulgata*)	OxA-31704	11,155	45	0.01	–	This paper
C	^{14}C AMS	M. Shell (*Patella vulgata*)	OxA-27856	11,190	38	0.04	–	Álvarez-Fernández et al (2016)
–	^{14}C	Indet. Charcoal	GaK-2548	10,400	500	–	–	Clark (1976)
D	^{14}C AMS	M. Shell (*Patella vulgata*)	OxA-27857	11,403	37	−0.32	–	Álvarez-Fernández et al (2016)
E/D	^{14}C AMS	Bone (Phalanx) (*Cervus elaphus*)***	OxA-34811	15,305	70	−19.81	5.4	This paper

*** The sample was taken from a shell-midden, on the top of Level E and on the bottom of Level D. The ^{14}C dated a bone belong to Level E.

Table 3

Calibrated dates from El Cierro. The raw radiocarbon determinations have been calibrated with OxCal 4.3 software (Bronk Ramsey, 2001, 2009a,b) against the IntCal13 calibration curve (Reimer et al., 2013) with a ΔR = − 117 ± 70 established for the late Pleistocene and ΔR = − 105 ± 21 for the Early Holocene in the region (Soares et al., 2016).

	Calibrated (BP)			
	from	to	from	to
	68.2%		95.4%	
OxA-31702 (**B sup**)	8090	7970	8145	7940
OxA-31705 (**B sup**)	9415	9295	9460	9235
OxA-35634 (**C**)	12,945	12,775	13,005	12,730
GaK-2548 (-)	12,715	11,400	13,265	10,745
OxA-34810 (**C**)	12,725	12,665	12,750	12,610
OxA-31704 (**C**)	12,825	12,655	12,925	12,600
OxA-27856 (**C**)	12,860	12,685	12,955	12,620
OxA-27857 (**D**)	13,105	12,895	13,190	12,775
OxA-34811 (**D/E**)	18,675	18,490	18,745	18,390

place between ca. 13.1–12.6 cal BP, and Mesolithic occupations between ca. 9.4–8.0 cal BP.

4. Methodology

The archaeological materials studied here come from excavations in Azilian (Levels D, D/C and C) and Mesolithic levels (Level B) between 1977 and 1979, and from the 2014 to 2016 fieldwork. In these latter seasons, samples were collected for archaeozoological, anthracological, palynological, sedimentological and palaeomagnetic analyses. The volume sampled for the Azilian was *ca.* 13,500 cm³ (Level D: ca. 6,000 cm³; Level D/C: ca. 2,500 cm³; Level C: *ca.* 5,000 cm³) whereas

for the Mesolithic level it was *ca.* 5,000 cm³. As the levels were rich in carbonates, the concretion containing the remains was broken up and the sediment was floated in water and then sieved through screens down to a 0.4 mm mesh size to recover small biotic and abiotic remains.

4.1. Biotic resources

4.1.1. Archaeobotanical evidence

The Azilian palynological record was obtained from samples taken in Levels C and D. The sedimentary characteristics of the Mesolithic shell-midden (Level B) did not allow the collection of samples for palynological analysis. The samples were processed using the classic physical–chemical method and the sporo-pollen contents were identified and counted with optical microscopy (Burjachs et al., 2003).

Charcoal fragments from the Azilian (Levels D, D/C and C) and Mesolithic (Level B) occupations were systematically recovered by water sieving of sediments and the material was subsequently selected following the standardized anthracological methods for caves and rock-shelters (Badal et al., 2003). Charcoal was fractured by hand along the three anatomical observation planes following the identification keys for both non-charred and charred wood. Nomenclature follows the guidelines in *Flora europaea* (Uzquiano, 2018: see references therein).

4.1.2. Archaeozoological evidence

Archaeofauna remains were recovered from all the excavated levels. In the case of macrovertebrates and birds, fragments < 1 cm in size that are unclassifiable included display recent fractures have not been taken into account. All the remains of microvertebrates, fish and invertebrates (molluscs, crustaceans and echinoderms), recovered by screening with metallic mesh sizes down to 0.4 cm have been studied. Identifications have been made with the reference collections held by the different hosting institutions of some of the authors of this paper.
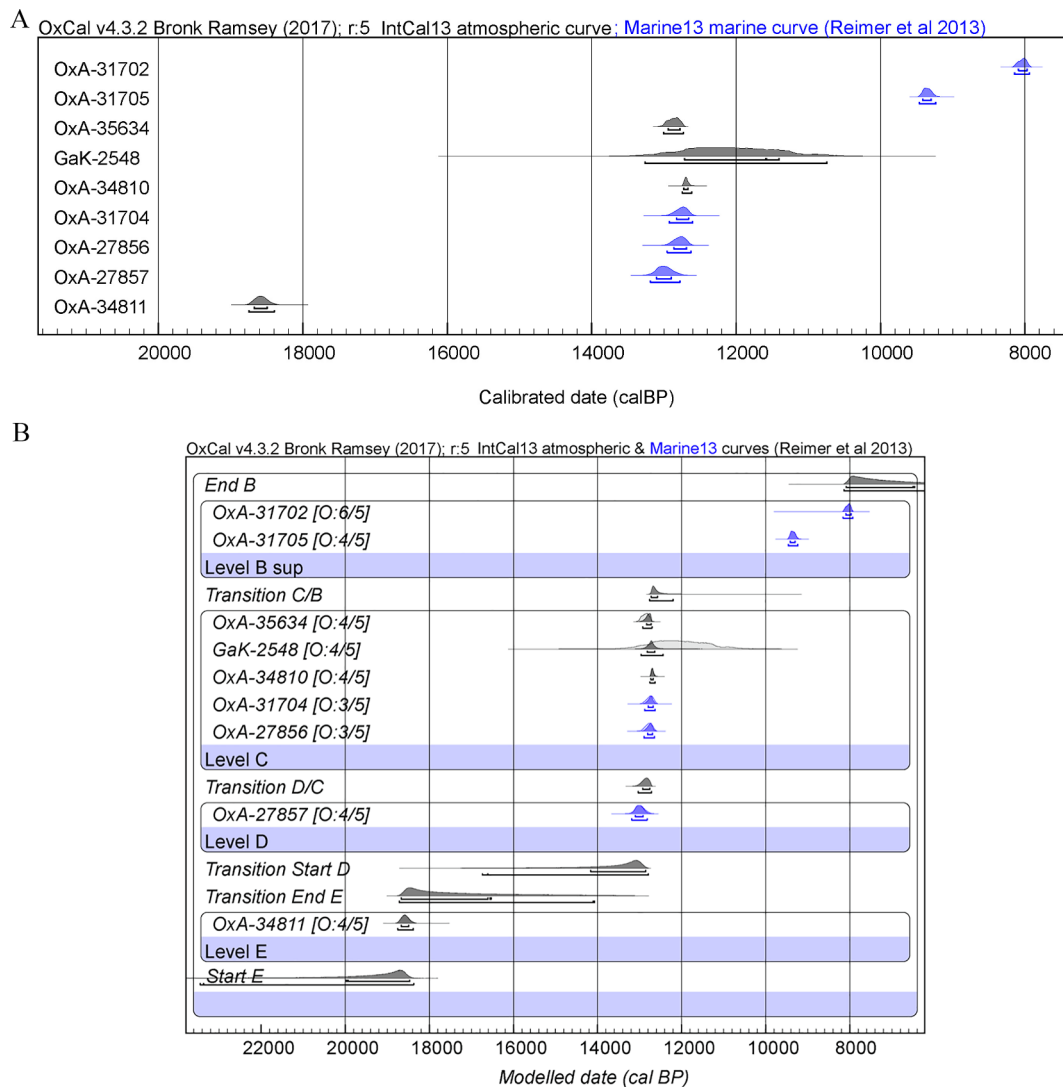
Fig. 3. Radiocarbon dates obtained at El Cierro Cave. A) Calibration of the dates with the IntCal13 and Marine13 curves (Reimer et al. 2013). In black the terrestrial samples, in blue the marine ones B) Modelling of available radiocarbon dates using Bayesian statistical approaches, built in OxCal V4.3 (Bronk Ramsey 2009 a,b).

For the large mammals, several osteological atlases have also been used (e. g. Pales and Garcia, 1981). The study of Le Gall (1984) has been followed for the fish remains.

In the case of large mammals, when it was not possible to assign the remains to a specific taxon, they were grouped in different size categories of mammals: large (horse and bovids), medium (red deer and wild boar) or small size (Iberian ibex and roe deer). To estimate the age of death of each species, criteria related to dental eruption (e.g. Bull and Payne, 1982, Mariezkurrena and Altuna, 1983, Pérez Ripoll, 1988, Pérez Barbería, 1994; Tomé and Vigne, 2003) and epiphyseal fusion (Reitz and Wing, 2003) were used.

To quantify the different remains, Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI) were used. Additionally, the Number of Remains (NR) has also been considered (e. g. Reitz and Wing, 2003, for the mammals; e. g. Moreno, 1994, for the molluscs; Campbell, 2008, for the echinoderms; Gruet and Laporte, 1996, for the crabs; Álvarez-Fernández et al. 2013b, for the goose barnacles; Alvarez-Fernández et al., 2014: 70, for the sessile cirripeds).

The taphonomic observations where registered using a Leica EZ4 stereo microscope (6.5-32x). It was possible to determinate anthropic modifications (e. g. Shipman and Rose, 1983; Blumenschine and Selvagio, 1988), thermoalterations (e. g. Stiner et al., 1995) and carnivore damage (e. g. Haynes, 1983; Binford, 1981).

Information about the biotopes of the different taxa has been taken from specific studies for large mammals (e. g. Barone, 1966), small mammals (e. g. Sesé, 2005), birds (e. g. del Hoyo et al., 1992–2010), fish (e.g. Doadrio 2002), terrestrial molluscs (e. g. Welter-Schultes, 2012), marine molluscs (e. g. Palacios and Vega, 1997), crustaceans (e. g. Ingle, 1996; Southward, 2008) and echinoderms (e.g. Southward and Campbell, 2005).

The nomenclature of FAUNA EUROPAEA was followed for large mammals, birds and terrestrial molluscs (Fauna Europaea version 2019.06, Zoological Museum Amsterdam/University of Amsterdam, http://www.faunaeur.org; retrieved 01-10-2019). In the case of small mammals, the work of Wilson and Reeder (2005) has been used, whereas the study of amphibians and reptiles has followed Speybroeck et al. (2010). WoRMS nomenclature was used for the marine invertebrates (WoRMS Editorial Board, 2019). Fish classification followed the Eschmeyer Catalog of Fishes (http://www.calad
emy.org/scientists/catalog-of-fishes-classification/) [ref. 5–5-2019].

Finally, biometric data were collected for well-preserved marine mollusc shells in order to establish criteria for a consideration of possible size changes in the species in the course of the sequence and to determine what might be their causes. Statistical tests (Kolmogorov-Smirnov and Mann-Whitney U-tests) were applied for this purpose.

Table 4
Classification of anthracological remains from the Mesolithic and Azilian layers at El Cierro Cave.

Levels /Taxa	B	C	C/D	D
Salix sp.	—	—	1	—
Quercus robur type	70	35	2	1
Corylus avellana	3	—	—	—
Fraxinus excelsior	6	—	—	—
Quercus ilex	3	2	—	—
Hedera helix	1	—	—	—
Crataegus monogyna	1		—	—
Arbutus unedo	—	1	—	—
Erica sp.	4	—	—	—
Fabaceae	—	4	—	—
Indeterminable	17	2	2	2
Total	**105**	**44**	**5**	**3**

4.2. Abiotic resources

The lithic remains have been classified according to the typelist of D. Sonneville-Bordes and L. Perrot (1954, 1956a,b). The technological study has based on the *chaîne opératoire* concept (e. g. Lemonnier, 1976; Pelegrin et al., 1988). The distinct *chaînes opératoires* can be reconstructed and the strategies to obtain the blanks (blades and flakes) and their use can be determined. Smaller knapping debris was merely quantified. Typology and technology are combined with a macroscopic observation of raw materials to identify their provenance and to explore the management strategies. The working method has been textural analysis (Álvarez-Alonso et al., 2013; Tarriño, 2006) using a stereo microscope normally at x10 or x20 magnification.

5. Results

5.1. Biotic resources

5.1.1. Archaeobotanical evidence

The vegetation cover identified in the older Azilian layer in El Cierro Cave (Level D) reflects the more adverse climate conditions in this transition period. Birch predominated in the small arboreal cover, only accompanied by *Pinus*, while Poaceae and Compositae liguliflora were the characteristic herbaceous taxa in that open landscape (Fig. 4).

The situation changed in the later Azilian layer (Level C), when climate amelioration is perceived in greater taxonomic diversity and the floral composition. Although the arboreal representation does not increase substantially, significant differences are seen: retreat of *Betula* and appearance of *Quercus robur* sp., *Corylus* and *Salix*. In the herbaceous-shrub layer, the representation of the two main components Compositae liguliflora and Poaceae) is inverted and Polygonaceae, Brassicaceae, Rosaceae, Primulaceae, *Helleborus* sp., Ranunculaceae,

Umbelliferae and Liliaceae appear in the pollen record. The increase in humidity compared with Level D is observed above all in the higher number of fern spores (Fig. 4).

Few anthracological remains have been found in the Azilian levels in general and therefore these assemblages must be interpreted with caution. The abundance of deciduous oak may reflect a preference for that type of wood by the occupants of El Cierro Cave. This corroborates the anthracological data from other Azilian occupations in north Spain, where deciduous woodland became the main source of firewood for those communities (Uzquiano, 2018). However, the presence of willow (*Salix*), strawberry tree (*Arbutus*) and Fabaceae suggests that other catchment areas were used (riverbanks and hillsides on different substrates) (Table 4).

Information about the vegetation from the Mesolithic level comes exclusively from the anthracological study (Table 4). This level has provided the largest number of remains and the greatest diversity, both qualitatively and quantitatively. The flora reflects the expansion of deciduous woodland characterising the early Holocene and its systematic exploitation, mainly of deciduous oak (*Quercus robur*), hazel and ash (*Corylus* and *Fraxinus*), as well as *Hedera* and *Crataegus* (deciduous shrubs), in agreement with other palynological and anthracological records in northern Spain (Uzquiano, 2018). The discreet presence of *Quercus ilex* compared with deciduous oak is in accordance with the slow expansion of holm oaks in north Spain at that time (Uzquiano et al., 2016).

5.1.2. Archaeozoological evidence (Tables 5, 6 and 7)

Small vertebrate remains are very scarce in both the Azilian and the Mesolithic levels. They consist of disarticulated bone fragments and isolated teeth. A total of 20 remains (NR) have been identified, with a MNI of 13 individuals. Specifically, Azilian levels have yielded a low number of remains and individuals (NR: 13 NR; MNI: 8). They belong to
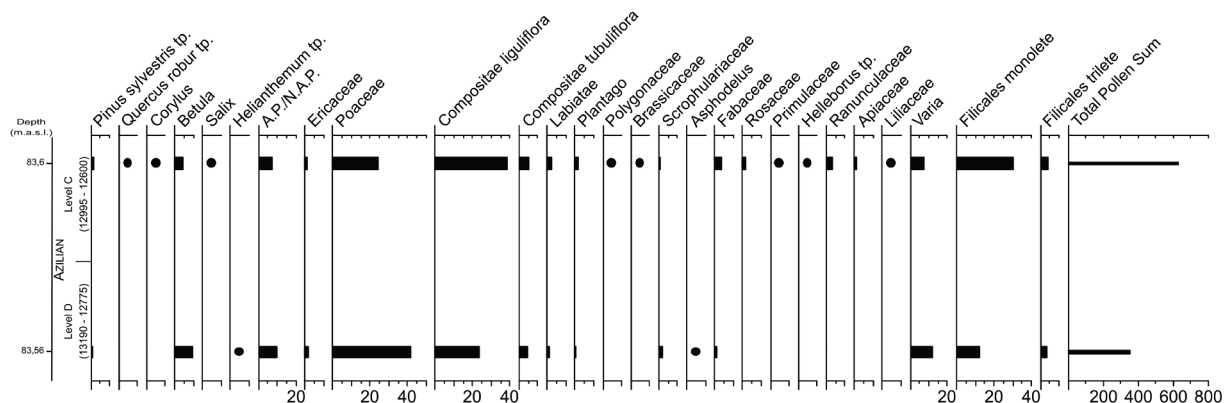

Fig. 4. Pollen diagram from level D and C at El Cierro Cave.

Table 5
Vertebrate remains from El Cierro, according to NR and MNI. Information about the age of the animals is also included in the case of the large mammals. A: Adults; J: Juveniles.

Levels/Taxa	B		C		C/D		D	
	NR	MNI	NR	MNI	NR	MNI	NR	MNI
Cervus elaphus Linnaeus, 1758	32	3 (A:2; J:1)	26	3 (A:2; J:1)	37	3 (A: 3)	38	5 (A:2; J:3)
Capreolus capreolus Linnaeus, 1758	—	—	3	1 (A: 1)	3	1 (A: 1)	7	2 (A:1; J:1)
Capra pyrenaica Schinz, 1838	2	2 (A:1; J:1)	4	1 (A: 1)	6	2 (A: 1; J: 1)	4	1 (A:1)
Equus ferus Linnaeus, 1758	—	—	—	—	2	1 (J: 1)	—	—
Bos/Bison	—	—	—	—	—	—	1	1 (A: 1)
Sus scrofa Linnaeus, 1758	1	1 (A: 1)	—	—	—	—	3	1 (J: 1)
Canis sp.	1	1 (A: 1)	—	—	—	—	—	—
Large mammal	—	—	—	—	—	—	8	—
Medium sized mammals	56	—	63	—	84	—	82	—
Small mammals	27	—	11	—	25	—	20	—
Indet	140	—	148	—	97	—	105	—
Subtotal Mammals	**259**	**7 (A: 5; J: 2)**	**255**	**5 (A: 4; J: 1)**	**254**	**7 (A: 4; J: 3)**	**268**	**10 (A: 5; J:5)**
Microtus agrestis (Linnaeus, 1758)	—	—	—	—	2	2	1	1
Microtus arvalis (Pallas, 1778)	—	—	—	—	2	2	1	1
Arvicola amphibius (Linnaeus 1758)	1	1	—	—	1	1	—	—
Apodemus sylvaticus-flavicolis (Melchior, 1834)	—	—	1	1	—	—	—	—
Sorex araneus-coronatus Linnaeus, 1758: Millet, 1928	1	1	—	—	—	—	—	—
Sorex minutus	1	1	—	—	—	—	—	—
Talpa sp.	2	1	—	—	—	—	—	—
Subtotal Rodents	**4**	**3**	**1**	**1**	**4**	**2**	**2**	**2**
Salamandra salamandra (Linnaeus, 1758: Boulenger, 1879)	2	1	5	2	—	—	—	—
Subtotal Anphibians	**2**	**1**	**5**	**2**	—	—	—	—
Scolopax rusticola (Linnaeus, 1758)	1	1	—	—	—	—	—	—
Corvux corax (Linnaeus, 1758)	—	—	—	—	—	—	1	1
Passeriforme indet.	—	—	1	1	5	1	—	—
Aves indet	3	1	—	—	—	—	—	—
Subtotal Birds	**4**	**2**	**1**	**1**	**5**	**1**	**1**	**1**
cf. Mugilidae	1	1	—	—	—	—	—	—
Salmonidae	1	1	1	1	3	1	—	—
Anguilla anguilla (Linnaeus, 1758)	1	1	—	—	1	1	—	—
Indet.	—	—	3	—	2	—	—	—
Subtotal Fish	**3**	**3**	**4**	**1**	**6**	**2**	—	—

Table 6
Marine invertebrates from El Cierro, according to NR and MNI.

Levels/Taxa	B		C		C/D		D	
	NR	MNI	NR	MNI	NR	MNI	NR	MNI
Patella vulgata Linnaeus, 1758	235	228	75	67	86	86	307	304
Patella depressa Pennant, 1777	97	97	—	—	5	5	45	36
Patella ulyssiponensis Gmelin, 1791	114	114	—	—	5	5	40	34
Patella sp.	1020	298	125	15	125	16	371	212
Phorcus lineatus da Costa, 1778	144	23	—	—	3	1	7	6
Littorina littorea (Linnnaeus, 1758)	—	—	2	2	21	8	8	7
Nucella lapillus (Linnnaeus, 1758)	—	—	—	—	—	—	2	2
Gibbula cineraria (Linnnaeus, 1758)	2	2	—	—	—	—	—	—
Gibbula sp.	—	—	—	—	1	1	—	—
Stramonita haemastoma (Linnnaeus, 1767)	1	1	—	—	—	—	—	—
Mytilus galloprovincialis Lamarck, 1819	570	48	11	3	8	2	129	12
Ostrea edulis Linnaeus, 1758	6	2	—	—	—	—	—	—
Scrobicularia plana (da Costa, 1778)	56	10	—	—	—	—	—	—
Ruditapes decussatus (Linnaeus, 1758)	1	1	—	—	—	—	—	—
Subtotal Marine Molluscs	**2246**	**824**	**213**	**87**	**254**	**124**	**909**	**613**
Pollicipes pollicipes (Gmelin, 1790)	3	1	—	—	—	—	—	—
Eriphia verrucosa (Forskal, 1775)	6	1	—	—	—	—	3	1
Balanus crenatus Bruguière, 1789	—	—	9	9	16	16	—	—
Semibalanus balanoides (Linnaeus, 1767)	—	—	4	4	4	4	—	—
Perforatus perforatus perforatus (Bruguière, 1789)	26	26	—	—	—	—	18	18
Chthamalus montagui Southward, 1976	3	3	—	—	—	—	—	—
Chthmalus sp.	28	28	—	—	—	—	—	—
Balanidae indet.	2	2	—	—	—	—	—	—
Subtotal Crustaceans	**68**	**61**	**13**	**13**	**20**	**20**	**21**	**19**
Paracentrotus lividus (Lamarck, 1816)	2425	10	9409	41	5892	63	121	2
Subtotal Echinoderms	**2425**	**10**	**9409**	**41**	**5892**	**63**	**121**	**2**

Table 7
Terrestrial molluscs from El Cierro, according to NR and MNI.

Levels/Taxa	B		C		C/D		D	
	NR	MNI	NR	MNI	NR	MNI	NR	MNI
Obscurella bicostulatum Gofas, 1989	36	36	—	—	—	—	—	—
Obscurella hidalgoi (Crosse, 1864)	—	—	11	11	368	148	18	18
Menkia horti Boeters, Gittenberger & Subai, 1985	2	2	2	2	1	1	—	—
Pomatias elegans (O.F. Müller, 1774)	5	5	—	—	—	—	1	1
Zospeum shaufussi Frauenfeld, 1862	21	21	404	404	2	2	—	—
Zospeum suarezi Gittenberger, 1980	10	10	19	19	—	—	—	—
Carychium tridentatum (Risso, 1826)	2	2	—	—	—	—	—	—
Azeca goodalli (Férussac, 1821)	—	—	2	2	1	1	—	—
Cochlicopa lubricella (Rossmässler, 1835)	—	—	—	—	1	1	—	—
Cryptaceca monodonta (Folin & Bérillon, 1877)	—	—	—	—	1	1	1	1
Cryptaceca subcylindrica Folin & Bérillon, 1877	4	4	2	2	—	—	—	—
Lauria cylindarcea (E. M. da Costa, 1778)	—	—	1	1	1	1	—	—
Vallonia escentrica Sterki 1892	1	1	—	—	—	—	—	—
Clausilia bidentata (Ström, 1765)	5	2	—	—	8	3	1	1
Discus rotundatus(O.F.Müller, 1774)	1	1	—	—	2	2	—	—
Vitrea contracta (Westerlund 1871)	4	1	—	—	5	5	—	—
Vitrea subrimata (Reinhardt, 1871)	—	—	27	27	—	—	—	—
Vitrina pellucida (O.F. Müller, 1774)	1	1	—	—	—	—	—	—
Zonites sp.	17	17	6	6	9	9	—	—
Oestophorella buvinieri(Michaud, 1841)	12	12	91	45	20	20	1	1
Mengoana brigantina (Ortiz de Zárate y López, 1949)	—	—	—	—	—	—	7	3
Helicella itala (Linnnaeus, 1758)	3	3	11	11	32	32	2	2
Elona quimperiana (Férussac, 1821)	1	1	—	—	—	—	—	—
Cepaea nemoralis(Linnnaeus, 1758)	30	13	8	8	12	12	12	3
Subtotal Terrestrial Molluscs	**155**	**132**	**584**	**538**	**463**	**238**	**43**	**30**

Rodentia (*Arvicola amphibius, Microtus arvalis, Microtus agrestis* and *Apodemus sylvaticus-flavicollis)* and Amphibia (*Salamandra salamandra*). In the Mesolithic level the evidence is also limited (NR: 7; NMI: 5). The species *A. amphibius, Sorex araneus-coronatus, Sorex minutus, Talpa* sp., and *S. salamandra* have been determined.

Of the 750 **large mammal** remains ascribed to the Azilian, 58.1% have been determined (n = 436) and 134 have been identified to taxonomical level. Red deer predominates (75.4%) followed by Iberian ibex (10.4%), roe deer (9.7%, in Levels C/D and D), wild boar (2.2%) and horse (1.5%, only in Level D). A single remain of a large bovid has been identified. Red deer is represented by 12 individuals, seven adults and five immature animals, Iberian ibex and roe deer by four individuals, three adults and one immature, the large bovid by an adult and the wild boar and horse by one immature individual each (Table 1).

A total of 239 remains attributed to the Mesolithic have been studied, of which 41% (n = 98) have been determined. Only 34 have been identified to taxonomic level. Most of them belong to red deer (88.2%) followed by Iberian ibex (5.8%). Wild boar and indeterminate canid are represented by a single remain each. In Level B, therefore, the minimum number of individuals is seven, represented by three red deer, two Iberian ibex, a wild boar and a canid. The red deer and Iberian ibex include both adult and immature individuals.

The scarcity of identifiable remains prevents us from knowing if there existed a differential prey transport of the fauna found at the Mesolithic and Azilian levels of El Cierro.

The taphonomic analysis of the remains shows that they were manipulated anthropically to similar extents in the Azilian and Mesolithic (7.1% and 8.3% of the remains, respectively). The alterations consist of cutmarks, dismembering marks, skinning and bone breakages (Fig. 5). They appear on the remains of red deer and Iberian ibex, but also on the medium-sized and small mammals. Signs of heat alteration also appear (1.5% in the Azilian; 6.7% in the Mesolithic). Bones have also been affected by the action of carnivores (2.3% in the Azilian; 4.6% in the Mesolithic), which left grooves, punctures, gnawing, pits and crenulated edges. These are found on red deer, but also on other large, medium and small mammals. Finally natural agents have altered the remains at El Cierro, through the precipitation of calcium carbonate
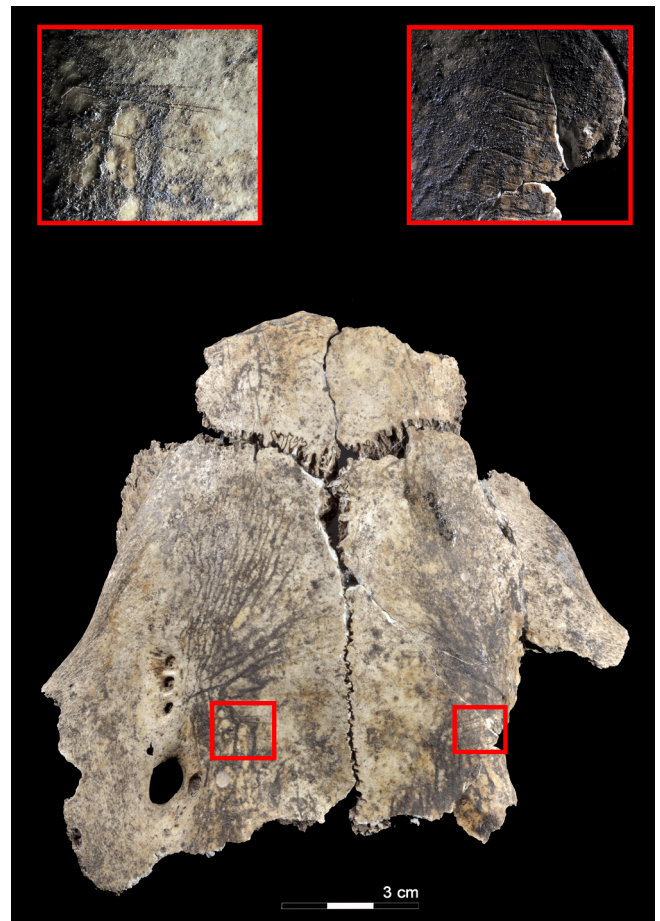

Fig. 5. Skinning marks on a *Cervus elaphus* skull from Level C at El Cierro (magnification x10).

(30.8% in the Azilian; 16.3% in the Mesolithic) which often hampers the taxonomic and taphonomic analysis of the bones. Other natural agents damaging the bones have been roots, sub-aerial exposure, precipitation of manganese oxides, as well as rolling and polishing of the surfaces.

Seasonality can only be detected in the Mesolithic by the presence of a fawn that died in its first summer of life. In the Azilian assemblage, four fawns were hunted between June and September, attesting to hunting from the site during the summer.

Few remains of **birds** have been found. Six remains correspond to the Azilian, and four to the Mesolithic. In this latter period a remain identified as *Scolopax rusticola* (Eurasian woodcock) has been determined. Remains of paseriforms and a *Corvux corax* (common raven) bone have only been documented in Azilian levels. None of them display evidence of anthropic alterations.

Ten **fish** remains come from the Azilian, and three come from the Mesolithic level. Vertebrae are the most common element. Salmonids (trout and/or salmon) and the European eel (*Anguilla anguilla*) have been identified in both periods. Heat-affected elements are present in Level C (a salmonid vertebra) and Level B, the Mesolithic level (a Mugilidae, i.e. mullet, vertebra). Fish in the Salmonidae family are either anadromous or purely freshwater. Eels can also be found in freshwater (catadromous), while mullets are chiefly marine (coastal) and brackish water fish.

Marine and terrestrial invertebrates (molluscs, crustaceans and echinoderms) (Fig. 6)

Molluscs gathered on rocky substrates, mostly with nutritional value, predominate throughout the sequence. *Patella* sp. is the most common marine gastropod in terms of the MNI (94.6% in the Azilian; 89.5% in the Mesolithic). However, due to their fragmentation and the precipitation of calcium carbonate it has not been possible to identify the limpet species in frequencies of 31.1% for the Azilian and 40.4% for the Mesolithic. Three species have been recognised: *P. vulgata*, *P. depressa* and *P. ulyssiponensis*. The first of these is always the most abundant species (72.8% in the Azilian; 51.9% in the Mesolithic). The percentages of the other species vary between 6.5% and 22.1% for *P. depressa* and between 6.2% and 26% for *P. ulyssiponensis*. *L. littorea* has been identified in very small percentages only in the Azilian levels (2% of the total MNI). *P. lineatus* is represented in the Mesolithic level by 2.5% of the MNI and about 1% in the Azilian.

Shells of bivalves are very scarce. Mussel (*Mytilus galloprovincialis*), the only bivalve living on rocky shores, represents ca. 2% of the MNI in the Azilian and 5.8% in the Mesolithic. *Scrobicularia plana* (peppery furrow shells) and *R. decussatus*, which live on sandy-muddy substrates, only appear in the Mesolithic level (1.3%).

The maximum diameter in both periods has been measured for the most abundant marine shells; on the one hand for *P. vulgata* ($n = 240$, median = 35.39 and IQR = 7.34, for the Azilian; $n = 110$, median = 31.93; Q3-Q1 = IQR = 7.61, for the Mesolithic); and on the other hand for *Patella* sp., including the sizes for *P. vulgata*, *P. depressa* and *P. ulyssiponensis* ($n = 253$, median = 35.37 and IQR = 7.26, for the Azilian; $n = 236$, median = 28.03 and IQR = 7.65, for the Mesolithic). The Kolmogorov-Smirnov test for normality was significant in all cases (p-value < 0.05). The results of the Mann-Whitney U test allow us to affirm that there was a significant decrease in the maximum diameter from the Azilian to the Mesolithic in both *P. vulgata* and *Patella* sp. (p-values < 0.000).

Crustaceans are very scarce. These are species that live on rocky substrates in the intertidal zone. Goose barnacle plaques only appear in the Mesolithic level. The warty crab is the only decapod recorded,

Fig. 6. Marine invertebrates documented at El Cierro Cave. Crustaceans: 1. *Pollicipes pollicipes* (Level B). Echinoderms: 2. *Paracentrotus lividus* (Level B). Mollusks: 3. *Patella depressa* (Level B); 4. *Scrobicularia plana* (Level B); 5. *Mytilus galloprovincialis* (Level D); 6. *Littorina littorea* (Level D); 7. *Patella vulgata* (Level D).

appearing in both the Azilian and the Mesolithic. Balanoids associated with warmer waters have been identified in the Mesolithic (*Chthamalus montagui*; *Chthamalus* sp.) and cold-water species in the Azilian levels (*Semibalanus balanoides*; *Balanus crenatus*).

Echinoderms, to be precise the species *Paracentrotus lividus*, appear in all the levels. They are most abundant in the Azilian (the MNI was calculated with the hemipiramidals).

Shells of continental molluscs are abundant, especially in the Azilian levels. They are terrestrial species, as no freshwater species have been documented. 24 species have been determined; all of them may live in the surroundings of the cave. Most of them are very small (seven measure < 4 mm). The only medium-sized species that might have been gathered and consumed by the human groups, *Cepaea nemoralis*, appears in very small numbers (MNI = 23 in the Azilian; MNI = 13 in the Mesolithic). No individuals affected by heat have been found.

Zospeum shaufussi, Zospeum suarezi and *Menkia horti* are strictly cave-dwelling mollusc species, characteristic of karst caves and small in size. Some individuals conserve their colouring, which indicates that they died recently. The specimen of *Pomatias elegans* from Level D also conserves its characteristic colouring and will similarly be a modern individual. It will therefore represent a contamination, like the previous three species.

Eight gastropod species have only been identified in the Azilian layers: *Obscurella hidalgoi, Pomatias elegans, Azeca goodalli, Cochlicopa lubricella, Cryptaceca monodonta, Lauria cylindarcea, Vitrea subrimata* and *Mengoana brigantina*. These may indicate a turning point in environmental conditions around the cave in the transition from the Upper Pleistocene to the Holocene. However, apart from O. *hidalgoi* and *V. subrimata*, all these species appear in very small numbers (one to three specimens) and therefore this hypothesis needs to be tested by future research.

5.2. Abiotic resources

A total of 104 lithic remains has been recorded; 85 in the Azilian and 19 in the Mesolithic period (Table 8).

The Azilian assemblage includes six retouched pieces (7% of the total number of remains): a double backed bladelet, a non-straight backed bladelet and four substrate tools (a denticulate, a notch and two *écaillés*). The predominant debitage products are flakes. Two quartzite cores used to obtain flakes and a hammerstone have been documented. Micro-debris (< 1.5 cm) makes up 44.7% of the remains, which possibly indicates debitage was carried out at the site during this period. In contrast, the Mesolithic assemblage contains only one retouched piece, a truncated piece that was possibly used like an *écaillé*, owing to the presence of a splinter at the opposite end to the truncation. There is no evidence of laminar reduction in this level, only flakes and small flakes, knapping waste and debris, which indicate minimal debitage activity at the site.

Despite the small size of the lithic assemblage, it includes different types of raw materials in both periods (Table 9). Materials available in the proximities of the site, basically quartzite and radiolarite, predominate in the two periods. "Black chert" and rock crystal only appear in the Azilian levels. These local materials make up 68.4% of all the Mesolithic remains (*n* = 19) and 61.1% of the Azilian pieces (*n* = 85). Quartzite represents similar percentages, ca. 42%, in both periods. Two flake cores were also documented in the Azilian. Radiolarite (15.9% in the Azilian; 26.3% in the Mesolithic) appears in the form of knapping waste, small flakes and debris in both periods. 39 pieces of flint have been classified, 25 in the Azilian and 6 in the Mesolithic. In the Azilian, at least four remains of Piloña flint and two of Monte Picota flint have been identified, as well as four possible pieces of Urbasa flint and one each of the Treviño and Chalosse varieties. The Mesolithic assemblage includes one piece of an altered flint, one each of Piloña and Monte Picota flint, and possibly one of Urbasa and two of the Chalosse variety.

6. Discussion

6.1. Biotic resources

6.1.1. Vegetation

The palaeobotanic record at El Cierro reflects the transition between the last cold episode of the Younger Dryas (Levels D and C) and the climate amelioration characterising the onset of the Holocene (Level B). The climatic regression in the Younger Dryas involved a reduction in woodland in north Spain compared with the previous late glacial interstadial. However, within this general trend, some differences are seen in the various biogeographic zones. In littoral and sub-littoral areas, Poaceae and/or Compositae expanded in the open landscape, while cryoxeric plants maintained a limited presence. In the small arboreal cover, some deciduous trees, like *Quercus, Corylus* and *Betula*, appeared together with pines. In inland montane areas, the lesser humidity was reflected in a new spread of *Artemisia*, although it did not reach its previous extent in the Oldest Dryas.

The improvements in the Holocene climate allowed the arboreal colonisation of the open landscape. In more oceanic areas, mixed broadleaf forest (deciduous oak, with *Betula, Corylus, Salix, Alnus* and *Fraxinus* among others) prevailed over sclerophyll woodland (evergreen *Quercus, Ilex, Arbutus, Laurus*, etc.) and stands of gymnosperms (pines, *Juniperus* and *Taxus*). Coniferous woodlands persisted on the highlands, on the inner leeward slopes, and inside the more continental depressions (Iriarte-Chiapusso et al., 2016; Uzquiano et al., 2016).

6.1.2. Fauna

The remains of microvertebrates documented in both the Azilian and Mesolithic levels at El Cierro are too scarce to perform a complete palaeoenvironmental reconstruction. The explanation could be found in the origin of the accumulation. Small vertebrate skeletons may accumulate by accidental deaths or by predation and deposition by owls or diurnal birds of prey, which display clear preferences regarding the characteristics of their nesting palaces. In the case of El Cierro, it has been established that bird raptors were settled inhabitants during Palaeolithic periods (Álvarez-Fernández et al., 2016). Therefore, the absence of birds of prey, and consequently the low number of small vertebrate fossil remains, could be explained by an increase of human activity in the surroundings, which has also been identified, for example, at Peña Larga site (Rofes et al., 2013). However, some data can be discerned about the ecological affinities of these taxa based on their

Table 8
Lithic remains from El Cierro Cave.

Type Name/Level	B	C	C/D	D
Backed bladelet	—	—	1	—
Double Backed bladelet	—	—	—	1
Denticulates	—	—	—	1
Ecaillé	—	—	1	—
Ecaillé-burin	—	—	1	—
Side-scrapers	—	—	—	—
Notches	—	1	—	—
Piece with abrupt retouch	—	—	—	—
Truncated pieces	1	—	—	—
Cores	—	1	1	—
Flakes	9	3	10	13
Small flakes (< 2 cm)	2	2	19	—
Blades	—	—	—	—
Bladelets	—	—	2	—
Cornice edges	—	—	—	—
Blade flanks	—	—	—	—
Knapping waste (< 1,5 cm)	3	—	8	4
Debris	3	4	10	—
Soft hammer	—	—	1	—
Pebbles	1	1	—	—
Total	**19**	**12**	**54**	**19**

Table 9
Lithic raw materials from El Cierro Cave.

Raw Material/Level	B	C	C/D	D
Quartzite	8	9	19	8
"Black Chert "	—	—	1	1
Radiolarite	5	1	9	3
Rock Crystal	—	—	1	—
Flint	6	2	24	7
Total	**19**	**12**	**54**	**19**

presence or absence. On the one hand, it has been interpreted that there was a water course in the surroundings of El Cierro during the two periods, because of the presence of A. amphibius. On the other hand, the identification of S. araneus-coronatus and S. minutus remains would be related with high environment humidity.

Concerning **large mammals,** the levels in the El Cierro sequence show that the hunting strategy was focused on red deer. This situation marked a continuation of the strategy in the Magdalenian (Álvarez-Fernández et al., 2016; Portero et al., 2019). However, some changes can be noted in comparison with previous periods. Thus, the percentages of Iberian ibex and large bovids decrease, whereas the proportion of roe deer increases. Horse maintains a small percentage, but only in the Azilian. Wild boar has been documented in both periods. The data obtained at El Cierro are very similar to the results at other sites with levels attributed to the Pleistocene-Holocene transition, such as La Riera (Levels 27 to 30) (Altuna, 1986) and El Mirón (Levels 11.1 in the "cabin", 102 in the "corral" and 305 in the "trench") (Altuna et al., 2004; Marín, 2010). They equally attest seasonality in their occupations, in spring and summer, as at El Cierro.

The remains of **birds** are very scarce and of little environmental significance because they do not display evidence of anthropic manipulation.

Fish remains suggest that specimens were caught both in freshwater (Sella River) and estuarine (Sella Estuary) or marine environments. Salmon and trout produce aggregation of fish when spawning in freshwater, making an easy prey using barriers or harpoons. Eels can also be easy to catch using barriers and traps on their way to the sea to breed.

A change in the species of **marine invertebrates** gathered during the transition from the Pleistocene to the Holocene can be observed over the three levels in the shell-midden at El Cierro. In both archaeological periods, gathering on rocky substrates, probably in the whole intertidal zone, was the usual practice, as the ecology of the mollusc, crustacean and echinoderm species indicates. The collection of limpets (mainly *P. vulgata*, but also *P. depressa* and *P. ulyssiponensis*) predominates in the two periods, in addition to mussels and, in much smaller numbers, the toothed topshell. In contrast, the common periwinkle only appears in the Azilian levels. The purple sea urchin was also gathered in both periods. Crabs, also present in both the Azilian and the Mesolithic, would have been caught in an opportunistic way as the molluscs were being gathered. Remains of goose barnacles are only found in the Mesolithic level. Marine invertebrates gathered on rocky substrates are well documented at Azilian and Mesolithic sites all across northern Spain (Álvarez-Fernández, 2011; 2015).

Species gathered on sandy/muddy substrates (mainly the peppery furrow shell) only appear in the Mesolithic. They would probably have been procured in the lower valley of the River Sella, whose estuary as we know it today would have begun to form in the early Holocene. The gathering of these types of species has been documented at El Carabión (Level 1) (Pérez, 2017), among other Mesolithic sites in northern Spain (Álvarez-Fernández, 2015).

The biometric analysis of the limpets (the most numerous invertebrates) shows that their size decreased from the Azilian to the Mesolithic. A similar decline has been observed in the few sequences in northern Spain with Late Pleistocene and Early Holocene levels where biometric analyses have been performed, such as La Garma A (Upper

Magdalenian levels *versus* Mesolithic level) (Álvarez-Fernández et al., 2011). We consider that this decrease in size is related to the rise in sea surface temperature in the Holocene (Naughton et al., 2009, 2016). This is also seen at El Cierro by the replacement of the cold-water species *L. littorea* by the warm-temperate species *P. lineatus*. This substitution has been known since the beginnings of archaeomalacological research in northern Spain (Vega del Sella, 1916) and has been confirmed by studies at numerous sites (see summary in Álvarez-Fernández, 2011, 2015). In a similar way, during the early Holocene warm-temperate climate limpets *P. depressa* and *P. ulyssiponensis* continue to be gathered, together with the cold-water limpet *P. vulgata* as can equally be observed at El Cierro. This change in temperature would affect other marine organisms, such as sessile barnacles (Carriol and Álvarez-Fernández, 2015). At El Cierro we have documented the change from cold-water species (*Semibalanus balanoides,* a boreo-arctic species and *Balanus crenatus,* an arctic-boreal temperate species) in the Azilian to species preferring warmer waters (*Chthamalus* sp., *Chthamalus montagui*) in the Mesolithic. The goose barnacle *P. pollicipes* in the latter period is also an indicator of the rise in sea surface temperature, as it is always associated with Holocene deposits (Álvarez-Fernández et al., 2013b).

El Cierro has provided the best record of **continental snails** currently known in the region, due to the large variety of species, some of whose shells are < 1 cm in height. The species *Cepaea nemoralis*, documented in both Azilian and Mesolithic levels would possibly be the only one used as food by humans. Its consumption has been described at other sites in northern Spain, such as Cubío Redondo (Aparicio, 2001) and El Truchiro (Álvarez-Fernández et al., 2013a) during the Mesolithic. The finds of the other small terrestrial species are probably due to fortuitous causes, not involving humans; for example by being washed into the cave after the animals died. The malacofaunal assemblages in the two periods at El Cierro indicate environmental conditions not too different from the present time as all the species inhabit the area around the site today. No freshwater molluscs have been found.

6.2. Abiotic resources

6.2.1. Lithic technology

The lithic assemblages obtained in the Azilian and Mesolithic occupations at El Cierro are too small to be characterised. The number of pieces is insufficient for technological approaches to each of the periods, enabling comparisons between them. A preference for non-laminar reduction can be noted (industry on blades only appears in the Azilian levels). The cores that have been found were used to obtain flakes. The few tools that have been found are not diagnostic and too limited to be able to reach typological conclusions for each of the cultural sequences. A double backed bladelet in Level D can be highlighted. According to J. Fernández Tresguerres (2004), this type of implement starts to become common in northern Spain in the Azilian and therefore it supports the chronocultural attribution of the level. Indeed, the few lithic remains are coherent with the little that is known of the toolkit associated with coastal Azilian and Mesolithic deposits (as seen for example in La Poza ĺEgua; Arias et al., 2007). In this sense, the reference sequence for northern Spain is still the deposit in La Riera, where the change from the Azilian (unguiform endscrapers and Azilian points) to the Mesolithic (Asturian picks) is clearly observed (Straus and Clark, 1986b).

6.2.2. Raw materials

Materials procured in the proximities of the cave of El Cierro (mainly quartzite) predominate in both Azilian and Mesolithic levels. They would have been acquired in the form of cobblestones on the river terraces of the Sella, as has been documented at other Palaeolithic sites in the valley of the same river (Álvarez-Alonso et al., 2013). Flint appears in a wide range of allochthonous types, and the pieces are generally very small, with a heavy patina, in the form of knapping waste.

The identification of the sources is hampered by the difficulty in observing the material, together with the absence of a tradition in provenance studies in the regional literature. Local or regional types are represented by Piloña and Monte Picota/Piedramuelle flint. The former type was probably obtained in the form of blocks or nodules freed from the bedrock by natural processes in the alluvial deposits near their primary outcrop (Duarte et al., 2016). The exact provenance of the latter cannot be determined at the present. Some evidence of all the flint types defined as 'tracer' varieties in northern Spain: Urbasa, Treviño and Chalosse (Tarriño et al., 2016), has also been observed in both the Azilian and the Mesolithic. In the case of the Mesolithic occupations at La Uña, a cave located on the southern side of the Cantabrian Mountains, the presence of allochthonous types (at least Urbasa and Treviño silex) are also classified (Herrero-Alonso, 2018). However, in Cantabrian Spain, a general use of local raw materials has been defined for the late Pleistocene-Early Holocene transition (Fernández-Tresguerres 2007; Fano, 2007, 2019), either quartzite (e.g. at La Riera: Straus and Clark,1986a) or flint (e.g. El Carabión; Pérez, 2017).

7. Conclusions

El Cierro Cave possesses one of the most complete prehistoric stratigraphies in northern Spain, with archaeological levels where the transition between the Upper Palaeolithic and the Mesolithic can be follow. In the latter case, El Cierro is one of the few archaeological sites in SW Europe reflecting the environmental changes that took place in the area and their impact on the life of the last hunter-gatherer groups.

Of the remains dated in the Azilian (Levels D and C; ca. 13.1–12.6 ky cal BP) and the Mesolithic (Level B; 9.4–8.0 ky cal BP), the biotic evidence has contributed most information.

The palaeobotanic record is based on the documentation of pollen, spores and charcoal. Despite the meticulous excavation technique, no plant macro-remains (seeds and fruits) have been found. During the Younger Dryas, herbaceous-shrub communities were accompanied by colonising trees like pine and birch, as well as other deciduous species. Later in the sequence, in the Mesolithic, deciduous woodland expanded, with a greater abundance of deciduous oak and hazel. Shrub formations also expanded but to a much lesser extent.

Despite the absence of seeds and fruits, the possible collection of acorns and hazelnuts can be perceived indirectly from the archaeobotanical data. Other subsistence strategies documented in El Cierro included hunting, fishing and shell-fishing. Specialisation in hunting red deer is seen throughout the sequence. Wild boar and roe deer, species that reflect the expansion of woodland, were also captured but less often. Seasonality studies indicate that hunting was carried out during the summer. There is no proof that the bird remains found in the sequence are evidence of fowling.

The fishing of salmonids and the European eel, probably in the River Sella, is equally observed in the whole sequence. Remains of Mugilidae, probably caught in the estuary of the Sella, only appear in the Mesolithic.

One of the most characteristic activities documented in the recent levels at El Cierro is shell-fishing. The large number of remains of marine invertebrates shows that those deposits can be regarded as 'shell-middens'. Continuity is seen in the sequence, probably because of the proximity of the cave to the coast in the Younger Dryas (when the shore was about 5 km from the cave) and in the early Holocene (when the coastline had approached to 2 km from the cave). The foraging was carried out in the whole inter-tidal zone, with different species from rocky substrates (mostly limpets) and from sandy/muddy substrates in the Mesolithic, which can be related to the formation of the Sella estuary at that time. Crustaceans (crabs and goose barnacles) and echinoderms (sea urchins) were probably gathered opportunistically.

The presence of some marine invertebrates can be related to palaeoenvironmental changes (increase in sea surface temperature) that took place in the Pleistocene-Holocene transition. Species tolerant of cold water were replaced by others adapted to more temperate seas. In this way, the gastropod *Littorina littorea* (only found in the Azilian) was replaced by *Phorcus lineatus*. Certain balanoid species and barnacles only appear in the Mesolithic. The rise in sea temperature may also have contributed to the decrease in the size of limpets compared with previous periods.

Small mammal remains found in archaeological deposits can also be used for palaeoclimate reconstruction. However, very few were found at El Cierro. This scarcity is thought to be due to the absence of predators producing the microvertebrate tanatocenosis, rather than the techniques used to collect the remains.

A large number of terrestrial gastropod species have been recovered (the most diverse prehistoric assemblage known in northern Spain), many of which are < 5 mm in height. However, except for *O. hidalgo* and *V. subrimata*, which may indicate environmental changes in the Pleistocene-Holocene transition, all the other species are found in the surroundings of the cave today. Of the 24 taxa that have been identified, only the larger gastropod *C. nemoralis* might have been gathered as food by the human groups occupying the cave in both the Azilian and Mesolithic.

No artefacts made from hard animal matter (weapons, objects of adornment, etc.) have been found in any of the levels and therefore this type of object cannot be characterised at El Cierro.

Regarding abiotic resources, the lithic assemblage is quite limited in the three levels. Tools are undiagnostic as well as infrequent and do not allow differentiation between the Azilian and Mesolithic levels.

More information was obtained by studying the lithic raw materials. In both the Azilian and Mesolithic periods, raw materials gathered near the cave, on the river terraces of the Sella, were used predominantly. However, evidence of flint types defined as "tracer" varieties in northern Spain (Urbasa, Treviño and Chalosse) in the Azilian and Mesolithic periods at El Cierro is indicative of human mobility and exchange networks, inherited from the previous Magdalenian period. The identification of these flint varieties questions the idea that groups became more regionalised from the Azilian onwards, with lesser mobility. The systematic study of flint assemblages from other sites in northern Spain will provide more precise data about the mobility of human groups in the transition from the Pleistocene to the Holocene.

CRediT authorship contribution statement

Esteban Álvarez-Fernández: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing - original draft, Writing - review & editing. **Julián Bécares:** Investigation, Writing - review & editing. **Jesús F. Jordá Pardo:** Formal analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Amaia Agirre-Uribesalgo:** Investigation, Methodology, Writing - review & editing. **David Álvarez-Alonso:** Investigation, Methodology, Writing - review & editing. **Mª Teresa Aparicio:** Investigation, Methodology, Writing - review & editing. **Inmaculada Barrera-Mellado:** Investigation, Methodology, Writing - review & editing. **Pilar Carral:** Investigation, Methodology, Writing - review & editing. **René-Pierre Carriol:** Investigation, Methodology, Writing - review & editing. **Miriam Cubas:** Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Marián Cueto:** Investigation, Methodology, Writing - review & editing. **Katerina Douka:** Investigation, Methodology, Writing - review & editing. **Mikelo Elorza:** Investigation, Methodology, Writing - review & editing. **María-José Fernández-Gómez:** Investigation, Methodology, Writing - review & editing. **Sonia Gabriel:** Investigation, Methodology, Writing - review & editing. **Naroa García-Ibaibarriaga:** Investigation, Methodology, Writing - review & editing. **María-José Iriarte-Chiapusso:** Investigation, Methodology, Writing - review & editing. **Carlos Llave:** Investigation, Methodology, Writing - review & editing. **Adolfo Maestro:** Investigation, Methodology, Writing - review & editing. **Sergio Martín-Jarque:** Investigation, Methodology, Writing - review & editing. **Rodrigo**

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