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Archaeology of the Pleistocene-Holocene transition in Portugal: Synthesis and prospects

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A B S T R A C T

The Tardiglacial of Portugal has been associated with the Magdalenian culture and lithic industries characterized by tool miniaturization, a diversity of microlith types, and the absence of a intentional blade production. The technological characterization, the chronology and the phasing of the Portuguese Magdalenian have been defined based on data recovered from open-air sites of the Estremadura region (Central Portugal). This paper presents an overview of the research undertaken over the last twenty-five years, including results from research and preventive archaeology fieldwork outside this region, namely in the Côa, Sabor and Vouga Valleys (northern Portugal), as well as in the Guadiana Valley and Algarve regions (southern Portugal). Our chronological boundaries are the Greenland Stadial 2-1b and the 8.2 ka event, from Early Magdalenian to Early Mesolithic. Regarding vegetation, deciduous *Quercus* underwent expansion during the warm phases of the Tardiglacial and retracted during cold ones, when pines increased. After the Solutrean, the faunal assemblages show a decrease in the variability of the represented species and an increase in fish, birds, small mammals and rabbits (*Oryctolagus cuniculus*).

Concerning the cultural sequence, the Middle Magdalenian remains uncharacterised. After the Upper Magdalenian, and thenceforward, the use of local raw materials and of cores-on-flakes (burin or carinated endscraper type) for bladelet production gradually increased. In terms of lithic armatures typology, a four-stage sequence can be discerned: 1) Upper Magdalenian with axial points rather than backed bladelets, quite common in previous phases; 2) Final Magdalenian with an increase in the diversity of armature types; 3) Azilian with geometric microliths, curved backed points (Azilian points) and Malaurie points, and 4) Early Mesolithic without retouched bladelet tools or at best a persistence of Azilian armature types.

There were some changes in the Palaeolithic rock art of the Douro basin between phase 3 (Final Magdalenian)

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and phase 4 (Late Azilian): figurative animal representations give place to animal depictions characterized by their geometrical bodies, often filled-in, and red deer becomes the best-represented animal.

1. Introduction

The origins of Palaeolithic research in Portugal are closely connected to the French school, which accounts for the adoption of the terminology and the phasing of the 'classic' Périgord sequence (Zilhão, 1997a; Gameiro, 2012). Heleno (1944) searched for the "European origins of the Portuguese people" and the presence in Portugal of French researchers (Breuil, Zbyszewski and Roche), and their collaboration in a number of archaeological projects, reinforced this connection. According to Zilhão (1997a,b), the techno-typological variability and the dates obtained for the Portuguese Estremadura define Early (19,500–16,000 cal BP), Upper (between 14,500 and 13,000 cal BP) and Final Magdalenian phases (13,000–11,500 cal BP), whose characterization, however, does not follow the 'classic' Magdalenian subdivisions of Southwestern France (Breuil, 1913; Sonneville-Bordes, 1960). In Portugal, the absence (or scarcity) of remains asigned to the Middle Magdalenian is arguably due to a sedimentary hiatus (Zilhão, 1997a). The early phase is divided into two diachronic technological facies (Cabeço de Porto Marinho and Cerrado Novo), while the final phase includes the Rossio do Cabo facies, characterized by a production scheme of small twisted bladelets with marginal retouch, and the Carneira facies, defined by Malaurie points, Azilian points and trapezoid geometrics. According to Zilhão (1997a,b) proposal, the Final Magdalenian would end during the Pre-Boreal (now Greenlandian stage). During the Early Mesolithic, at Areeiro III site, the lithic industry is characterised by carinated "endscraper" cores for the production of Dufour and Areeiro bladelets. Despite the existence of curved backed points, an Azilian index fossil, the absence of bone industry, as well as the technological continuity between the Franco-Cantabrian Magdalenian and the Azilian, made the differentiation of an Azilian period impossible (Zilhão, 1997a, p. 45).

Bicho (1994) initially recognized two technological facies only, *Rio Maior*, which spans the entire Magdalenian, and *Carinated*, which starts around 12,500 cal BP and would still be present in Pre-Boreal Areeiro III, which he classifies as Epipaleolithic, thus stressing the technological continuity with the previous period. This author has since abandoned this facies concept, and used Early, Late and Final Magdalenian instead, emphasizing the absence of data supporting a Middle Magdalenian (Bicho, 1997). Lately, Bicho and Haws (2012), argued that Portuguese Magdalenian is a homogeneous cultural reality, with no ruptures in terms of technology, subsistence or settlement and spanning the 20,000–10,000 cal BP interval.

Based only on the Cabeço de Porto Marinho sequence, Marks and Mishoe (1997) established a distinction between *Early Magdalenian* and *Late Magdalenian*, the latter phase being differentiated by an increase in the typological variability of microliths. The scarcity of tools on blades, when compared with the rest of Southwestern Europe, is used as an argument to individualize this group since this technical choice is unrelated to the availability of flint, which is abundant in the vicinity of the site (Marks, 2000).

In recent years, the study of the final Upper Palaeolithic blank production methods in the lower Côa Valley and Portuguese Estremadura (Gameiro, 2012) has confirmed the phasing proposed by Zilhão (1997a), particularly the existence of a production of small bladelets of the Areeiro type using cores-on-flake (carinated "endscrapers" and "burins") during the ca. 13,500–12,000 cal BP interval, and the existence of the Rossio do Cabo facies. Lately, the use of the term Azilian has been proposed for the Côa Valley industries (Aubry et al., 2017), formerly called "Carneira facies" Final Magdalenian (Zilhão, 1997a,b).

Araújo (2016b), in her thesis on the Early Mesolithic of Portugal, established a chrono-cultural framework for this cultural phase, confirming the rarity of retouched bladelet tools in the open-air sites dated to the Early Holocene, with the exception of the lithic assemblage of Areeiro III, associated with radiocarbon dates of ca. 9500-9000 cal BP and showing a strong technical and typological convergence with the Rossio do Cabo facies. Nevertheless, the available data do not allow a clear definition of the characteristics of the transitional lithic industries.

2. Materials and methods

This paper presents a synthesis of paleoenvironmental data and summarizes some aspects of material culture (lithic industries and art) dating from between 20,000 and 8200 cal BP, i.e. between GS-2.1b and the 8.2 ka event (Rasmussen et al., 2014). Nevertheless, the rare Early and Middle Magdalenian, as well as the Early Mesolithic sites, are only mentioned when deemed useful to understanding the long-term cultural process; therefore, focus will be centered on the period between 14,000 and 11,500 cal BP.

A significant number of Tardiglacial sites have been identified in recent years, not only as a result of ongoing research projects in Estremadura, the Côa Valley and the Algarve regions, but mostly in the scope of preventive archaeology works: in the Sabor Valley (north of the Côa Valley), in the Vouga Valley (halfway between Estremadura and the Côa Valley) and in the Guadiana Valley (to the South) (Fig. 1). However, existing data continue to be partial and resulting from single occupation open-air sites; presently, a complete stratigraphic sequence covering the Pleistocene-Holocene transition (14,000 to 10,500 cal BP) is yet to be identified.

The available Paleobotany data provide a broad perspective of the Portuguese territory during the period in question but not enough detail is yet available to establish the correlation with climate change events documented in the Greenland ice-core records (Rasmussen et al., 2014).

An overview on the faunal assemblages known to date will be presented as well. Nevertheless, the degree of preservation of bone material varies according to region; apart from Fariseu (Côa Valley) no other sites from the Iberian massif have preserved faunal remains. Only in the Estremadura (Ocidental Meso-Cenozoic basin) and Algarve (Meridional Meso-Cenozoic basin) is faunal preservation documented.

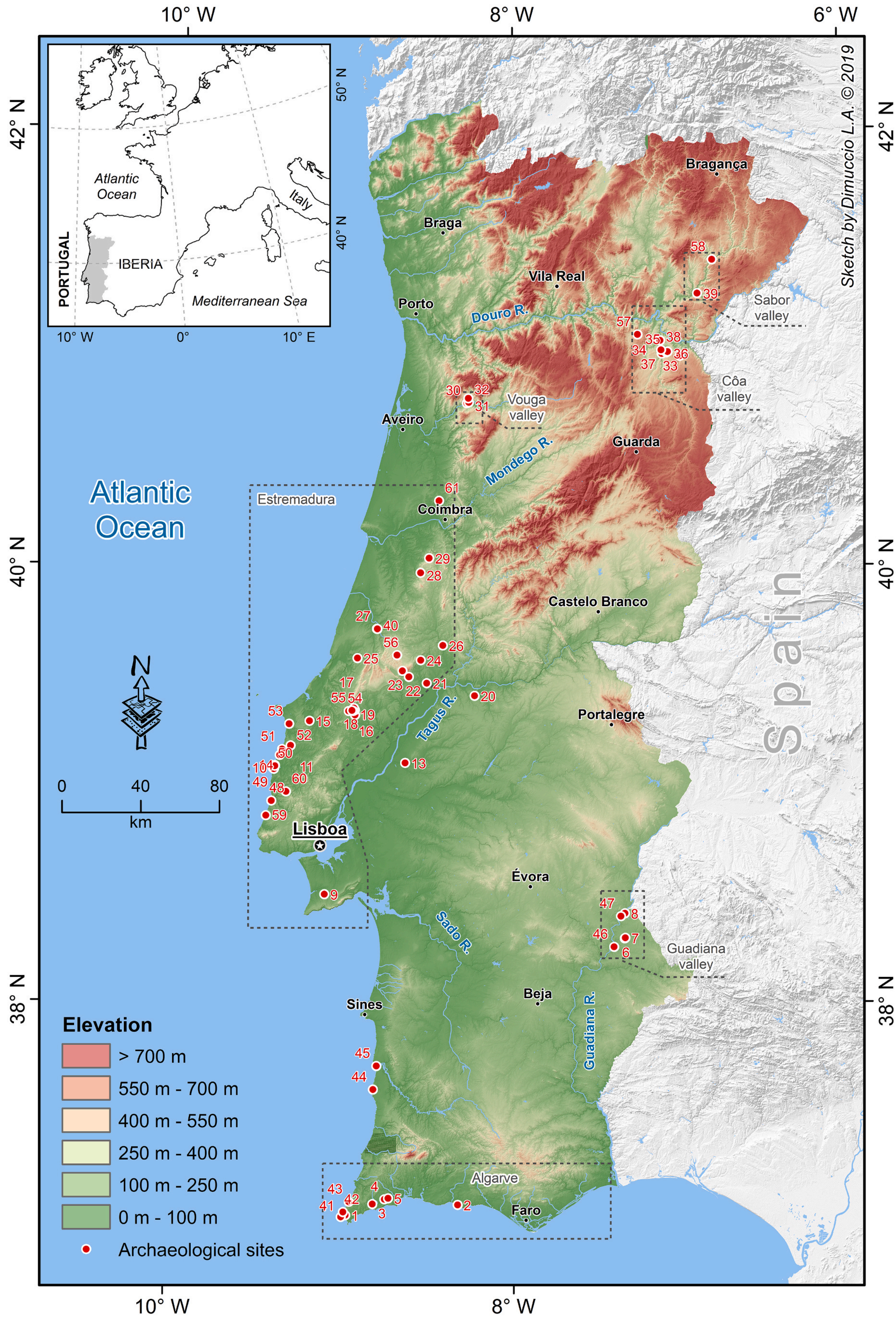
The study of lithic industries follows the *chaîne opératoire* approach and is presented according to the six main geographic units referred above (represented in Fig. 1), individualized according not only to their history of research, but also in terms of their distinct lithological environments. The map in Fig. 1 shows virtually all the known Late Pleistocene and Early Holocene sites. Sites featuring sequences with both Late Pleistocene and Early Holocene occupations, as well as those where chronology within this time span is yet to be defined, were included in the Pleistocene-Holocene transition category.

3. Paleoenvironmental data

3.1. Paleoclimate

During the Late Pleistocene, human societies were affected by deglaciation, sea-level rise and climatic instability in the North Atlantic, Europe and Greenland at a global or planetary scale (Naughton et al., 2016). Understanding human cultural change and establishing a correlation between the observed technical and cultural adaptations and paleoclimatic history has been a major challenge for prehistorians.

During the last decades, considerable progress has been made in the



(caption on next page)

Fig. 1. - Map of Late Pleistocene and Early Holocene archaeological sites in Portugal, according to data obtained from the Endovélico National Database, Cultural Heritage, Ministry of Culture. **Late Pleistocene sites**: 1-Vale Santo 4; 2-Praia da Galé; 3-Vale Boi; 4-Monte do Januário; 5-Cruz da Pedra; 6- Monte da Ribeira; 7 -Chancudo 3; 9-Cabeço dos Cinco Pinheiros; 10-Baião; 11-Vale da Mata; 12-Cerrado Novo; 13-Pinheirocas 2; 14-Rossio do Cabo; 15-Lapa do Suão; 16-Pinhal da Carneira; 18-Vascas; 19-Cabeço de Porto Marinho; 20-Cadoiças; 21-Bairrada; 22-Lapa dos Coelhos (Almonda); 25-Olival Fechado; 26-Gruta do Caldeirão; 29- Abrigo 1 de Vale de Covões; 33-Ínsula II; 34-Cardina I/II; 35-Fonte do Olmo; 36-Devesa 3; 39-Foz do Medal; 40-Telheiro da Barreira; 45-Pedra do Patacho; **Pleistocene-Holocene transition sites:** 8-Malhada do Mercador 2; 17-Abrigo Grande das Bocas; 23-Lapa do Picareiro; 28-Buraca Grande; 30-Rôdo; 31-Bispeira 8; 32-Vau; 37-Quinta da Barca Sul; 38-Fariseu; 46-Monte Roncanito 21; 58-Volta do Cocão; **Early Holocene sites:** 24-Costa do Pereiro; 27-Cruz da Areia; 41-Armação Nova/Rocha das Gaivotas; 42- Barranco das Quebradas 1; 43-Castelejo; 44-Palheirões do Alegra; 47-Barca do Xerez de Baixo; 48-S. Julião; 49-Pinhal da Fonte; 50-Cabeço do Curral Velho; 51-Ponta da Vigia; 52-Toledo; 53-Vale Frade; 54-Areeiro III; 55-Fonte Pinheiro; 56-Casal do Papagaio; 57-Prazo; 59-Magoito; 60-Cova da Baleia; 61-Vale Sá.

study of climate changes, which were more frequent than previously thought (Rasmussen et al., 2014). For the period of concern here, a multi-proxy study comparing terrestrial and marine data from Northwest Iberia improved the characterization of its different climatic phases (Naughton et al., 2016): Oldest Dryas, which was a complex event with three phases, (a) extremely cold/relatively wet, (b) cool/dry, and (c) warmer/increased moisture; Bølling-Allerød interstadial (increase in temperature and precipitation); Younger Dryas (cold and dry; winter precipitation in northern and central Western Iberia); Holocene interglacial.

A recent study by S. Davis (2019) on the variation in the size of rabbit bones - both modern (from Europe) and archaeological (from Portugal) - indicates that during the last glaciation the present-day Portuguese territory was some 7 or 8° colder than nowadays.

3.2. Chronostratigraphy

Estremadura remains the best-known area when it comes to correlating sedimentary sequences and palaeoenvironmental events (Angelucci, 2002; Cunha et al., 2006; Aubry et al., 2011, 2017). Levels corresponding to the Early, Upper and Final Magdalenian have been dated by radiocarbon and thermoluminescence in different *loci* of the archaeological site of Cabeço de Porto Marinho (Fig. 1-n°29), within a sequence of colluviated aeolian sands (Zilhão, 1997a). The other open-air sites are single-phase occupations with no preservation of spatial structure (Zilhão, 1997a; Angelucci, 2002; Almeida, 2008; Aubry et al., 2011, 2015). Cave occupations are scarcer than in Upper Palaeolithic chronologies: the cave sites known or claimed to have been used during the Magdalenian are Gruta do Caldeirão (Fig. 1-n°26), Buraca Grande (Fig. 1-n°28), Lapa do Picareiro (Fig. 1-n°23), Lapa do Suão (Fig. 1-n°15) and Lapa dos Coelhos (Fig. 1-n°22), to which a couple of rock-shelters, e.g., Abrigo 1 de Vale dos Covões (Fig. 1-n°29), and Abrigo das Bocas (Fig. 1-n°17), can be added (Bicho et al., 2003; Almeida et al., 2004; Aubry et al., 2011, 2017; Gameiro et al., 2017). One of the following situations can be observed in these sequences: thin sedimentary deposits accumulated during the Bølling-Allerød stabilization phase,

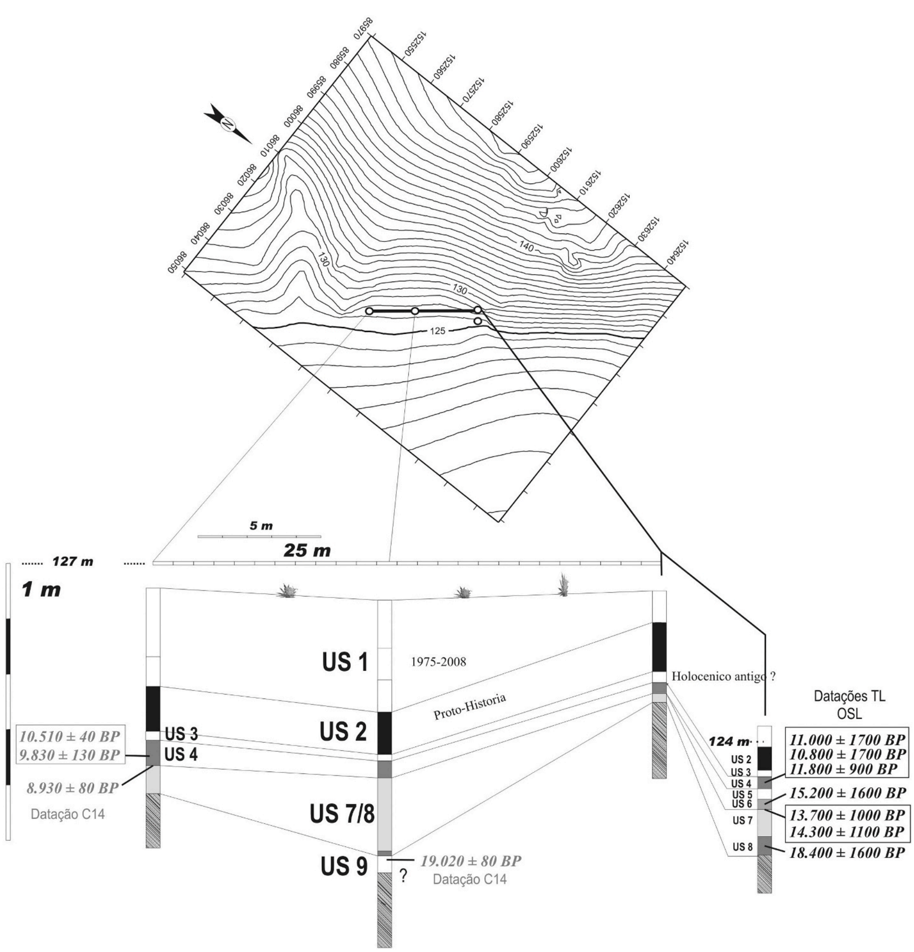


Fig. 2. Stratigraphic layout of the archaeological site of Fariseu (Côa Valley) (Aubry, 2009).

culturally attributed to the Upper/Final Magdalenian (Lapa dos Coelhos, Abrigo 1 de Vale dos Covões and Lapa do Picareiro) or palimpsest levels containing materials of different chronologies (such as Buraca Grande and Lapa do Suão). At Gruta do Caldeirão (Zilhão, 1997a), a sedimentary gap was identified, postdating the Solutrean and corresponding to the period between 21,000 and 17,500 cal BP characterized by a humid cool climate phase, in correspondence with the GS-2.1b/GS-2.1a of Rasmussen et al. (2014). This general pattern might explain the rarity of Early Magdalenian contexts, the redeposition of Solutrean materials in alluvial plain contexts, documented at Olival da Carneira, Arneiro and Passal (Zilhão, 1997a). Later, a sedimentary hiatus corresponding to the period between 16,000 and 14,500 cal BP might account for the difficulty in isolating contexts ascribable to the Middle Magdalenian. From the Allerød onwards, the number of known sites increases significantly. A new cold episode, probably GS1 (Rasmussen et al., 2014), likely led to an increase in erosive processes between 13,000 and 11,500 cal BP, which may account for the erosional scattering of such Final Magdalenian open-air contexts as Bairrada.

In the Côa Valley, the Fariseu site (Fig. 1-n°38), located at the interface between alluvial plain and slope, yielded a paleoenvironmental and archaeostratigraphic (Fig. 2) record covering the time span between 18,500 and 11,500 cal BP (Mercier et al., 2006; Aubry, 2009; Aubry et al., 2010, 2015). The micromorphological study (Sellami, 2009) and the radiocarbon, TL and OSL datings obtained at this site (Mercier et al., 2006; Aubry, 2009) support the idea of a correspondence between mobiliary and rock art representations, as well as correlation between the alternating alluvial and slope sedimentation phases and the climate oscillations of the Tardiglacial identified in deep-sea records (Aubry et al., 2010). Cryoclasts present in layers 7/8 and layer 4 of the sequence may be related to Heinrich 1 (ca. 16,000–14,000 cal BP) and Heinrich 0 (12,000–11,500 cal BP) events, while the alluvial deposits from layers 5 and 6 would correspond to the climate improvement of the Bølling-Allerød interstadial.

The TL and OSL dates of Fariseu layer 4 (Table 1), obtained on fragments of burnt quartzite and sediment, are consistent with their stratigraphic position and in agreement with the ^{14}C dates on bone samples (Aubry, 2009). The formation of this unit by slope processes, resulting from cryoclastic degradation of metasediments, mostly accumulated at the base of the slope, at the edge of the alluvial plain, is identical in nature to layer 3 of Quinta da Barca Sul (Fig. 1-no. 37) (Aubry et al., 2010); the respective archaeological contents are similar as well (Aubry, 2009; Gameiro, 2009, 2012).

3.3. Vegetation dynamics in the Pleistocene-Holocene transition

Pollen sequences covering the Pleistocene-Holocene transition were recovered in 13 sites (Supplementary material -Table 1). Eight sites are located in the Serra da Estrela mountain range; the mainland areas of southern Portugal and the central coast were not sampled. Still, and overall, sequences are distributed throughout the study area and sampling sites are diverse, allowing the detection of a variety of ecological trends.

Data from Dryas I was retrieved only in Lagoa de Marinho, in the NW, where low values of arboreal pollen (deciduous *Quercus* and *Pinus sylvestris*) and high values of shrubby and herbaceous taxa such as *Erica*, Poaceae and *Artemisia* suggest an open mountain vegetation (Ramil Rego et al., 1998). There is no data regarding lower elevation areas.

The beginning of the Bølling-Dryas II-Allerød is usually characterized by an increase in arboreal vegetation, namely deciduous *Quercus* in the NW and *Pinus* (mostly *P. sylvestris* but also some *P. pinaster)* in the sandy soils of the southwest coast (Queiroz, 1999). The Serra da Estrela sequences indicate an increasing presence of trees (*Betula* and *Pinus*) and shrubs near the sampling site (van der Knaap and van Leeuwen, 1997). The expansion of *Quercus* in the NW seems to have been slightly interrupted during Dryas II, and *P. sylvestris* expanded, decreasing later on, in the Dryas III, during which there is an expansion of grasslands due to climate forcing (Ramil Rego et al., 1998). At Lagoa do Golfo and Lagoa de Santo André, in the SW, *P. sylvestris* dominated throughout this period.

During the Allerød, there is a marked expansion of woodlands, from north to south; deciduous *Quercus* dominate these woodlands, except in the SW coast, where pines continue to dominate and expand, with an understorey of Ericaceae (Santos and Sánchez-Goñi, 2003). But even here there is an expansion of deciduous *Quercus* and several hygrophilous and mesophilous taxa such as *Salix*, *Alnus* and *Corylus* (Queiroz, 1999). In mountain areas of central Portugal, such as Serra da Estrela, there is a decline in Poaceae and, overall, pioneer taxa (van der Knaap and van Leeuwen, 1997). We would stress that in the southernmost sequence, CM5 Beliche, thermomediterranean taxa such as *Olea*, *Pistacia* and *Phillyrea* remain absent (Fletcher et al., 2007).

The expansion of woodlands was abruptly interrupted during Dryas III. The declining temperatures and dryness of this period led to major responses in the vegetation. The decline of deciduous oak woodlands is visible in all pollen sequences, leading to an increase in xerophytic taxa, mostly herbaceous plants. Some sites present specific trends, due to their location. At Lagoa de Marinho, in the NW, even *P. sylvestris* values decrease significantly (Ramil Rego et al., 1998), but in the high-mountain sequence of Serra da Estrela there is an increase in *Pinus* and *Artemisia* (van der Knaap and van Leeuwen, 1997). The Chã das Lameiras pedoanthracological data demonstrate that, along with the increasing presence of xerophytic herbaceous communities documented by palynology, there is an increasing presence of shrubby Fabaceae (López-Sáez et al., 2017). In the south-western and southern coasts, the abrupt decline in *Quercus* is accompanied by an increase of *Pinus*. At Cabeço do Porto Marinho, in central Portugal, charcoal analyses

Table 1
TL/OSL dates for Portuguese Magdalenian and Pleistocene-Holocene transition sites (after Aubry, 2009; Bicho and Haws, 2012; Gaspar et al., 2016b).

Site	Layer	Lab ref.	Method	Material	Age (ka)
Quinta da Barca Sul	3 (UA8)	GifTLQBS4	TL	Burnt quartzite	11.9 ± 1.1
Quinta da Barca Sul	3 (UA7)	GifTLQBS3	TL	Burnt quartzite	11.6 ± 1.2
Quinta da Barca Sul	3 (UA5)	GifTLQBS2	TL	Burnt quartzite	12.7 ± 1.0
Fariseu	4b	Cobble 17	TL	Burnt quartzite	11 ± 1.1
Fariseu	4c	Cobble 2	TL	Burnt quartzite	10.8 ± 1.7
Fariseu	4e	Cobble 8	TL	Burnt quartzite	11.8 ± 0.9
Fariseu	6	Sedc6	OSL	Sediments	15.2 ± 1.6
Fariseu	7	Cobble 24	TL	Burnt quartzite	13.7 ± 1.0
Fariseu	7	Cobble 9	TL	Burnt quartzite	14.3 ± 1.1
Fariseu	8	Sedc8	OSL	Sediments	18.4 ± 1.6
Carneira II	60–70		TL	Flint	10.5 ± 0.7
CPM	13		TL	Flint	14.1 ± 1.1
Lagoa do Bordoal	LEPT2		OSL	Quartz	14.8 ± 2.9
Foz do Medal	1034	X6566	OSL	Sediments	12.35 ± 0.9

Table 2
Radiocarbon dates for Portuguese Magdalenian, Pleistocene-Holocene transition sites and Early Holocene (after Zilhão, 1997a; Monteiro-Rodrigues and Angelucci, 2004; Aubry et al., 2008a; Valente and Carvalho, 2009; Bicho and Haws, 2012; Pereiro, 2013; Araújo et al., 2014; Sousa and Gonçalves, 2015; Araújo, 2016b; Carvalho et al., 2016; Benedetti et al., 2019 and unpublished data from Rôdo and Vau provided by Carmen Manzano and Sérgio Gomes). Because of the reservoir effect, dates on shell were not considered. CPM = Cabeço de Porto Marinho; VCA1 = Abrigo 1 de Vale de Covões; BXB = Barca do Xerez de Baixo * 2σ calibration according to OxCal v4.3.2 Bronk Ramsey (2017); r-5; IntCal 13 Atmospheric curve (Reimer et al., 2013).

Site	Layer	Lab Ref.	Sample	Date BP	Date cal BP (2σ) *
CPM-I	Lower	SMU-2015	Charcoal	16,340 ± 420	20,770–18,795
Caldeirão	Fa	ICEN-69	Bone	15,170 ± 740	20,355–16,620
CPM-IIISW	Lower	WK-3126	Charcoal	16,180 ± 290	20,232–18,868
CPM-I	Lower	ICEN-542	Charcoal - hearth	15,820 ± 400	20,150–18,309
Caldeirão	Eb	ICEN-70	Bone	14,450 ± 890	19,966–15,243
CPM-IIIS	Lower	SMU-2668	Charcoal	14,050 ± 850	19,385–14,666
CPM-II	Middle	SMU-2476	Charcoal	15,410 ± 195	19,108–18,223
CPM-VI	Lower	SMU-2634	Charcoal	15,420 ± 180	19,070–18,275
CPM-IIIS	Lower	WK-3127	Charcoal	15,040 ± 210	18,747–1,7829
Olival Fechado	2	Beta-179279	Charcoal - *Pinus sylvestris*	13,460 ± 80	16,488–15,942
Buraca Grande	9	OxA-5522	*Baguette demi-ronde*	13,050 ± 100	15,957–15,287
Rôdo	6/NA1	17C/0829	Leguminosae	13,050 ± 40	15,832–15,383
Lapa do Picareiro	G	OxA-5527	Charcoal - *Pinus*	12,320 ± 90	14,824–14,011
VCA-1	5	Beta-201013	Bone	12,340 ± 50	14,686–14,102
Bispeira 8	5	17C/0838	Leguminosae	12,010 ± 60	14,686–14,102
CPM-I	Upper	ICEN-687	Charcoal	12,220 ± 110	14,675–13,779
Lapa dos Coelhos	4	GrN-18377	Charcoal - *Pinus sylvestris*	12,240 ± 60	14,465–13,955
Lapa do Picareiro	F	Wk-6677	Charcoal	12,210 ± 60	14,336–13,860
VCA-1	8b	Gif-12080	Charcoal	12,220 ± 24	14,223–14,008
VCA-1	8b	UA33482	Charcoal	12,050 ± 70	14,088–13,749
CPM-IIIS	Middle	ICEN-689	Charcoal - hearth	11,810 ± 110	13,945–13,427
Lapa do Picareiro	F	Wk-4219	Charcoal	11,780 ± 90	13,772–13,442
Lapa do Picareiro	E-Middle	Wk-5431	Charcoal	11,700 ± 120	13,764–13,296
Galeria da Cisterna	3	OxA-11129	Phalanx - *Capra sp.*	11,755 ± 80	13,720–13,445
CPM-I	Upper	SMU-2011	Charcoal	11,680 ± 60	13,709–13,380
Bispeira 8	4	17C/0837	Leguminosae	11,680 ± 60	13,709–13,380
Lapa do Picareiro	E-Lower	Wk-4218	Charcoal	11,550 ± 120	13,605–13,119
Lapa dos Coelhos	3	GrN-18376	Bone - *Cervus elaphus*	11,660 ± 60	13,597–13,340
Buraca Grande	GC2	Gif-96307	Bone	11,390 ± 110	13,446–13,066
Caldeirão	Eb	ICEN-72	Bone	10,700 ± 380	13,316–11,393
CPMIIIT	Upper	ICEN-690	Charcoal - hearth	10,940 ± 210	13,270–12,428
CPMIII	Upper	ICEN-545	Charcoal	11,160 ± 130	13,261–12,748
CPMII	Upper	SMU-2637	Charcoal	11,110 ± 130	13,198–12,724
Pinhal da Carneira	4	SMU-2635	Charcoal - hearth	10,880 ± 90	12,995–12,670
Lapa do Suão	7	Gx-27590	Charcoal	10,900 ± 70	12,961–12,692
Galeria da Cisterna	3	GrA −9722	Bone	10,820 ± 60	12,810–12,651
VCA1	5	UA33479	Bone	10,540 ± 95	12,695–12,140
Fariseu	4	Beta −213130	Bone	10,510 ± 40	12,601–12,244
Bocas 1	0+	ICEN-900	Bone - *Bos primigenius*	9880 ± 220	12,150–10,671
CPM VI	Middle	SMU-2636	Charcoal	10,160 ± 80	12,100–11,404
Bocas 1	Fundo	ICEN-901	Bone	10,110 ± 90	12,047–11,324
VCA1	8b	UA24593	Bone	10,010 ± 90	11,940–11,240
Magoito	1B C	ICEN-82	Charcoal	9910 ± 100	11,767–11,171
Fariseu	4	Ua-32645	Bone	9830 ± 130	11,759–10,781
VCA1	4	Beta-201014	Charcoal	10,020 ± 40	11,718–11,316
VCA1	7	UA33480	Bone	9725 ± 75	11,264–10,786
Casal do Papagaio	Base	ICEN-369	Bone	9710 ± 70	11,247–10,787
Casal do Papagaio	Middle	ICEN-372	Charcoal	9650 ± 90	11,220–10,739
Vau	5/NA2	17C/0813	Leguminosae	9680 ± 40	11,210–10,805
Magoito	1B	ICEN-577	Charcoal	9490 ± 60	11,083–10,580
Prazo	C5A	GrA-15861	Charred Pinecone fr.	9410 ± 70	11,068–10,425
Prazo	C5–C6/1	Ua-20495	Charcoal *Fraxinous sp.*	9525 ± 70	11,126–10,595
VCA1	8b	UA33481	Bone	9315 ± 90	10,724–10,254
Rôdo	6/NA1	17C/0825	Leguminosae	9360 ± 40	10,696–10,443
Cardina	4.2	Beta-460529	Bone	9220 ± 30	10,400–10,240
Cardina	4.2	Beta-460528	Bone	9160 ± 30	10,500–10,260
Rôdo	6/NA1	17C/0824	Leguminosae	9050 ± 40	10,254–10,176
Fariseu	4	GX-32147-MAS	Chamois Teeth	8930 ± 80	10,235–9765
Areeiro III	Structure 1	ICEN-546	Charcoal	8570 ± 130	10,125–9275
Areeiro III	Main level	ICEN-547	Charcoal	8860 ± 80	10,199–9679
Ponta da Vigia	Hearth 2	Sac-1747	Charcoal - *Pinus pinaster*	8850 ± 90	10,198–9629
Areeiro III	Structure 2	ICEN-494	Charcoal	8850 ± 50	10,168–9710
Ponta da Vigia	Hearth 2	ICEN-51	Charcoal	8730 ± 110	10,153-9535
Ponta da Vigia	Hearth 3	Sac-1741	Charcoal - *Pinus pinaster*	8670 ± 80	9913–9501
BXB	Structure E	OxA-13266	Charcoal - *Q. coccifera*	8729 ± 36	9887–9556
Cruz da Areia	Structure 3	Beta 343555	Charcoal – *Pinus pinaster*	8720 ± 40	9820–9551
Areeiro III	Main level	ICEN-688	Charcoal	8380 ± 90	9533–9137
BXB	Combustion area	Beta-120607	Charcoal	8640 ± 50	9732–9527
BXB	Structure A	OxA-13406	Charcoal - *Q. coccifera*	8150 ± 40	9252–9006
BXB	Structure A	OxA-13265	Charcoal - *E. arborea*	8248 ± 35	9401–9091

(*continued on next page*)

Table 2 (*continued*)

Site	Layer	Lab Ref.	Sample	Date BP	Date cal BP (2σ) *
BXB	Structure A	OxA-13264	Charcoal - *E. arborea*	8250 ± 37	9402–9091
Vale Sá	Structure	Gif-10348	Charcoal	8500 ± 110	9765–9143
Costa do Pereiro	2	WK-35997	Bone - *Cervus elaphus*	8680 ± 80	9693–9548
Costa do Pereiro	1b	WK-30215	Bone – *Capra pyrenaica*	8564 ± 37	9560–9482
Cova da Baleia	Structure CBL-N7-5-L2,	Beta-295903	Charcoal	8460 ± 50	9540–9333
Prazo	Hearth C6	GrA-15986	Charcoal *Quercus sp.*	8370 ± 70	9526–9142
Prazo	Hearth C5	GrN-26402	Charcoal	8380 ± 60	9525–9258
Prazo	Hearth C5	CSIC-1621	Charcoal	8397 ± 38	9496–9305
Cova da Baleia	Structure V10-52-L2	Beta-295905	Charcoal	8320 ± 40	9464–9141
Cova da Baleia	Structure CBL-R10-24-L3	Beta-295904	Charcoal	8250 ± 50	9409–9033
Cova da Baleia	Structure CBL-L7-2-L3	Beta-294170	Charcoal	8230 ± 50	9400–9029
São Julião A	Q1,B1	ICEN-179	Charcoal	8120 ± 100	9401–8663

indicate the presence of pines and a shrubby vegetation, including some indicators of thermicity, such as *Olea europaea* and *Arbutus unedo* (Zilhão et al., 1995). Some of these taxa have also been identified at nearby Lapa do Picareiro (Bicho et al., 2003).

The onset of the Holocene is marked by new and abrupt changes in vegetation. From north to south there is a great expansion of *Quercus*. However, as opposed to the Late Glacial climatic warmings, evergreen *Quercus* soon gains some relevance and in the southernmost sequence of CM5 Beliche it is even more abundant than deciduous oaks (Fletcher et al., 2007). Overall, south-western sequences still document high values of pines but there is a replacement of *P. sylvestris* by *P. pinaster* (Queiroz, 1999) although the former continues to exist in the area during the Mid-Holocene (Soares and Silva, 2018; Monteiro, 2018). In central and northern Portugal, deciduous *Quercus* thrive. In the NW they became largely dominant as the Holocene deciduous oak forests were rapidly established (Ramil Rego et al., 1998). The sequences of Serra da Estrela suggest a rapid expansion of oaks at low altitudes and an expansion towards higher altitudes, taking several centuries to reach the sampling sites (van der Knaap and van Leeuwen, 1997). Here, the expansion of heathlands was slow while at Chã das Lameiras there is an expansion of Fabaceae and a decrease in *P. sylvestris* (López-Sáez et al., 2017). Even in northeast Portugal, nowadays with marked Mediterranean climate, archaeopalynological data from Prazo dating from the mid-10th millennium cal BP onwards suggest a dominance of deciduous *Quercus*, with high values of *Olea* and *Pistacia*, among other thermophilous shrubby taxa. Charcoal data attested the local presence of both deciduous and evergreen *Quercus*, as well as *P. pinea/pinaster*, *A. unedo*, among others (Monteiro-Rodrigues et al., 2006). At Foz do Medal, located slightly to the north, charcoal from secondary deposits dating from the mid-9th millennium cal BP document the presence of evergreen *Quercus*, *P. pinaster* and *Fraxinus*, among others (unpublished data). All this data not only suggest a rapid expansion of Holocene forests but also that they differed in composition, depending on regional conditions and previous ecological history.

3.4. Fauna

The animal remains referred to herein were recovered from levels corresponding to the Magdalenian, Azilian and Early Mesolithic (ca. 20,000–8200 cal BP) at fourteen sites distributed in four mainland areas of Portugal: Fariseu (Côa Valley); Vale dos Covões, Gruta do Caldeirão, Lapa do Picareiro, Lapa dos Coelhos, Lapa do Suão, Abrigo das Bocas, Costa do Pereiro, Toledo, Vale Frade, Pinhal da Fonte (Estremadura region); Barca do Xerez de Baixo (Guadiana Valley); Vale Boi and Barranco das Quebradas (Algarve).

A common trait of the faunal assemblages is the prevalence of mammal remains. These represent between 90 and 100% of the animal remains found at most sites - excepting the Early Mesolithic sites of Toledo (close to 86%), Vale de Frade (less than 77%) and Barranco da Quebradas where the assemblages are exclusively shellfish (Table 3).

The ungulates found at Portuguese archaeological sites dated to the last 30,000 years include red deer, roe deer, wild boar, aurochs, equids, ibex and chamois. The latter two species seem more important during the Solutrean and are related to rockier landscapes, higher altitudes and colder environments (Bicho and Haws, 2012). Deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) are abundant at Lapa do Picareiro, Vale Boi and Toledo (Supplementary material – Table 2). Aurochs is the most represented species at Barca do Xerez de Baixo, an Early Mesolithic butchering site. Red deer, horse and rabbit were also found at this inland site (Valente, 2013; Araújo, 2016a, 2016b).

As shown in Table 3, Magdalenian faunal assemblages document the consumption fish, birds, rabbits and molluscs (Chauviére, 2002; Davis, 2002: 42; Callapez, 2003; Bicho et al., 2003; Davis et al., 2007; Gabriel and Béarez, 2009: 332; Gabriel, 2011; Roselló and Morales, 2010; Moreno-Garcia, 2011; Regala, 2011; Bicho and Haws, 2012; Manne et al., 2012; Valente, 2013; Araújo, 2016a, 2016b; Carvalho et al., 2016; Gameiro et al., 2017). Most of these were also recorded in Solutrean levels at Caldeirão and Lapa dos Coelhos, as well as in Early Mesolithic sites of Portuguese Estremadura (Dupont and Araújo, 2010; Gabriel, 2011; Araújo et al., 2014; Carvalho et al., 2016). Mammal remains with butchery cut marks and other impact traces likely suggest that bone marrow extraction may have occurred, and bones may have been used to produce tools (Gabriel and Béarez, 2009). Rabbit (*Oryctolagus cuniculus*) is the most abundant taxon at Fariseu, Caldeirão, Lapa do Picareiro, Lapa dos Coelhos and Lapa do Suão (Supplementary material - Table 2). It is always problematic to establish whether rabbits were brought by humans or result from natural accumulation by predators (Davis, 2019; Hockett, 1999; Hockett and Bicho, 2000; Hockett and Haws, 2002; LLoveras et al., 2011). Nevertheless, taphonomic studies have demonstrated that, at least since the Solutrean, rabbits were hunted and part of human diet (LLoveras et al., 2011).

Fish taxa document the exploitation of the freshwater environments close to Fariseu, Lapa dos Coelhos and Lapa do Picareiro (Bicho et al., 2003; Gabriel and Béarez, 2009; Roselló and Morales, 2010). Fishes included in the marine division, found both in marine-estuarine milieus, are present at Gruta do Caldeirão, Toledo, Vale de Frade and Vale Boi (Table 3) (Zilhão, 1997b; Gabriel, 2011). In the Caldeirão cave, the four teeth of *Sparus aurata* identified should correspond to adornments (cf. Zilhão, 1997a: 154) probably exchanged or brought from the littoral. The presence of clupeids at Lapa do Picareiro (Bicho et al., 2003) cannot be used to suggest incursions to the coast for fishing, as some of the species in the Clupeidae family include anadromous fish, such as the allis shad and twait shad, which migrate into fresh water to spawn.

Besides shellfish that could be procured for food in marine-estuarine environments (Vale Boi, Gruta do Caldeirão, Vale de Frade, Toledo, Pinhal da Fonte and Barranco das Quebradas) (Table 3/Supplementary material - Table 2) (Callapez, 2003; Dean et al., 2011; Manne et al.,

Table 3
Animal remains found in levels corresponding to the Magdalenian and Early Mesolithic (20,000–8200 cal BP). For sake of comparison we use the number of remains identified per taxa (NISP) found in each site/layer. "P" indicates that a given taxa is present, but no inventory is published in detail. Shellfish are also listed in terms of presence/absence, as the existing data is mostly presented counting the minimum number of individuals found (MNI) or weight. (*) Indicates the presence of fluvial organisms. Site label: VB = Vale Boi; CLD = Caldeirão; S7-9 and S4-6 = Lapa do Suão (Layers 7–9; 4–6); PIC-F/G and PIC-E/L = Lapa do Picareiro (Layers F/G; E/L; E/U); LC-4 and LC-3 = Lapa dos Coelhos (Layer 4 and layer 3); VCA1-3/4 = Vale dos Covões 1 (Layers 3 and 4); BCS = Bocas); FAR-4 = Fariseu (Layer 4); CP = Costa do Pereiro; TOL = Toledo; VFR = Vale de Frade; PF = Pinhal da Fonte; BXB = Barca do Xerez de Baixo; BQ = Barranco das Quebradas 1 and 3 (Layer 3 and 5/10). Data collected from: Chauviére (2002); Bicho et al. (2003); Callapez (2003); Davis (2002): 42; Davis et al. (2007); Gabriel and Béarez (2009): 332; Roselló and Morales (2010); Zilhão et al., 2010: 7; Gabriel (2011); Moreno-Garcia (2011); Regala (2011); Bicho and Haws (2012); Manne et al. (2012); Valente (2008), 2010 & 2013; Carvalho et al. (2016); Araújo (2016a,b); Gameiro (2017). Data for VCA 1 is still unpublished (S. Gabriel unpublished data). Taxonomic list for terrestrial taxa adopts Bencatel et al. (2019) taxonomic reference list.

	Early/Midlle Magdalenian			Upper Magdalenian			Final Magdalenian				Azilian		Early Mesolithic						
	VB	CLD	S-7/9	PIC-F/G	PIC-E/L	LC-4	PIC-E/U	S-4/6	LC-3	VCA1-3/4	BCS	FAR-4	CP	TOL	VFR	PF	BXB	BQ1-3	BQ3-5/10
MAMMALS																			
Insectivora (Eilipotyphla) - Insectivores	–	–	–	–	–	–	–	–	–	–	–	–	–	25	1	–	–	–	–
Carnivora - Carnivores	9	66	18	–	–	–	–	1	1	–	–	–	–	12	5	–	23	–	–
Artiodactyla - Even-toed ungulates	135	86	43	276	28	9	34	8	8	P	P	14	40	190	7	–	470	–	–
Perssodactyla - Odd-toed ungulates	51	6	1	–	–	–	–	–	–	–	P		1	9	17	–	10	–	–
Rodentia - Rodents	–	1	–	–	–	–	–	–	–	–	–	3	–	–	–	–		–	–
Lagomorpha	163	5265	12191	9638	594	132	717	377	218	**P**	**P**	79	21	760	110	–	205	–	–
Medium/large mammals indet.	–	–	–	–	–	–	–	–	–	–	–	638		668	72	–		–	–
Small mammals indet.	–	–	–	–	–	–	–	–	–	–	–	182	–	–	–	–	–	–	–
Micromammals indet.	–	P	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	–	–
Total Mammals	358	5424	12253	9914	622	141	751	386	227	–	–	922	62	1664	212	–	708	–	–
% Total NISP	**98,62**	**99,27**	**100,00**	**100,00**	**100,00**	**90,38**	**100,00**	**99,74**	**98,70**	–	–	**98,40**	**100,00**	**86,04**	**76,81**	–	**99,58**	–	–
BIRDS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Birds	–	28	**P**	**P**	**P**	–	**P**	**P**	–	–	–	1	–	67	5	–	–	–	–
Total Birds	–	28		–	–	–	–	–	–	–		1		67	5	–	–	–	–
% Total NISP	–	**0,51**		–	–	–	–	–	–	–		**0,11**		**3,46**	**1,81**	–	–	–	–
REPTILES	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Reptiles	–	–	–	–	–	–	–	–	–	–	–	–	–	58	–	–	–	–	–
Total Reptiles		28		–	–	–	–	–	–	–		1		67	5	–	–	–	–
% Total NISP		**0,51**		–	–	–	–	–	–	–		**0,11**		**3,46**	**1,81**	–	–	–	–
AMPHIBIANS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amphibians	–	–	–	–	–	–	–	–	–	–	–	–	–	2	22	–	–	–	–
Total Amphibians	–	–	–	–	–	–	–	–	–	–	–	–		2	22	–	–	–	–
% Total NISP	–	–	–	–	–	–	–	–	–	–	–	–		**0,10**	**7,97**	–	–	–	–
FISH	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Freshwater/Anadromous/Catadromous	–	–	–	**P**	**P**	15	**P**	–	**P**	–	–	13	–	–	–	–	–	–	–
Marine-Estuaine	–	**4**	–	–	–	–	–		**P**	–	–		–	143	37	–	–	–	–
Total Fish	–	–	–	–	–	15	–	–	–	–	–	13		143	37	–	–	–	–
% Total NISP	–	–	–	–	–	**9,62**	–	–	–	–	–	**1,39**		**7,39**	**13,41**	–	–	–	–
INVERTEBRATES	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Terrestrial	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	88	–
Freshwhater	–	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–
Marine-Estuaine	5	7	–	–	–	–	–	–	–	–	–	–	–	–	P	P	3	8975	16982
Shellfish	**P**	**P**	**P**	**P**	**P**		**P**	**P**	**P***		**P**	–	–	–	–	–	–	–	–

(*continued on next page*)

Table 3 (*continued*)

	Early/Midlle Magdalenian			Upper Magdalenian			Final Magdalenian			Azilian			Early Mesolithic						
	VB	CLD	S-7/9	PIC-F/G	PIC-E/L	LC-4	PIC-E/U	S-4/6	LC-3	VCA1-3/4	BCS	FAR-4	CP	TOL	VFR	PF	BXB	BQ1-3	BQ3-5/10
Total Invertebrates	5	8	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3	9064	16982
% Total NISP	**1,38**	**0,15**	-	-	-	-	-	-	-	-	-	**0,11**	-	-	-	-	**0,42**	**100,00**	**99,47**
TOTAL NISP	**363**	**5464**	**12253**	**9914**	**622**	**156**	**751**	**387**	**230**	-	-	**937**	**62**	**1934**	**276**	-	**711**	**9064**	**17072**

2012; Valente, 2008, 2010; 2013; Araújo, 2016a); molluscs were also used for shell beads, as the presence perforated *Littorina obtusata* indicates (Callapez, 2003; Chauviere, 2002; d' Errico and Vanhaeren, 2002; Regala, 2011).

4. Lithic industries

The widespread of technological approaches as well as the identification of sites outside the classic Estremadura region, during the last twenty-five years, is reason enough to address the issue focusing on six main geographic units (shown in Fig. 1). Apart from Estremadura and Algarve, situated in areas of limestone substrate, the other regions are situated in the Iberian massif, where only quartz and siliceous metamorphic rocks are available. In Table 4 a summary of the main characterizing traits of the lithic production is displayed.

4.1. Estremadura

Estremadura is the best-known region, because its limestone substrate, and hence the existence of caves, shelters and local availability of flint motivated its survey since the 19th century. However, the sedimentary gaps mentioned above do not allow neither a detailed characterization of the Solutrean-to-Early Magdalenian transition nor the definition of a Middle Magdalenian phase. These hiatuses seem to correlate with climate changes (Zilhão, 1997a, 1997b; Aubry et al., 2008a, 2011; Gameiro, 2012) and do not imply the changes in population dynamics and demographic density that some have argued for (Bicho and Haws, 2012).

In this region, flint is always the most used raw material, due to the existence of sources located at < 10 km from the sites. Other locally available rocks, such as quartzite, which is often used for expedient flake debitage, were also used; its percentage can reach up to 20% (Lapa dos Coelhos layer 3). Good quality quartz was used for bladelet debitage in Lapa dos Coelhos layer 4, where it represents up to 36% of the assemblage (Gameiro, 2012; Gameiro et al., 2013).

Only four sites contain occupations that have been ascribed to the Early Magdalenian: CPM, Caldeirão, Cerrado Novo and Vascas, and only the first two have radiometric dates (Table 2). Bladelet tools are not very diversified; pointed bladelets are absent and marginal retouch is used to regularize the edges of blanks with a rectangular tendency (> 40%) (Fig. 3). Cores-on-flake are used, in proportions that remain under 45%, to produce bladelet blanks Flake and bladelet-oriented debitage account for 80% and 20%, respectively, of the lithic tool-kits. Inverse retouch is common on retouched flakes and scrapers (Fig. 4).

The Middle Magdalenian has not been characterized yet, since there are only two sites with remains ascribable to this phase: Buraca Grande, with a directly dated semi-circular *baguette* (Aubry and Moura, 1993) (Table 2), that is hard to associate with other elements from its level of provenience; and, based on its dating (Table 2), the open-air site of Olival Fechado, were a production of backed points or microgravettes coexists with marginally backed bladelets obtained from cores-on-flakes (burin-like) (Silva, 2003).

The Upper Magdalenian is documented at eight sites: CPM (*loci* I and IIIs), Lapa dos Coelhos layer 4, Galeria da Cisterna, Gruta do Caldeirão, Picareiro, Vale da Mata, Vascas and Lapa do Suão. In Lapa dos Coelhos layer 4, a high percentage of microgravettes was identified; they coexist with rectangular backed bladelets (Fig. 5.1). The blanks were obtained through the exploration of cores-on-flakes (burin-like) (Fig. 5.5). There is an independent laminar production and a production of small flakes through bipolar debitage on anvil during the final reduction stages (Gameiro, 2012; Gameiro et al., 2013).

The Rossio do Cabo Final Magdalenian facies, identified at three sites (Pinhal da Carneira, Rossio do Cabo and Lapa dos Coelhos), can be distinguished from the previous phase by the absence of autonomous laminar production and the increased use of cores-on-flake for bladelet debitage (Fig. 6). At Lapa dos Coelhos, from the Upper Magdalenian

Table 4
Lithic industries' characteristics by period and region.

cal BP	Phase	Industrial characteristics by region				
		Estremadura	Côa and Sabor Valleys	Vouga Valley	Guadiana Valley	Algarve
19,500–16,000	Early Magdalenian	Different core types in balanced proportions Rectangular bladelets (marginal retouch to regularize the edge).	n.a.	n.a.	n.a.	n.a.
16,000–14,500	Middle Magdalenian	?	?	?	?	?
14,500–13,000	Upper Magdalenian	Cores-on-flakes become more frequent and burin spalls are more often used as bladelet blanks. Backed bladelets similar to microgravettes and backed points are frequent.	Small and uncharacteristic sample		Microgravette at Monte da Ribeira site?	Small and uncharacteristic sample.
13,000–12,000	Final Magdalenian	Cores-on-flakes (mainly burin type) are dominant. Marginally retouched bladelets (Areeiro ou Dufour type, depending on the authors) coexist with backed points. Huge variety of armatures.	Bipolar debitage on anvil is frequent (on quartz and last stage of flint cores).	Cores-on-flakes (mainly burin type) are dominant. Marginally retouched bladelets (Areeiro or Dufour type, depending on the authors) coexist with backed points. Bipolar debitage on anvil is frequent (on quartz and last stage of flint cores).	Expedient production of flakes and chips, the latter produced by bipolar debitage on anvil. Small assemblages of backed and marginally retouched bladelets.	Expedient production of flakes and chips, the latter produced by bipolar debitage on anvil. Elongated blanks are rare and except for denticulate and notched bladelets there are no armatures
12,000–11,000	Azilian	Reduction strategies similar to the previous phase. Trapeze, curved backed points and Malaurie points are present.	Reduction strategies similar to the previous phase. Trapeze, curved backed points are present.	Reduction strategies similar to the previous phase. Curved backed points points are present.	Reduction strategies similar to the previous phase. Malaurie points are present.	n.a.
11,000–8200	Early Mesolithic/ Epipaleolithic[a]	Rare retouched bladelet tools or at best persistence of backed bladelets armature types. Geometric microlilths. Blank production orientated towards flake production. Bipolar debitage on anvil is frequent.				

n.a. - not available.
[a] According to different authors.

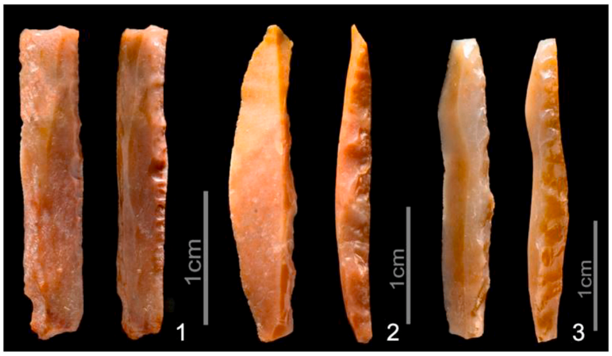


Fig. 3. CPM I (Lower) - Early Magdalenian: 1- truncated, marginally retouched bladelet. Retouch technique: *raclage* with soft material; 2 and 3 - Backed bladelets. Retouch technique: hard-hammer percussion. Local flint (Cenomanian). Photos by J.P. Ruas.

(C4) to the Rossio do Cabo Final Magdalenian facies, the typological variety of microliths increases and pointed or bipointed bladelets are frequent (Fig. 7) (Gameiro, 2012; Gameiro et al., 2013). At Abrigo 1 de Vale de Covões, levels 3 and 4 were ascribed to a Final Magdalenian occupation, due to an absence of Azilian points and it is possible that levels 5–8b could date to the Upper Magdalenian (Aubry et al., 2008a; Klaric et al., 2010; Gameiro, 2018).

Concerning Bairrada, Bocas, and Vascas, a review of the literature suggests that the association of curved backed points, or Azilian points, marginally retouched bladelets, and on-flake and unguiform endscrapers seen at the first two of these sites is consistent with their ascription to the Late Azilian; while Carneira and Olival da Carneira are best described as Laborian (Aubry et al., 2017). Recently, as part of preventive archaeological works carried out in the Leiria region, two open-air sites were identified and ascribed to the final phase of the Magdalenian or to the Early Mesolithic period: Cortes and Telheiro da Barreira, (Andrade et al., 2013; 2010–2011). The absence of absolute datings and the small lithic assemblages do not allow certainty, but the techno-typological features — numerous informal tools, along with unguiform endscrapers, a diversified bladelet tool-kit (Areeiro bladelets, backed and fusiform points), debitage over flake edge (carinated endscrapers and burins) for the production of bladelet blanks — are arguably consistent with the Azilian.

Some authors refer to the Pre-Boreal (Greenlandian) and Boreal sites as Epipaleolithic, characterized by a continuity of Upper Palaeolithic technological features (Bicho, 1994, 2000; Bicho and Haws, 2012; Carvalho et al., 2016). Others refer to the same sites as Early or Initial Mesolithic, since the assemblages feature a distinct technological design, and the type of occupation and mode of subsistence are also distinct (Araújo, 2003, 2016a,b). Our knowledge of human occupation during this period is based on the archaeological record of cave and rock-shelter sites located in the karst system of Serra d'Aire e Candeeiros, such as Lapa do Picareiro, Casal do Papagaio, Costa do Pereiro and Pena d'Água (Bicho, 1994; Bicho et al., 2011; Bicho and Haws, 2012; Pereira and Carvalho, 2015; Pereira et al., 2016) and on the open-air sites of Vale Sá, Areeiro III, Cruz da Areia, Cova da Baleia, Toledo, Pinhal da Fonte, Cabeço do Curral Velho, Ponta da Vigia, Vale Frade and Cabeço de Porto Marinho *locus* V (Bicho, 2000; Aubry et al., 2008b; Pereiro, 2013; Sousa and Gonçalves, 2015; Araújo et al., 2014; Araújo, 2016b). Some technological aspects of the lithic industry from Areeiro III and Costa do Pereiro (Table 2) are in continuity with Magdalenian and Azilian tradition, even though these sites are dated to the Greenlandian stage. At Areeiro III, a site located close to excellent flint sources, the lithic industry is characterized by an important flake tool production, carinated "endscraper and burin" cores to produce Areeiro bladelets, (i.e. marginally retouched bladelets, 15 mm or less in length (Zilhão, 1997a)), but also some backed bladelets (Araújo, 2016b). At Costa do Pereiro, the exploitation of quartzite and quartz was mainly aimed at the production of flakes while flint, characterized by the low percentage of cortex and the small size of the cores, was used to produce flakes and bladelets. These blanks were subsequently modified into various retouched tools (scrapers, denticulates and endscrapers); bladelet tools reach 20% of the total, and include trapeze, backed bladelets, marginally retouched bladelets, Azilian and Malaurie points (Carvalho et al., 2016). All the other Early Mesolithic (or Epipaleolithic, depending on the authors) sites feature simple and expedient flake production, frequent bipolar on anvil debitage (pièce esquillée type) rare (but present at Ponta da Vigia for example) or non-existent bladelet production and an absence of armatures in most cases (Araújo et al., 2014; Araújo, 2016b).

4.2. Côa Valley

The discovery of open-air Palaeolithic art in the Côa Valley, in 1994, guided research into surveys aimed at the identification of sites occupied during the end of the Pleistocene, unknown in this area of the peninsular interior until then (Zilhão, 1997a; Aubry, 2009). The occupation of this territory during the end of the Tardiglacial was confirmed straight away by the first sondage carried out at the Cardina site in 1995, based on the recovered lithic assemblage, which included a unguiform endscraper, a backed point and a trapeze, the definitory types of the Final Magdalenian Carneira facies of Portuguese Estremadura (Zilhão, 1997a). The excavation of the Quinta da Barca Sul site, between 1996 and 2001, revealed a level of schist slabs (top of SU3) in a sequence of slope deposits on top of an alluvial deposit and a small but technically homogeneous lithic assemblage, including some

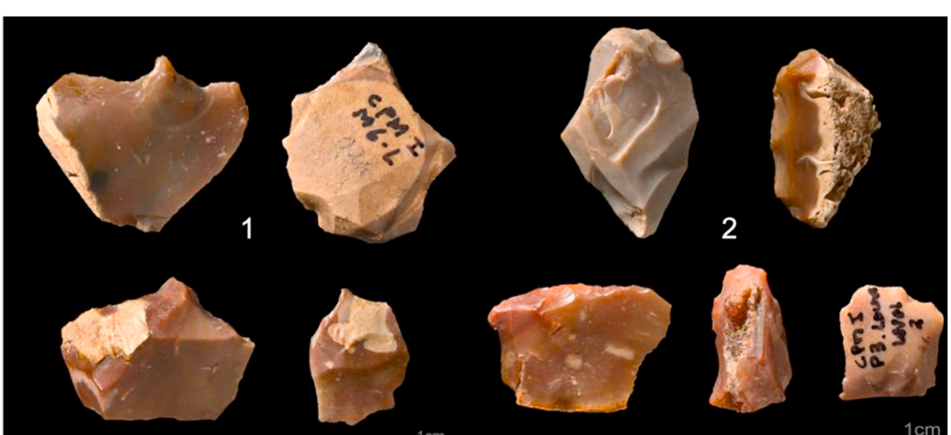


Fig. 4. CPM I (Lower) - Early Magdalenian: 1 – perforators on local flint (Cenomanian); 2 – endscrapers on local flint (Cenomanian). Photos by J.P. Ruas.

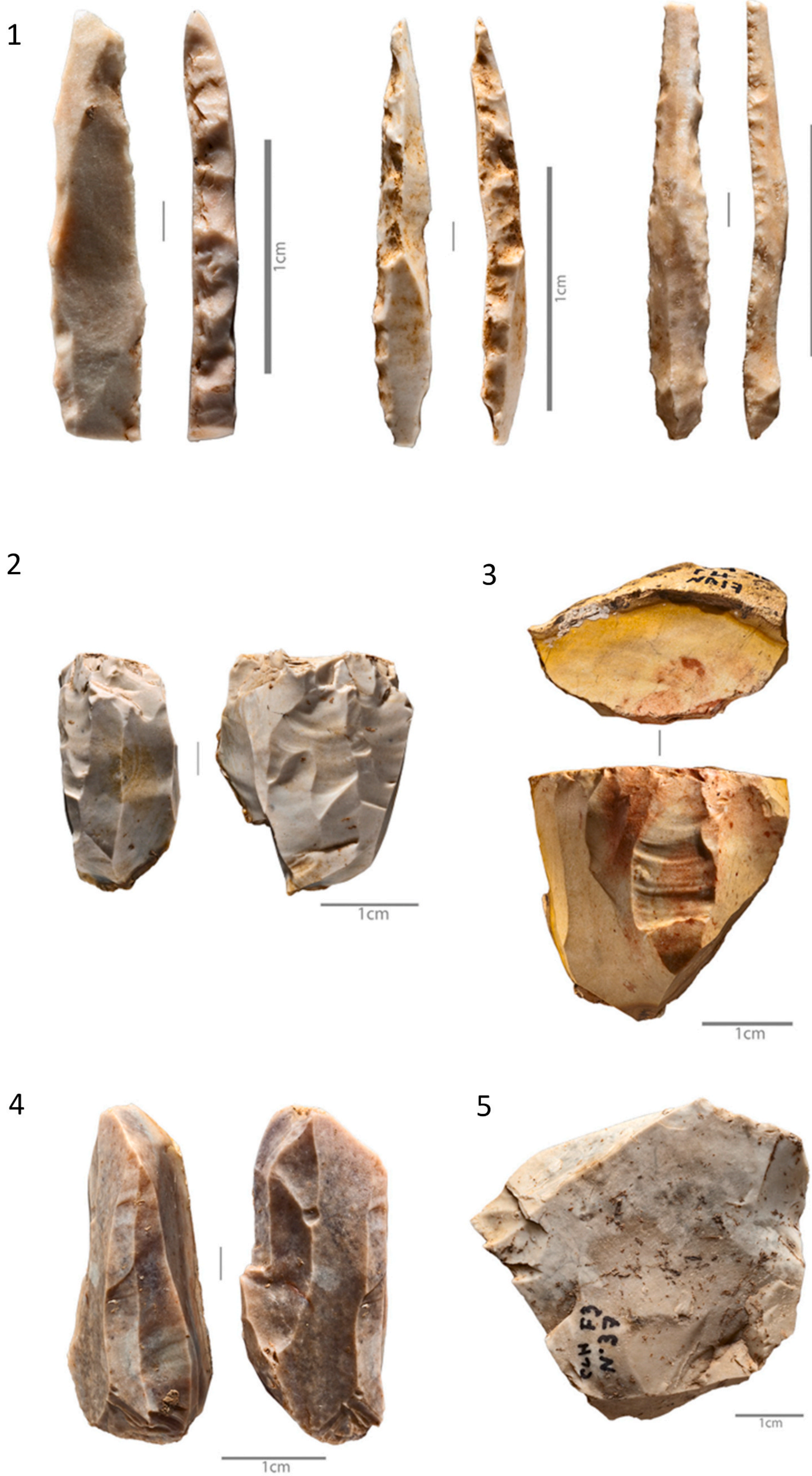


Fig. 5. Lapa dos Coelhos US4 – Upper Magdalenian: 1 - Microgravettes. Retouch technique: hard-hammer percussion. Local and Regional flint (Cenomanian). 2 and 3 – Bladelet core-on-flake on Cenomanian flint; 4 – Bladelet core on Cenomanian flint pebble; 5 – Transversal burin/bladelet core on bajocian local flint. Photos by J.P. Ruas.

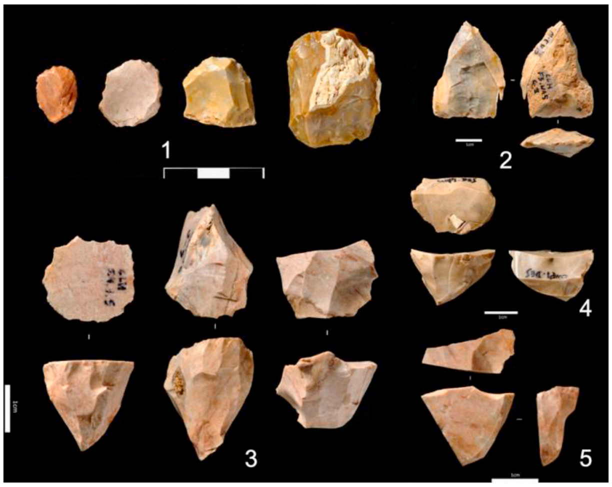


Fig. 6. Lapa dos Coelhos US3 – Final Magdalenian: 1 – endscrapers on Cenomanian flint.; 2 – burin/bladelet core with a refitted burin spall on Cenomanian flint.; 3 – bladelet cores on Cenomanian flint.; 4 – bladelet core with refitted bladelet on Bajocian flint; 5- bladelet core-on-flake on Cenomanian flint. Photos by J.P. Ruas.

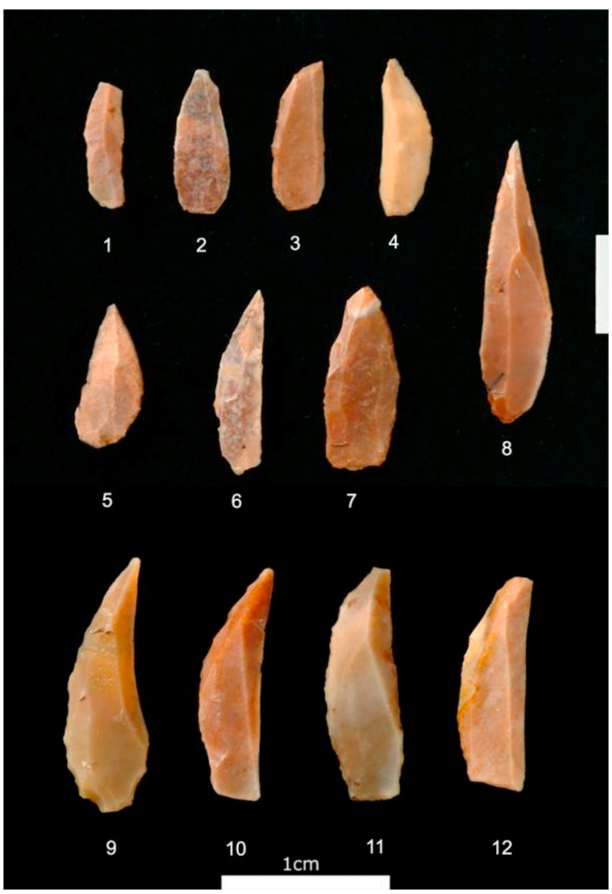


Fig. 7. Lapa dos Coelhos US3 – Final Magdalenian: 1-12- marginally retouched bladelets on Cenomanian flint (1–7 can be called Areeiro-type bladelets). 9–12 - produced on burin spalls: the ventral face of the flake blank is well apparent on the right side of the dorsal face. Photos by J.P. Ruas.

endscrapers on flake, unguiform endscrapers, curved backed points, a trapeze and two segments (Aubry, 2009). The results of TL dating in the region (Valladas et al., 2001), which included the results obtained from three heated quartzite fragments unearthed in layer 3 of Quinta da Barca Sul (11,900 ± 1100, 11,600 ± 1200 and 12,700 ± 1000

Fig. 8. Fariseu US3 and US4 – Azilian: 1 - backed curved point/Azilian point on silcrete (US3), 2 - backed curved point/Azilian point on silcrete and 3- fusiform point; 4 - quartz bladelet core; 5 - quartz cristal with prepared platform, to be used as a bladelet core. Photos J.P. Ruas.

years ago) confirmed the attribution of layer 3 to the end of the Tardiglaciar, previously proposed based on typo-technological criteria (Aubry et al., 1997). OSL dates of 14,000–15,000 years ago were obtained for layer 4, and are identical to the dates obtained for layers 5 and 6 of the Fariseu site, thus confirming an occupation of the site during Final Magdalenian.

At the Fariseu site, the typo-technological study of SU4 indicates a use of local raw materials for the production of flakes, later transformed into scrapers, endscrapers and denticulates, and a production of Azilian points, backed points, marginally retouched bladelets (Fig. 8: 1, 2 and 3) and scarce geometrics on fine grain siliceous rocks and alloctonous flint types (Aubry, 2009; Gameiro, 2009, 2012). The archaeological level at the base of stratigraphic unit (SU) 6, dated to 15,200 ± 1600 years ago shows evidence of fluvial erosion; the smaller lithic elements have probably been washed away and are under-represented. A single backed bladelet was recovered from this level.

The lithic assemblage from the base of Quinta da Barca SU2, labelled Upper Magdalenian because of the association of backed bladelets with two triangles (Aubry et al., 1997, p. 131), may be contemporaneous with this phase, but the reduced thickness and questionable coherence of the site's stratigraphic sequence prevents us from considering it as a reliable context in the scope of this discussion (Aubry, 2001; Aubry et al., 2017).

Recent excavations at the Cardina site (Aubry et al., 2015), allowed the identification of pointed bladelets but no curved backed points have been identified; this type of points characterise Fariseu SU4 and Quinta da Barca Sul SU3 and have recently been ascribed to the Late Azilian (Aubry et al., 2017). However, there are lunate-like rock crystal geometrics in the first spits of Cardina SU4, in association with backed bladelets of various typologies; the ^{14}C datings indicate an occupation of the site during the Greenlandian stage (Table 2) and these levels were considered Sauveterrian (Aubry et al., 2017). A decrease in the use of flint and silcrete was observed throughout the stratigraphic sequence of Cardina, from the Gravettian to the Tardiglaciar, indicating a contraction of the geographic area used and an increased dependence on local and regional raw materials (Aubry et al., 2012, 2016).

4.3. Sabor Valley

The Sabor Valley is located in a rugged geographical area to the north of the Douro River. In broad terms, the Sabor River flows in a northeastern-southwesterly direction, between the Gamoneda Mountains (Zamora, Spain) and the Douro River, in a deeply-incised peripheral area of the Spanish Meseta. The differences in elevation between the Valley floor and the top of the slopes are of up to 800 m (Silva et al., 1989). However, as a result of local geomorphology (Silva et al., 1989) and tectonic activity (Pereira and Azevedo, 1995), fluviatile terraces do exist in a few wider sections of the Valley. Long diachronic sequences of occupation have been identified in these geological contexts (Gaspar et al., 2016b). Among the human occupations of the Sabor Valley, S6 is of Magdalenian chronology (corresponding to phase FM4 of the Foz do Medal site) and S7 is Azilian (corresponding to phase VC1 of the Volta do Cocão site).

The Foz do Medal site is located on a large platform on the right bank of the Medal stream (a tributary of the Sabor River), some 9 m above the riverbed. This platform is currently submerged under the Baixo Sabor reservoir. The Magdalenian occupation was identified in SU [1055] in the central area and in the equivalent SUs [12001], [17004] and [26002] recorded during the evaluation sondages. This deposit underwent mass displacement along the slope, towards the watercourse; the difference in elevation between the upper and lower

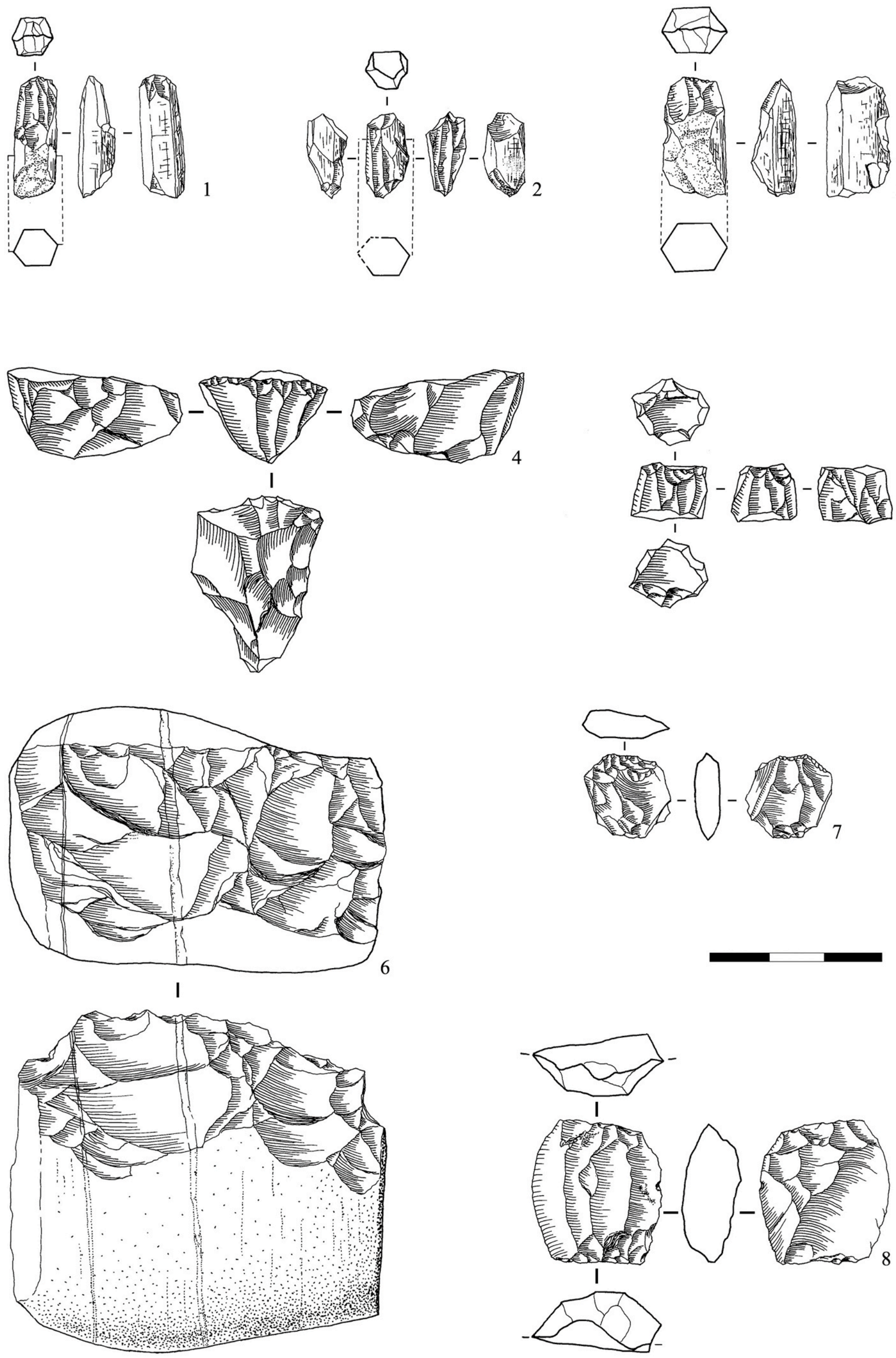


Fig. 9. Cores from Foz do Medal, made on fine-grain siliceous rocks. Core 1–3 and 7 on quartz crystal and hyaline quartz respectively. 1–3) 45° angle platform on quartz crystal core; 4) Carinated "endscraper" core for small flakes and bladelets; 5) Double opposed platform prismatic core for bladelets; 6) Unifacial core on pebble; 7–8) core with bipolar technique on anvil. Drawings by Fernanda Sousa.

parts of the deposit can reach 2.20 m, with a gradient that varies between 7° and 18° in the central intervention area.

This deposit features a high density of materials, reaching up to 3700 pieces per square meter (a total of 166,929 pieces). Blocks and slabs of schist and graywacke (local bedrock) have been identified, some up to 1.5 m in length, indicating the presence of an old structuring of the space, now impossible to identify. A total of 159,482 knapped stone elements were recovered and it is possible to observe the complete *chaîne opératoire*, including small debris, indicating on-site retouching. During this phase, the range of exploited lithic raw materials is quite wide, even though quartz is clearly dominant (Gaspar et al., 2016a). The aim was to obtain small-sized flakes, since bladelets are only 1.5% of the debitage, and blades are residual.

Reduction is mainly characterized by expedient strategies, core-trimming products being almost non-existent. Prismatic, bipolar and rock crystal cores (with no other preparation than the 45° platforms) are also present (Fig. 9). Carinated endscrapers are rare. Retouched tools reach 1.4% of the total assemblage and are dominated by pieces with simple retouch. A characteristic feature of this assemblage is the predominance of denticulates and notches; backed bladelets represent only 1% of the tool-kit. Although it has not been possible to obtain a direct date for this occupation, an OSL date obtained for the overlying deposit provides a *terminus ante quem* of 12,350 ± 930 years ago (Gaspar et al., 2016b) for the reworking of unit [1055].

In the VC1 phase of Volta do Cocão site, upstream of Foz do Medal, the use of quartz is also predominant, but the diversity of raw materials is drastically reduced. Cherts are residual. Reduction strategies are once more mainly opportunistic, aimed at obtaining flakes. As opposed to what happened during the Magdalenian, the presence of splintered cores outweighs the presence of prismatic cores. Regarding the tool-kit, pieces with simple retouch remain predominant, followed by notches and denticulates. Geometrics and unguiform (thumbnail) endscrapers are also present in this Azilian ocupation.

4.4. Vouga Valley

Archaeological work carried out in 2014/2015, in the scope of the Ribeiradio-Ermida Hydroelectric Project, led to the identification of three late Pleistocene archaeological sites in the Vouga Valley: Rôdo, Vau, and Bispeira 8. The excavation of these three archaeological sites

Fig. 10. Rôdo – Final Magdalenian: 1 – fragment of curved backed point (?) on regional Bajocian flint; 2-marginally retouched bladelet on allochthonous Cenomanian flint; 3 and 5 – Bipolar core/*pièce-esquillée* on allochthonous Cenomanian flint; 4 - Bipolar core/*pièce-esquillée* on quartz; 6 – burin/core-on-flake on regional Bajocian flint; 7 - thick endscraper/core-on-flake on allochthonous Cenomanian flint. Photos by C. Manzano.

yielded a large lithic assemblage; no faunal remains were preserved and study of these sites is still ongoing (Gameiro et al., 2018).

At Rôdo, a colluvial deposit (SU006) accumulated on top of the river terrace contained a lithic assemblage and some anthropogenic stone structures that may correspond to combustion features. The top of the sequence (SU003) was disturbed by post-depositional phenomena (ravine channels, recent reforestation and road construction). Excluding some blade fragments and microlithic types of probable Neolithic age, the lithic industry shows uniform techno-typological characteristics. Debitage is oriented towards the production of flakes and bladelets. Cores-on-flake (Fig. 10: 6 and 7) were exploited along their edges (mostly burin but also endscraper types) to produce bladelets; bipolar debitage on anvil is also frequent (Fig. 10: 3,4 and 5). Retouched tools are rare but flint unguiform endscrapers, marginally backed bladelets (Fig. 10: 2) and curved backed bladelets (Azilian points: Fig. 10:1) were identified. Quartz, quartzite and other coarse-grained cobbles were used for expedient flake debitage or transformed into denticulates, notches or scrapers and macro-tools. Regarding the chrono-cultural affiliation of these evidences, we would point out that the stratigraphic resolution of this open-air site doesn't support the construction of a solid sequence correlating material culture and radiocarbon dates (Table 2). Furthermore, we would also stress that: i) radiocarbon data suggest an occupation of the site that might have begun during the Middle Magdalenian and lasted until the Early Mesolithic; ii) the lithic assemblage does show Final Magdalenian techno-typological characteristics, which also support a possible Azilian occupation of the site.

At Vau archaeological site two clearly differentiated chronological horizons were identified: Holocene layers (SU001; 002 and 003) containing a few typically Upper Palaeolithic artefacts, as a result of post-depositional disturbance (ravine channels); and Pleistocene layers (SU005 and 013), which contain lithic artefacts only. A few marginally retouched bladelets, microliths and one Teyjat or Ahrensburg point (Fig. 11) were recovered atop the Gravettian occupation. Prismatic and “flake-edge cores” were used in bladelet debitage schemes and bipolar knapping on anvil is frequent. Reffiting indicates unipolar or centripetal expedient debitage in flake reduction sequences. This lithic assemblage suggests a short Tardiglacial occupation, which can be ascribed to Final Magdalenian despite the existence of a Mesolithic date (Table 2), which is not consistent with the lithic industry. Moreover, the top of the stratigraphic sequence shows evidence of erosion and was disturbed by recent farming-related activities, which hinder a better definition of the site's early Holocene occupation sequence.

Four negative structures were identified at Bispeira 8; some may have been used as fireplaces. Most of the artefact assemblage was recovered in SU002, which corresponds to the sedimentary unit covering all the negative structures and is a palimpsest containing artefacts of different ages. Structures 1 and 2 provided Late Paleolithic radiocarbon dates but reduced technological information: two quartzite flake cores in SU004, and one quartzite flake core, one quartz core, two quartz flakes and one quartzite flake in SU005. Structures 3 (SU020/027) and 4 (SU021/024/025) yielded Neolithic radiocarbon dates, one ceramic fragment and 14 lithic artefacts including one flint blade fragment, five flint bladelets, two quartz flakes and another flake on a coarse-grained rock.

At all three sites, most of the stone tools were produced using local raw materials such as quartz and other coarse-grained rocks gathered from the nearby alluvial gravels. By comparison with Vau's Gravettian layer, which features a high percentage of flint and silcrete, the more recent occupations of Vau, Rôdo and Bispeira 8 bear witness to a slight decrease in flint and silcrete use between the Early Upper Palaeolithic and the Tardiglacial, similar to the pattern previously identified at Cardina (Côa Valley) (Aubry et al., 2016).

The percentage of retouched tools, including index fossils such as armatures, is very low, which makes chrono-cultural attribution difficult. Based on lithic technology, the Rôdo human occupation can be ascribed to Final Magdalenian and Azilian; nevertheless, undergoing work on spatial analysis will test the existence of a Late Middle Magdalenian or Upper Magdalenian occupation as suggested by the 13,050 ± 40 BP (15,832–15,383 cal BP) ^{14}C dating. The Vau and Bispeira 8 sites seem to have been occupied during Final Magdalenian and Neolithic.

4.5. Guadiana Valley

Between 1998 and 2002, Pleistocene occupations were identified in the scope of the mitigation works required by the construction of a dam in the Guadiana River basin (Southern Portugal) (Almeida, 2013). Prior to this work, clusters of macrolithic material from this southeast quadrant of the country, mostly made on quartzite, labelled Languedocian by H. Breuil were all that could be considered of Pleistocene age (Breuil, 1917). Since then, the term Languedocian has been used as a short-hand designation devoid of chronological significance (Raposo and Silva, 1984) applied to an expedient technological scheme, dependent on the locally available raw material and probably motivated by functional imperatives (Almeida et al., 2013; Araújo and Almeida, 2013).

In this river basin, dry spells alternate with torrential flooding, which accounts for the erosion of low-elevation sedimentary formations and for the preservation of sites only on high alluvial or colluvial platforms. The intense agricultural exploitation of some platforms with a potential for sedimentary preservation originated the formation of palimpsests that are difficult to disentangle. At the same time, the absence of macro-organic remains has hampered radiometric dating and made it impossible to obtain data on diets and paleoenvironments. The study of lithic materials and their comparison with the cultural sequence identified in Estremadura (Zilhão, 1997a) allowed the identification of at least two Magdalenian sites: Monte da Ribeira 9 (Mourão) and Malhada do Mercador I-SW (Mourão) (Gameiro, 2012; Almeida et al., 2013). The human occupations of Chancudos 3 and Monte Roncanito 21 may date to the end of the Tardiglacial or the beginning of the Holocene, but the rough appearance of the lithic industry does not allow certainty. The absence of flint in this region underpins the dominance of quartz and quartzite, which account for more than 90%

Fig. 11. Vau – possible Teyjat ou Ahrensburg point (?) on regional Bajocian flint. Photo by C. Manzano.

of the raw materials, resulting in uncharacteristic industries and hindering inter-regional comparison.

The existence of quartz veins in the vicinity of Monte da Ribeira explains the predominance of this raw material: 73% of the total. Flint only reaches 1.57%, but lydite, a local fine-grained rock, is more abundant, at 4.44%. Laminar production is absent and most blanks are flakes produced expediently, with no investment in the conformation of mostly unipolar volumes. Most tools are notches, denticulates and retouched flakes. The endscraper group is not very significant (14%). Bladelet tools account for 19% of the artefacts and are mostly composed of fragments of flint backed bladelets; bladelet production is rather careful. It was possible to identify two exploitation modalities: convergent exploitation originating pyramidal cores and parallel exploitation originating cores with rectangular debitage surfaces. Although some cores provide evidence for bladelet production on quartz, no retouched bladelets on this raw material were identified. The existence of microgravettes (Fig. 12:25) and backed bladelets of rectangular tendency was considered an archaism supporting the attribution of this site to an Early or Upper Magdalenian phase (Gameiro, 2012; Gameiro and Almeida, in press).

The site of Malhada do Mercador I-SW, is interpreted as a single occupation site, despite the identification of different SU's. The stratigraphic differences result from recent farming. Quartz and quartzite materials account for 90% of the total, distributed equally among these raw materials, at 45% and 46% respectively. Around 33% of the tool-kit is composed of common tools (notches, denticulates and scrapers) with endscrapers reaching ca. 18% of the tools. Quartz and quartzite flakes are the most abundant type of blanks and are obtained by expedient, unipolar methods, taking advantage of the morphology of the volumes: flattish cobbles exploited from the thicker side, producing short flakes always partially cortical; the more globular cobbles are exploited from their natural dihedrons, resulting in larger flakes. The bladelet group accounts for 20% of the total; these blanks are made on flint, quartz and other indeterminate but fine-grained raw materials. Cores-on-flake are rare and the bipolar debitage on anvil, especially on quartz, is frequent. There is no deliberate blade production. The occurrence of trapezoids, Areeiro bladelets, marginally backed bladelets and a Malaurie point resulted in an ascription to the Azilian (Gameiro and Almeida, in press).

The sites of Chancudos 3 and Monte Roncanito 21 share some typological characteristics with sites ascribed to the Magdalenian (the presence of endscrapers, for example). At Monte do Roncanito 21, quartzite debitage is closer to the debitage schemes identified at Barca do Xerez, a site located upstream, on a platform overlooking the Guadiana River, and ascribed to the Early Mesolithic (with radiocarbon dates in the 9700-9200 cal BP interval; Araújo, 2016b). The Early Mesolithic site of Barca do Xerez is interpreted as an animal processing site and knapping activities are simple, expedient and clearly adapted to the morphology of local quartzite cobbles in order to produce flakes (Araújo and Almeida, 2013; Araújo, 2016b).

The absence of absolute datings does not allow for solid conclusions. However, two hypotheses can be put forward: we are dealing with contemporaneous contexts and the observed differences have a

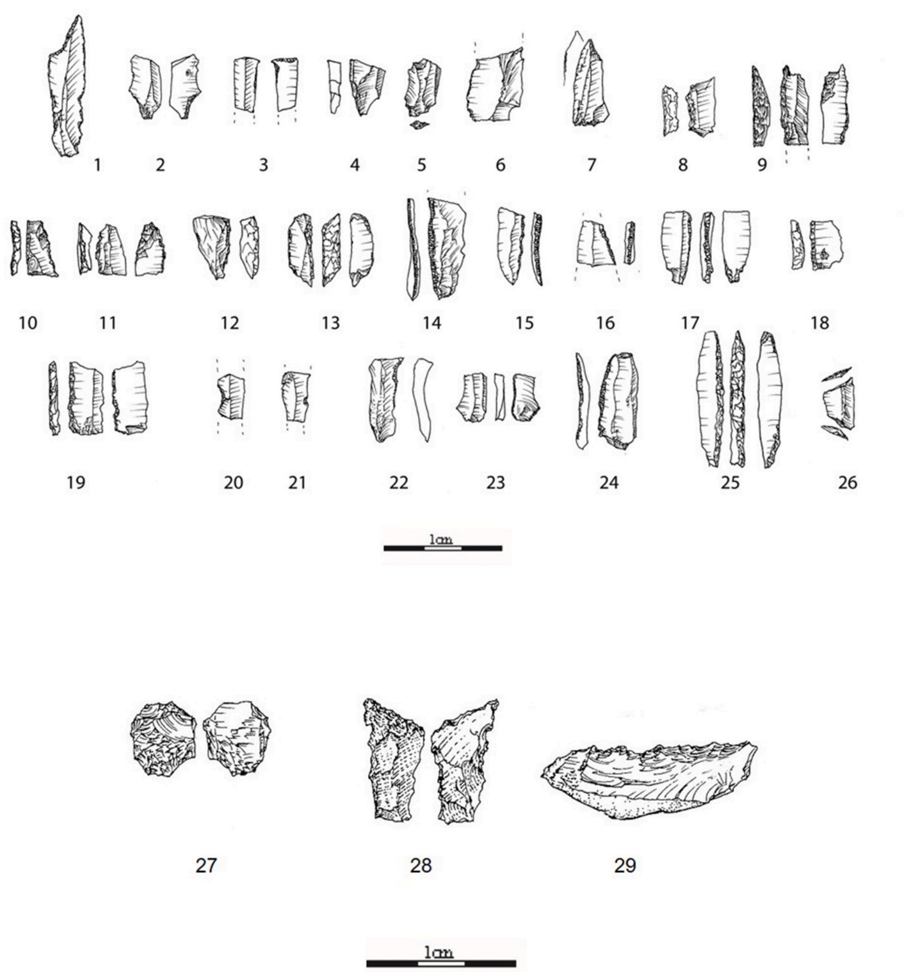


Fig. 12. Monte da Ribeira – Upper Magdalenian? 1 - truncated backed point, 2–24 – backed bladelets fragments and complete exemplars; 25 – microgravette; 26 – trapeze; 27 - *pièce esquillée*; 28 and 29 – denticulated tools. Flint and other indeterminate local raw materials. Drawings by K. Monigal

functional explanation or these differences may have chronological significance and Monte Roncanito 21 may document a phase predating the Early Mesolithic, probably already Holocene, but with a persistence of Palaeolithic technological elements (Almeida et al., 2013).

4.6. Algarve

So far, the available data for the Pleistocene-Holocene transition period in Southern Portugal are limited and mostly concern the southwestern region of the Costa Vicentina (Fig. 1). As a result of various research projects carried out since the 1990s, Tardiglacial occupations have been recorded at the rock-shelter of Vale Boi and the open-air sites of Praia da Galé, Lagoa do Bordoal, Ponta Garcia and Vale Santo 4, (Mendonça, 2009; Bicho et al., 2009, 2010). The open-air sites of Barranco das Quebradas, Rocha das Gaivotas and Castelejo are of Holocene age (Bicho, 2003; Stiner et al., 2003; Carvalho and Valente, 2005; Valente and Carvalho, 2009; Valente, 2008, 2010).

Except for Vale Boi, where the Magdalenian occupation overlies a Solutrean level, and Lagoa do Bordoal, with an OSL dating of 14,800 years ago, the remaining sites are unstratified (eroded, reworked or surface scatters; Mendonça, 2009) and the lithic assemblages recovered are small and typo-technologically uncharacteristic. Therefore, Tardiglacial age is possible but remains unconfirmed. Thus, a preliminary summary of the human occupation in the region between 14,000 and 8000 cal BP is feasible (Dean et al., 2011) but must bear this caveat in mind.

The trend towards microlitization starts with the Solutrean. The Tardiglacial industries are characterised by the exclusive use of local raw materials (quartz, graywacke, quartzite and flint) and are aimed at the expedient production of flakes and chips, the latter produced by bipolar debitage on anvil. Elongated blanks are rare and except for denticulated and notched bladelets there are no armatures (Mendonça, 2009). Two phases were identified in this region: Early/Middle Magdalenian and Final Magdalenian. A functional classification of the sites was proposed: Vale Boi would correspond to a base camp, Ponta Garcia and Vale Santo 4, where only surficial materials were identified, would correspond to procurement and knapping sites, and Lagoa do Bordoal and Praia da Galé would be temporary camps for the seasonal exploitation of hunting and aquatic resources (Bicho et al., 2010; Mendonça, 2009).

Barranco das Quebradas is located on a small coastal ravine perpendicular to a seashore characterized by limestone outcrops; five archaeological *loci* were discovered here. *Locus* 1 and *Locus* 3 belong to the earliest Holocene. The small, 40 to 120 cm-thick shell-midden deposits feature a limited number of uncharacteristic lithics; the mollusc taxa represented are *Monodonta lineata*, *Patella*, *Mytillus*, *Pollicipes* and *Thais haemastoma* species (Bicho et al., 2009, Stiner et al., 2003; Valente, 2008, 2010).

The Rocha das Gaivotas site is a shell-midden context featuring several occupations dating from the Early Mesolithic to the Early Neolithic. Interpreted as a raw material procurement site, located about 100 m from a flint source, Early Mesolithic layer 3 yielded two combustion structures and a very small number of artefacts. The predominant mollusc taxa are the same as at Barranco das Quebradas (Carvalho and Valente, 2005; Valente, 2010).

Castelejo, located between Barranco das Quebradas and Rocha das Gaivotas, has a human occupation dating to ca. 10,500 cal BP and is characterized by a very small number of lithics; besides molluscs, the faunal remains include fish and rabbit remains (Soares and Silva, 2004; Valente and Carvalho, 2009).

5. Art

Based on the five most represented themes in the Palaeolithic rock art of the Douro basin and the territory to the south of the Tagus River, a study applying multiple correspondence analysis and ascending hierarchical classification revealed the existence of at least four classes of horse and aurochs, as well as three classes of ibex, red deer stag and

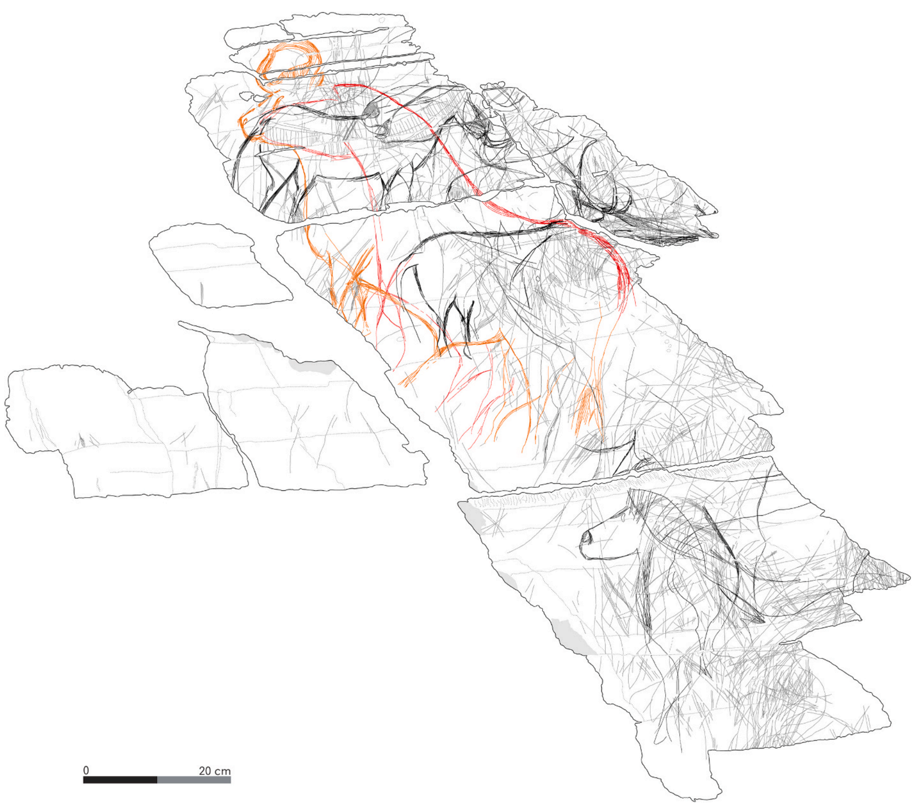


Fig. 13. - Fariseu rock 4 (drawing by Fernando Barbosa). Panel with phase 2 and 3 figures. Note the phase 2 horse (in red), reapropriated and partially superposed by a phase 3 male aurochs (in orange). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

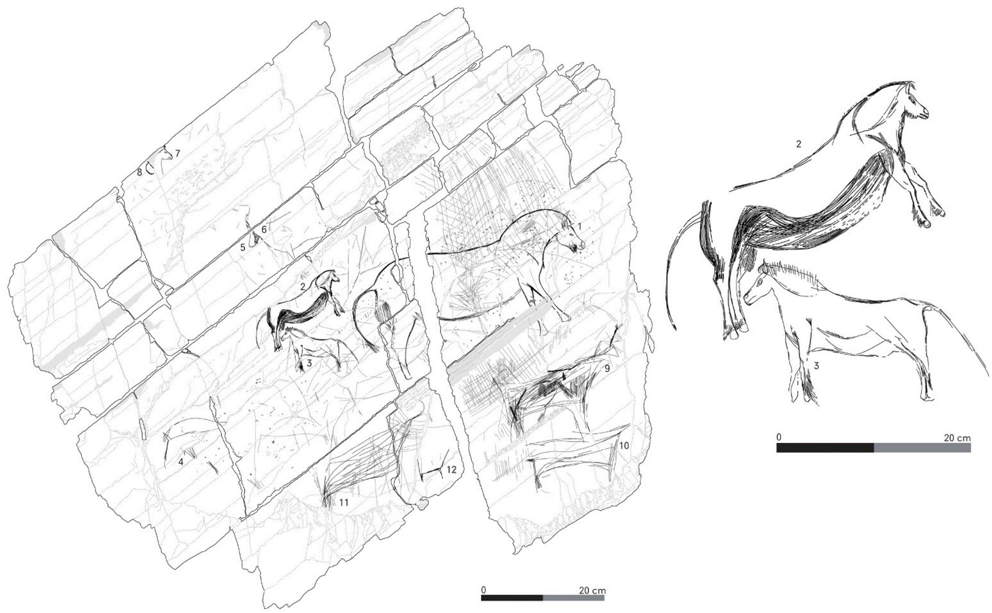


Fig. 14. Canada do Inferno rock 41 (drawing by Fernando Barbosa). Motifs 1 to 8 probably date from phase 3, while motifs 9 to 12 probably date from phase 4. Besides the differences in style, phase 4 motifs are situated on a marginal area of the panel, as compared to the other motifs, which confirms that phase 4 motifs were executed after the older motifs.

red deer doe depictions (Santos, 2017:136–164). The study of the parietal stratigraphy of rock art panels with more than one class and the sedimentary context of several sites in the Côa Valley allowed us to infer that these classes correspond to at least four phases of artistic production (Santos, 2017:129–255). In the scope of this article, we shall focus on phases 3 and 4.

Class 3 horses and aurochsen can be ascribed to Phase 3, as well as part of the ibexes, red deer stags and does of Class 2. These animal depictions feature naturalistic forms and well-proportioned bodies; the heads frequently show anatomical details (e.g., the mouth, ears, outlined nostrils, almond-shaped eyes). All four legs are usually represented, often in uni-angular profile. Hooves are also commonly represented, as are the chromatic variations of the coat and integument on heads and limbs. Incision is the most common technique, in its simple and repeated forms, although pecking and abrasion have also been identified (Santos, 2017:138–139, 144, 150, 155, 159, 163).

Phase 3 figures are usually found in panels where motifs from Phase 2 also occur. Nevertheless, it is sometimes difficult to accurately distinguish the figures of each phase, especially when dealing with red deer stags and does or ibexes. Actually, class 2 of these themes (red deer stags/does or ibexes) may belong to the same phases as the aurochsen (phase2) and horses (phase 3) of classes 2 and 3.

The cultural attribution of Phase 3 was based on stylistic comparison (Fig. 13). The most evident parallels are found in the Franco-Cantabrian region, in contexts ascribed to the Middle and Final Magdalenian (Santos, 2017: 233–245), generally corresponding to figures catalogued as "style IV" by Leroi-Gourhan (Leroi-Gourhan, 1995 [1965], 283–288). These representations are also very similar to an important group of figures, found in some portable rock art objects from the Magdalenian layer of Foz do Medal site (eg. Figueiredo et al., 2015a,b; Figueiredo et al., 2016), located in the Sabor Valley, approximately 27 km northeast of the Côa Valley. A *terminus post quem* is provided by the dating of Phase 2 to a period between the Upper Solutrean and the Magdalenian, based on style and geoarchaeological context (Santos, 2017:178–180).

Due to the low number of motifs from Phases 2 and 3, if considered separately, as well as the high frequency of rocks in which these phases occur together, their study was performed jointly (Santos, 2017:381–389). In the Côa Valley, the thematic distribution of this group is as follows: horse – 24.9%; aurochs – 19.8%; red deer stag – 14.5%; ibex – 13.6%; humans – 5.1%; red deer doe - 4%; chamois - 1%; feline – 0.6%. There are also isolated representations of fish, birds and perhaps bison. Indeterminate and incomplete figures reach 15.1%. If one adds to these figures the pre-existing depictions found in the same panels (Santos, 2017, vol. II, table 6.14), aurochs is the most represented motif (23.2%), followed by horse (22.3%), ibex (17.9%), red deer stag (11.4%), red deer doe (3.6%), humans (2.7%) and chamois (0.2%). The indeterminate and incomplete figures reach 16.1%. In relation to the preceding phases, the non-figurative repertoire increases and graphic units are more diversified (Santos, 2017, vol II, 485).

At Foz do Medal, the thematic distribution is somewhat different, mostly corresponding to caprine representations, followed by horses and aurochsen, red deer being very rare; humans are represented by a single figure (Figueiredo et al., 2015a:1576). Differences in relation to the Côa Valley parietal art may be due to several factors: only 92 figurative motifs occur in layer 1055 of Medal (as opposed to 470 in phases 2 and 3 of Côa), in which two different graphic facies may well be subsumed (Figueiredo et al., 2015a:1577).

The figures ascribed to Phase 3 denote important relations between Northern Portugal and the Cantabrian region. But, above all, they indicate a rupture of contacts with the South. In fact, representations broadly attributed to the Magdalenian in Southern Portugal (such as Fratel and Gardete in the northern bank of the Tagus River (Gomes, 2010:476), Porto Portel in the Guadiana basin (Baptista and Santos, 2013:220–226) and possibly some of the Escoural cave representations (e.g. Gomes, 2002) feature similar characteristics to depictions from Southern Iberia, where the sequence of Parpalló is an important reference (Villaverde Bonilla, 1994; Bicho et al., 2007).

Phase 4 animal depictions of the Douro basin are characterized by their geometrical bodies, often filled-in. The heads are represented without any internal detail. The four legs of the animals are usually represented in oblique or straight biangular perspective. Incision is the most common technique, both in the figures' outlines and in the filling-in of the bodies. Nevertheless, pecking, scraping and red painting also occur (Aubry et al., 2017:407–409). This type of rock art is well dated due to an important collection of portable art composed of 89 objects,

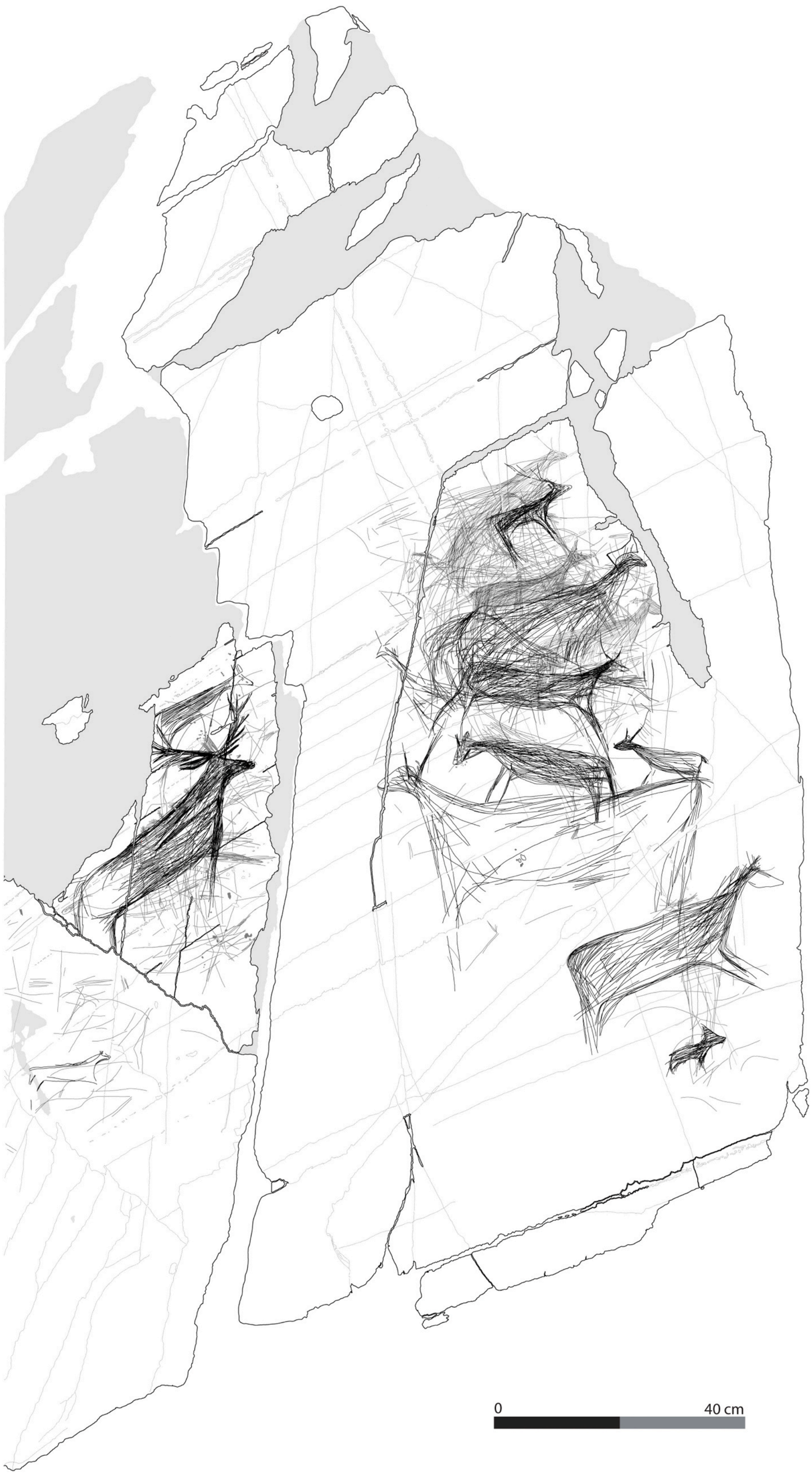


Fig. 15. Vale de José Esteves rock 13 (detail of a drawing by Fernando Barbosa). Note the prominence of the cervids, a characteristic of phase 4, to which this panel should be ascribed.

featuring the kind of representations we have just described. It was unearthed in Fariseu layer 4 and dated by radiocarbon, TL and OSL to between 12,000 and 10,000 years ago. In cultural terms, it is attributed to the Late Azilian (Santos et al., 2018).

Phase 4, which is very well documented in the Spanish northern sub-meseta (Bueno Ramirez et al., 2007), is also found in other sites of Northern Portugal, such as Pedra de Asma 7 in the Sabor Valley (Figueiredo, 2014:20–22). Given the morphological similarities between the incised figures of Côa Valley's Phase 4 and other pecked motifs from the north of Portugal, traditionally ascribed to the Holocene period, we consider that these animals all belong to the same period (Santos et al., 2018:54-55). Among them would be Cabeço do Aguilhão (Figueiredo et al., 2015b), Passadeiro (Sanches and Teixeira, 2014) and Parada (Teixeira, 2016). Some of these sites also feature deep incisions, locally called *unhadas do diabo* (lit.: the devil's scratches), which, according to some authors, can also be dated to this phase (Sanches and Teixeira, 2014).

As opposed to what happened during Phase 3, southern Portugal features a series of Phase 4 representations very similar to those we have been discussing. This is the case of some pecked figures of the Tagus Valley, namely those belonging to the old sub-phase of the naturalistic period, as defined by Varela Gomes (Gomes, 2007: 87, 91–102), as well as some incised figures of the Guadiana Valley, namely at Moinhola (Baptista and Santos, 2013:147–149) and Molino Manzánez (Collado Giraldo, 2006:224–225; Santos et al., 2018: 57). The "striated" figures of Escoural cave should also be attributed to this phase (Collado Giraldo, 2006:379; Santos et al., 2018:60).

The most represented animals during Phase 4 are red deer and ibex, in the Tagus Valley (Gomes, 2007:113) as much as in the Côa Valley (Santos et al., 2018:55–56). The latter is particularly relevant, because comparison with previous phases is possible. While the horse/aurochs pair, followed by ibex, dominates in the Magdalenian, the Azilian of Phase 4 is largely dominated by red deer (Fig. 15), followed by ibex.

Style change follows the same pattern. While Phase 3 has parallels in the Franco-Cantabrian zone, the Azilian graphic conventions are widespread across all of Southwestern Europe, from Portugal to Italy and from southern Spain to northern France (Santos et al., 2018:56–64). This graphical tradition seems to develop in Western Europe between 14,000 and 10,500 cal BP (Fig. 14) (Santos et al., 2018:68). Phase 4 may also have included schematic, not filled-in shapes (Santos et al., 2018:66). They have been identified, for example, in the Murat shelter of Southwest France (e.g. Lorblanchet, 1985, 1989, 1996), Peña de Estebanvella in the Spanish northern meseta (e.g. García-Díez, 2013) and eventually in the Côa Valley (Santos et al., 2018:66). Regarding the Medal collection, a recently initiated project intends to study the representations of layer 1055. Until the integral study of the collection is carried out, the characteristics of the most naturalistic representations against the more schematic ones, their respective numerical value and whether they correspond or not to the same moment are not clear, opening the road to multiple hypothesis, among them, the possibility that the transition between the most naturalistic figures and the more schematic ones could have occurred during the interstadial period.

6. Discussion

The existence of stratigraphic discontinuities between 20,000 and 18,000 cal BP and between 14,000 and 12,500 cal BP (Zilhão, 1997a) makes it more difficult to understand the diachronic variability of the lithic tool-kits and the paleoenvironment of the human groups who occupied the present-day Portuguese territory during the Tardiglacial. Although the number of known sites has increased significantly over the last 25 years, sites dated to the Early Magdalenian are still poorly known, the Franco-Cantabrian Middle Magdalenian (Langlais, 2007) remains uncharacterised and most sites are dated to the timespan of the Bølling/Allerød and Dryas III (Gameiro, 2012; Gameiro et al., 2013).

The pollen sequences of continental Portugal (Supplementary material - Table 1) document vegetation responses to the major climatic fluctuations of the Late Glacial and Early Holocene. Besides the expansion and retraction of woodlands, changes in their composition are also indicated by the available data, which are rather unevenly distributed across the territory. In most of the sequences, deciduous *Quercus* expands during the warm phases of the Tardiglacial and declines in the cold periods, during which pines were widespread. However, pine is the main taxa in Southwestern Portugal throughout the whole Pleistocene-Holocene transition, despite the variations in their overall percentage in the sequence and in the proportion of *Pinus sylvestris* and *Pinus pinaster*, the latter expanding during the warmer phases. The expansion of thermophillous taxa such as *Olea europaea*, *Pistacia* and *Arbutus unedo* during the warmer phases also shows considerable variation, depending on site location. Their significant and quick expansion during the Early Holocene is only justified by their survival in refugia throughout the territory during the colder phases, as documented by pollen and charcoal data.

The number of sites where a faunal record was preserved is very small (Supplementary material - Table 2), which hinders any interpretations of changes in subsistence strategies and the possible relationship with paleoenvironmental evolution. However, the study of faunal assemblages from cave sequences such as Caldeirão (Davis, 2002; LLoveras et al., 2011), Lapa do Suão (Haws and Valente, 2006), Lapa do Picareiro (Bicho and Haws, 2012) and Lapa dos Coelhos (Gameiro et al., 2017) allowed us to observe, after the Solutrean, a decrease in the variability of the represented species and an increase of fish, as well as birds, and small mammals, particularly rabbits (*Oryctolagus cuniculus*), reaching percentages above 90% in the Final Magdalenian levels of Lapa dos Coelhos for example (Gameiro et al., 2017). This has already been pointed out (Davis, 2002, 2019; Hockett and Haws, 2002; Stiner et al., 2003; Zilhão, 1997a): « *the emphasis on rabbits may have been the result of changes on their ecology as well as of the invention of new hunting technologies (such as snares or nets) or of an increase in human population numbers*» (LLoveras et al., 2011:2448). Deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) are also present during the Magdalenian and continue to represent a significant proportion of the hunted game in interior areas until the Early Mesolithic (Araújo et al., 2014; Araújo, 2016b; Carvalho et al., 2016), when marine and estuarine species occur but on coastal areas only (Dupont and Araújo, 2010; Araújo, 2016a). It has been proposed that, during the Magdalenian, settlement and subsistence strategies would be closer to the forager type, as opposed to the collector-oriented strategies of the Solutrean (Zilhão, 1997a).

These changes in diet and in subsistence strategies, as well as the appearance of new technologies, should had have an ideological impact, of which the thematic changes in art between the Magdalenian and the Azilian is the more evident feature. In fact, red deer not only becomes the most depicted species, but for the first time a single species dominates the graphic corpus by far (aurochsen, ibexes and horses are represented in similar numbers during the Gravettian and the first half of the Solutrean, the same happening with horses and aurochsen during the phases dated to between the Upper Solutrean and the final Magdalenian).

Inter-regional comparisons (Table 4) are only available for the Final Magdalenian. Based on the archaeological record from different regions, recent studies (Gameiro, 2012) have argued that regional variability reflects the adaptation of local groups to different raw material environments, but it has been demonstrated that some technological options were, nonetheless, maintained during the Tardiglacial for extensive periods of time. Moreover, variability in the typology of microliths might relate to the last phase of transformation (i.e. retouch) rather than to blank production strategies (Gameiro, 2012; Gameiro et al., 2013). The use of cores-on-flakes (burin or carinated endscraper type) increased from 20,000 to 11,000 cal BP. The use of this debitage strategy enables an efficient production of longer, narrower but thicker bladelets, naturally pointed and with a straight profile. This increase was accompanied by a typological diversification of armatures.

The use of cores-on-flakes has not been identified in Fariseu layer 4 (Côa Valley) and in the sites of the Guadiana Basin (Malhada do Mercador I and Monte da Ribeira) it does not reach the proportions recorded in the Estremadura sites. In the Sabor, Côa and Vouga Valleys and in the Guadiana Basin, the predominant use of quartz to make small microlithic blanks (bladelets and chips) explains the use of bipolar debitage on anvil, which is effective in these cases (Fig. 10: 4). The use of hyaline quartz crystals for bladelet production (Fig. 8: 5 and Fig. 9: 1–3) was identified in the Sabor (Gaspar et al., 2016a), Côa and Vouga Valleys (Gameiro, 2009, 2012; Gameiro et al., 2018); this strategy was also identified in these regions during the various phases of the Gravettian (Aubry, 2009; Klaric, 2009; Gameiro et al., 2018). In the Guadiana Basin, lydite and jaspers, sometimes gathered in the form of small slabs, were also similarly exploited, from a natural edge or dihedral (Gameiro, 2012; Almeida et al., 2013). Probably, this use of natural edges or dihedrals, requiring no more than the preparation of the striking platform, attests to the same technical concept: minimum preparation of the volumes for maximum profitability in the production of small, easily transportable blanks. With regards to differences in technical use, there appears to be an increase in the use of soft-stone hammers (Gameiro, 2017) and pressure retouch (Gameiro, 2012) from the Final Magdalenian onwards.

7. Conclusions

Concerning the transition between the end of the Pleistocene and the beginning of the Holocene, opinions have been divided between researchers who observe a technological rupture at an earlier moment (ca. 11,500 cal BP) (Zilhão, 1997a) and others who see continuity until 10,000 cal BP (Bicho and Haws, 2012). The use of the territory and subsistence options seem to reflect more variation, probably correlated with environmental changes. The expansion of forests and the increase of flooded areas, originated by sea rise, favoured costal circulation, as can be inferred from Early Holocene site location and subsistence choices (Araújo, 2016a, 2016b).

Taphonomic issues must be taken into account as well, such as the differential preservation of bone tools, which are fundamental in the phasing of the Franco-Cantabrian area, but also the role of rates of sediment accumulation and of climate oscillations between the cold phases of GS-1 (Rasmussen et al., 2014). The existence of sedimentary hiatus, the difficulties in discerning the contemporaneity of human occupations due to a radiocarbon plateau (Naudinot et al., 2019), the absence of radiocarbon dates for some of the sites, the existence of assemblages featuring uncharacteristic industries and, above all, the non-existence of a complete stratigraphic sequence covering the Pleistocene-Holocene transition (14,000 to 10,500 cal BP) keep us from attaining a more accurate understanding of this transition period.

Nevertheless, in terms of armature typology, a four-stage sequence can be discerned: 1) Upper Magdalenian with axial points rather than backed bladelets, quite common in previous phases; 2) Final Magdalenian with an increase in the diversity of armature types; 3) Azilian with geometric microliths, curved backed points (Azilian points) and Malaurie points, and 4) Early Mesolithic without retouched bladelet tools or, at best, a persistence of Azilian armature types. For the time being, there does not seem to be enough resolution to confirme a Late Azilian phase (with curved backed points) followed by a Laborian phase (with Malaurie points), as previously suggested (Aubry et al., 2017).

It has been said that after 14, 500 cal BP lithic industries show a tendency towards regionalization and follow different evolution lines, as compared to the rest of SW Europe (Zilhão, 1997a,b). Nevertheless, the effects of GS-1 climatic change might have restored extra-regional contacts allowing the import of typologies from other regions (Aubry et al., 2017). Blank production strategies remain similar between Final Magdalenian and Azilian but armature typology displays types suggestive of contacts and closer relationships with a broader region of Southwestern Europe: curved backed points (Azilian points) and backed and truncated points (Malaurie points) are present. Another (rare) example would be the Ahrensburg point (Fig. 11) recovered at the Vau site. On the other hand, the Early Holocene period seems to be characterized by a trend towards regionalism: simple expeditive debitage using local raw materials.

The expansion of contacts during GS-1 (Rasmussen et al., 2014). is also evident in art. In fact, as referred above, a striking morphological contrast between the northern Iberian animal depictions and their souhern counterparts can be observed during the Magdalenian. In Côa and Sabor, as in the Franco-Cantabrian zone, the naturalistic shapes attached to Leroi-Gourhan's style IV are common, while in the southern sites of Portugal, as in the remaining meridional sites of the Iberian Peninsula, no such figures are known to exist. During GS-1 however, the same animal figures with geometric bodies, generally filled-in, are found not only in the northern and southern sites of Iberia but also in other regions of Southwestern Europe (Santos et al., 2018).

This overview of the Late Pleistocene-Holocene transition in the Western façade of Iberia aims to summarize existent data but also to demonstrate that, despite the significant enhancement of research during the last twenty-five years, we still don't have enough data to accurately characterise the beginning of the Holocene.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quaint.2020.03.018.

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