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Osseous industry and exploitation of animal resources in Southern Iberia during the Upper Palaeolithic

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ABSTRACT

During the Upper Palaeolithic, several climatic events were recorded in some archaeological sites in the Southern Iberian Peninsula. The aim is to focus on the relations between those phenomena and the mammal species hunted by hunter-gatherers groups, and whose bones were used, along with lithics, as raw material for manufacturing their bone toolkits. Hunter-gatherers seemed to have had a preference on hunting ungulates species that are gregarious such as red deer and goat, one of the characteristics of the faunal assemblages from the archaeological sites located near the coastal zones, including Vale Boi and Cendres in Southern Iberia. Regarding their toolkits, there was a preference in choosing mammal bone for the manufacture of their hunting and fishing equipment, as well as other utensils of daily life, during the Gravettian and Solutrean. Hunter-gatherers were preferably hunting juvenile and female red deer that do not have antlers. The opposite occurred during the Magdalenian, where red deer antler was used much more as a raw material. The Final Magdalenian and Epimagdalenian saw a decrease in the quantities of osseous artefacts and even a total absence of harpoons in Southern Iberian archaeological assemblages.

1. Introduction

Since the Lower and Middle Paleolithic, humans took advantage of fragments and splinters of osseous materials as expedient tools (Gaudzinski, 1999; Pathou-Mathis, 1999; Backwell and d'Errico, 2001; Sponheimer et al., 2005; Tartar, 2009). However, it was only in the Upper Paleolithic, in Europe, that these raw materials became an important technological element, used in the manufacture of several kinds of tools that hunter-gatherers used in their daily tasks (Gaudzinski et al., 2005; Rosell et al., 2011).

They used bone splinters, resulting from butchering processes and marrow fracturing; extracted portions of cortical bone directly from large mammal bones; knapped and extracted large elements from antlers, gathered in the wild from shedding or resulting from hunting male red deer. The mechanical properties of these raw materials were recognized, as they react differently to impact and use. The artisan knew, by transmission of knowledge and self experience, which raw material should be used to manufacture a tool for a predetermined function, such as needles made from cortical bone or wedges made from antler (Tartar, 2009; Borao Alvarez, 2010). The aim of this paper is to focus on the cultural and stylistic similarities between hunter-gatherers bone toolkits through the kind of mammal species that were hunted and the relation to the changing climate and environments.

2. Geography and regional paleoenvironments

For the present analysis, the geographic area of interest is southwestern Iberia, which includes the regions of Algarve (Portugal), Andalucía, Murcia and Valencia (Spain). Fig. 1 shows the location of the archaeological sites mentioned in the text.

The Iberian Peninsula climate is influenced by the Atlantic Ocean in its western margins and in the eastern and southern parts is influenced by the Mediterranean Sea, where its waters encounter the colder Atlantic waters in the Strait of Gibraltar. The peninsula has great landscape variations due to altitudinal differences, microenvironments, mountain ranges, and vegetation. The southern part is constituted by the South Meseta and several mountain ranges: the Sierra Morena, the Betic System, Penibetic System and Sub-Betic System, and several major rivers such as the Guadalquivir with its major sedimentary basin located SW of the Betic mountain range (between Portugal and Spain), Genil, Segura, and Jocar, and other affluents such as Guadalentin, Almanzora, Cañoles and Serpis (Beazley and McNally, 1982).

The concepts of climatic evolution referring to the Upper Palaeolithic from North and Central Europe have to be carefully applied to Southern Iberia due to its geography, which is not

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Fig. 1. Geographic location of the archaeological sites with bone tools industry mentioned in the text.

homogeneous, having some refuge areas for both paleovegetation and fauna. Pollen deposition inside caves may reflect the vegetation from a wide area beyond the sites and by doing so may provide an index of local and regional vegetation (Carrión and Munuera, 1997). However, there are taphonomical agents to take into consideration, namely the cave sedimentation, differential preservation of pollen, the infiltration of waters inside the cave, and humans and animals frequenting the cave. All these aspects may create a mixture of pollen from different periods of time (Sánchez Goñi, 1993).

In their pollen analysis from the Cova Beneito (Alicante) archaeological site, Carrión and Munuera (1997) divided the sequence in 6 zones covering the time from the Middle Palaeolithic to the Solutrean. The beginning of the Gravettian cultural period (zone E1) saw an increase of *Poaceae*, *Chenopodiaceae*, *Artemisia*, and *Ephedra distachya* pollen percentages from the older Aurignacian cultural period. *Pinus* pollen percentage is not constant and *Quercus*, *Ericaceae*, and *Juniperus* are almost absent in Zone E1.

For the Solutrean cultural period (zone E2), the pollen sequence registers rises of *Poaceae*, *Chenopodiaceae*, and *Artemisia*. *Ericaceae* is also present, and other Mediterranean shrubs start to have higher frequencies by the end of the Solutrean. Deciduous *Quercus* has a constant presence but in lower percentage, becoming higher by the end of the Solutrean. *Juniperus* and *Pinus* are also present but with a minimum representation. This pollen concentration of *Pinus* together with high values of *Poaceae* pollen could indicate aridity changes and a steppe landscape during the Solutrean in this region (Carrión and Munuera, 1997).

For the Magdalenian cultural period, another archaeological site, El Pirulejo (Córdoba), provides information on paleovegetation (López Sáez et al., 2008). The Mediterranean Middle Magdalenian (sample 1) is marked by the presence of *Pinus pinea*, *Pinus sylvestris*, *Quercus caducifolios*, *Quercus perennofolios*, and *Castanea*, *Juglans*, *Betula*, *Alnus*, *Salix* and *Ulmus*. The Mediterranean shrubs present are *Erica arborea*, *Philyrea*, *Labiatae*, *Olea*, *Rhamnus*, *Pistacia* and *Myrtus*. The tree pollen is relatively low but diversified, showing an open landscape with xerophilous herbaceous species and shrubs.

The authors consider the samples 4 to 8 and 9 to 15 together as representatives of the Tardiglacial Bölling-Alleröd Interstadial (12000–15500 BP). During Bölling (samples 4–8), *Quercus perennifolios* and *Quercus caducifolios* are present, as well as *Pinus pinea*, *Betula*, *Alnus*, *Salix* and *Ulmus*. On the other hand, *Erica arborea*, *Philyrea*, *Rhamnus*, *Olea*, *Labiatae*, *Myrhus* and i all are less represented. In the herbaceous vegetation, *Caryophyllaceae* and *Artemisia* become less frequent. For the samples 9 to 15, corresponding to the Alleröd, the pollen percentages are a continuum of the preceding 4 to 8 samples, with some few exceptions such as *Caryophyllaceae* and *Artemisia* that almost disappear. This picture may indicate a more temperate climate with forest being reduced or localized at higher altitudes and the steppe areas progressively disappearing.

Region	Algarve			Andalucia				Valencia		Biomes
Assemblage	M	S	G	M	S	S / G	G	M	S	
Taxon NISP										
Ungulates										
Bos primigenius	*	****	**	~	*	~	*	*	~	woodland
Equus hydruntinus	~	~	~	~	~	~	~	*	*	
Equus caballus	**	*****	****	*	****	**	*	**	**	grassland / forest
Eqqus sp.	*	***	**	~~	~	~	~	~	*	
Cervus elaphus	****	******	*****	****	*****	***	**	*****	****	woodland
Sus scrofa	~	*	*	***	**	~	~	*	~	varied
Capra pyrenaica	~	*	*	*****	******	*****	****	****	***	rocky mountains
Rupicapra rupicapra	~	~	~	~	~	~	~	*	~	rocky mountains
Capreolus capreolus	~	~	~	*	**	~	~	~	~	woodland
Carnivores										
Vulpes vulpes	*	*	**	~	**	~	~	~	~	varied
Canis lupus	~	*	*	~	**	~	~	*	~	varied
Canis sp.	~	*	*	~	~	~	~	~	~	
Panthera leo	~	*	*	~	~	~	~	~	~	varied
Linx pardinus	*	*	*	*	**	~	*	***	**	woodland
Felix sylvestris	*	**	**	*	***	*	*	*	*	varied
Mustela sp.	~	*	*	~	~	~	~	~	~	semi-aquatic / bank rivers
Martes sp.	~	*	~	~	~	~	~	~	~	open forest / rocky mountains
Small mammals										
Oryctolagus cuniculus	****	******	******	******	******	******	****	******	******	forest / woodland
Microtus sp.	*	*	*	~	~	~	~	~	~	grassland / woodland
Lepus sp	~	~	~	~	~	~	~	***	*	
Marine Mammals										
Cetacea	~	~	*	~	~	~	~	~	~	
Delphinus delphi	~	~	~	**	~	~	~	~	~	coastal waters
Monachus monachus	~	~	~	*	~	~	~	*	~	coastal waters

Note: ~ (n=0); * (n=<10); ** (n=< 50); *** (n=<100); **** (n=<500); ***** (n=<1000); ****** (n=>1000);
M = Magdalenian, S = Solutrean, G = Gravettian

Fig. 2. Exploited animal resources by geographic region and chronology: Algarve (Manne, 2010), Andalucia (Aura et al., 2002; Riquelme, 2008; Yravedra, 2008) and Valencia (Aura et al., 2002).

The rest of the samples (13, 14 and 16) have different pollen percentages, including *Quercus perennifolios*, *Erica arborea*, *Quercus caducifolios*, *Betula*, *Alnus*, *Pinus pinea* and *Pinus sylvestris*. The Mediterranean shrubs, besides *Erica arborea*, have low frequencies of pollen. The herbaceous vegetation is represented by *Urtica dioica* and *Artemisia*. These samples show a clear progression of wooded land and a gradual rising of temperatures (López Sáez et al., 2008).

From Cueva Bajondillo (Torremolinos) a total of 103 pollen samples were recovered in 2000 that came from all stratigraphic levels documented in the cave, located in the west profile of the archaeological site (López Sáez et al., 2007; Fierro Enrique et al., 2011). The sequence goes from Bj/19 to Bj/1, covering the Middle Palaeolithic to the Neolithic. Level B/10 (24,344 ± 2653 BP) is related to Gravettian cultural period, and its pollen record shows a predominance of the herbaceous vegetation (>80%). For levels Bj/9 (18,701 ± 2154 BP), Bj/8 (17,582 ± 1521 BP) and Bj/7 (16,438 ± 1497 BP) corresponding to the Solutrean cultural period, the predominance of herbaceous vegetation continued. The trees and shrubs are less frequent than the herbaceous vegetation in the pollen record, but there is a higher frequency of *Pinus* than in level Bj/10, which may indicate more arid and dry conditions during the beginning of the Solutrean.

In levels Bj/6 (Solutrean) and Bj/5 (Magdalenian?) the pollen record shows a higher frequency of trees (60%) and shrubs (20%), and a decrease in herbaceous vegetation that started by the end of level Bj/7 (70%) to 40% in Bj/6 (López Sáez et al., 2007).

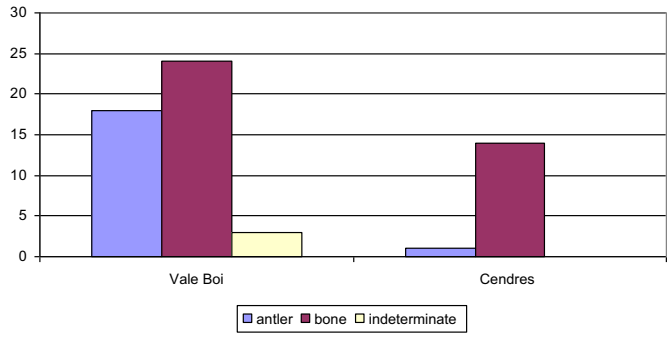

Fig. 3. Gravettian bone tools raw-material.

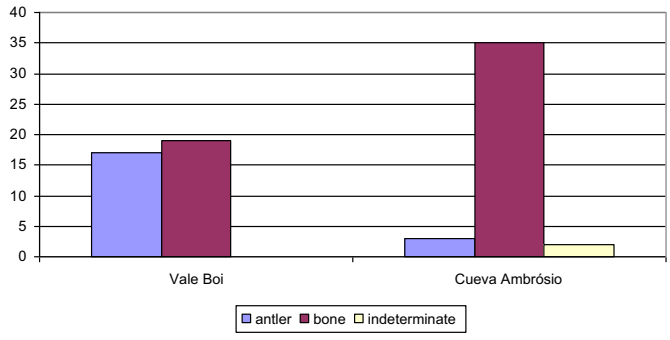

Fig. 4. Solutrean bone tools raw-material.

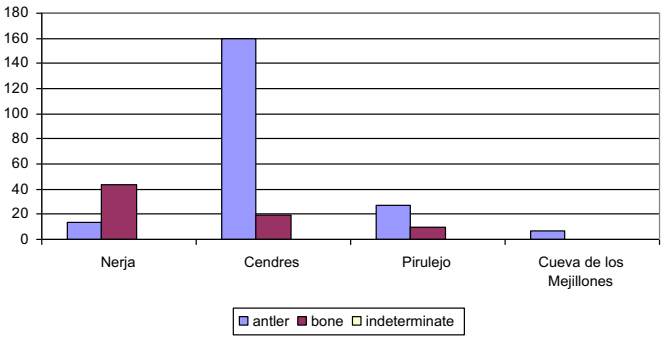

Fig. 5. Magdalenian bone tools raw-material.

It is important to link the terrestrial pollen analysis with pollen analysis of deep sea marine sediments, for they provide direct land–sea correlations (Fletcher et al., 2010). The western Mediterranean Sea was very sensitive to the rapid climatic and oceanographic glacial variability in the North Atlantic region (Sánchez Goñi et al., 2002). The analysis of the IMAGES core MD95-2043 collected in the central Alboran Sea (Fig. 1) presents a high resolution record of the last glacial period for Southwestern Iberia (Sánchez Goñi et al., 2002). The marine core MD95-2043 show that during the Gravettian there was alternating phases of forest development and warming of Sea Surface Temperature (SST), and semi-desert expansion together with cooling of the SST. During the interstadials, an expansion of deciduous and evergreen *Quercus* occurred, contrasted with the expansion of *Artemisia*, *Ephedra distachya type* and *Chenopodiaceae*, corresponding to semi-desert vegetation, which developed during the stadials (Fletcher and Sánchez Goñi, 2008). In the Solutrean, the core has low concentrations of pollen, but nevertheless showing an open landscape with *Artemisia*, *Cupressaceae* shrubs, some deciduous and evergreen *Quercus* were still present, in low frequencies, in some refuge areas of Southern Iberia. During the Last Glacial Maximum (LGM), the marine pollen record also shows a slightly more humid condition that permitted the development of *Ericaceae* and other shrub vegetation (Fletcher and Sánchez Goñi, 2008). During the Magdalenian, a contraction in the semi-desert vegetation of *Artemisia* and *Ericaceae* is noted and a development of deciduous and evergreen *Quercus* forest with the warming of the STT. During the Younger Dryas stadial, a re-expansion of semi-desert vegetation occurred, along with a cooling of the STT and a less marked contraction of the forest (Fletcher and Sánchez Goñi, 2008). In the beginning of the Holocene, a great expansion of *Quercus* evergreen forest was recorded together with *Artemisia* and *Cupressaceae* shrubs.

The terrestrial and marine pollen records show a rapid forest development during the interstadials for Southern Iberia, and an expansion of semi-desert vegetation during the stadials together with forest contractions. During the Gravettian, the climate would be very dry but cold with the expansion of herbaceous vegetation. By the beginning of the Solutrean this climate would continue, with higher frequency of herbaceous vegetation indicating an arid and cold climate but also rainy, due to the presence of *Pinus*. In the Magdalenian, there was recovery of woods, indicating the climate would have more rainy conditions and higher temperatures. This dynamic vegetation alternation is a response to the stadial and interstadial climate variability (Fletcher and Sánchez Goñi, 2008).

3. Hunting strategies and the bone tools assemblages

In Southern Iberia, hunter-gatherers were adapted to the topographic conditions, where short distances separate the littoral plain from mountain areas. During the Last Glacial Maximum, the regression of the sea level was as much as −130 m to −140 m below

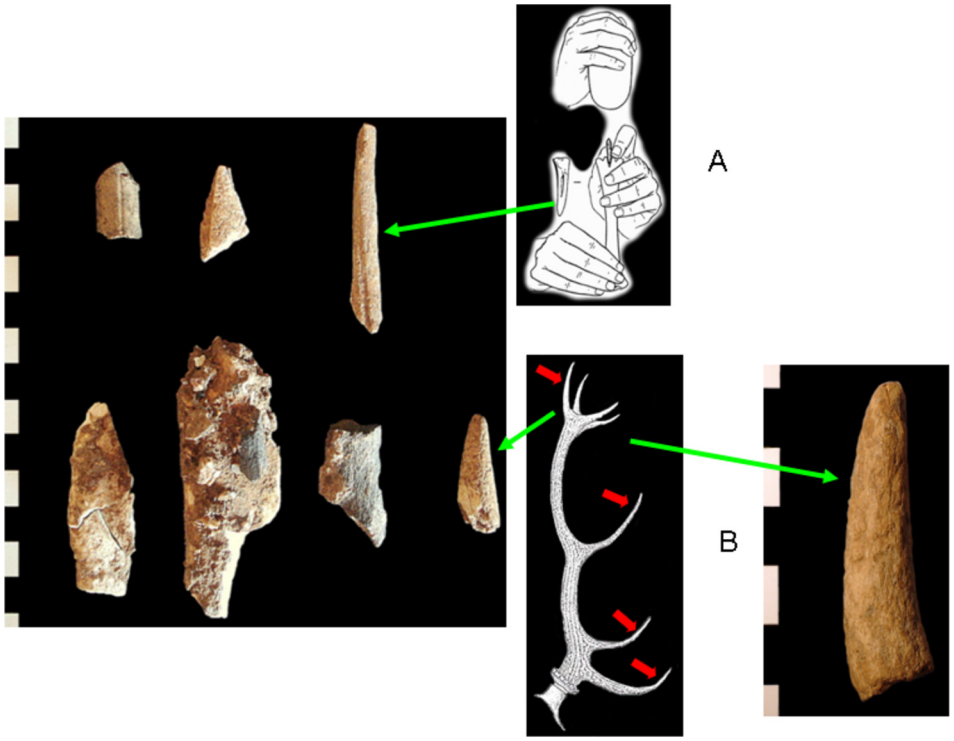

Fig. 6. Vale Boi debitage methods and techniques: A) bipartition of mammal long bone; B) direct percussion and flexion of antler tines. (Photos by ME).

Fig. 7. Mammal rib with traces of direct percussion and flexion, Ambrosio cave. (Photo by ME).

the modern shore line (Dias et al., 2000; Zazo et al., 2008), thus leaving a large area of the continental shelf uncovered. By 16 ka it rose until it reached −100 m, and later by the end of the Magdalenian the sea level was −40 m (Dias et al., 2000; Villaverde Bonilla et al., 2012) (Fig. 1). Thus, hunter-gatherers became capable of exploit the different habitats, taking advantage of resources inland and in coastal margins.

Hunter-gatherers seem to have chosen to hunt preferably ungulate species that are gregarious, that do not migrate over long distances (as do reindeer, for instance): groups of goats and red deer, especially females and juveniles (Tables 1 and 2). That seems to be a characteristic of sites located near the coastal zones, such as Vale Boi (Manne, 2010), Cendres, Beneito, and Cova Negra (Aura Tortosa et al., 2002) but also Ambrosio cave, located 60 km from the present coastline (Yravedra Sainz de los Terreros, 2001a,b, 2008). On the other hand, Parpalló has great quantities of knapped red deer antler, because here hunter-gatherers were hunting sub-adult and adult males with a large percentage of old and young individuals (Aura Tortosa et al., 2002; Asquerino Fernández and Riquelme Cantal, 2005). From the analysis of several faunal assemblages from Spanish archaeological sites of Southern Iberia, Yravedra Sainz de los Terreros (2001a,b) concluded that during the Gravettian there were fluctuations on the hunted species according to the location of the archaeological sites. Wild goat was the most hunted animal followed by red deer and horse, with the exception of rabbit, present in higher frequencies during all of the Upper Palaeolithic. During the Solutrean and Magdalenian, the hunting strategies became more focused on goat or red deer, depending on the location of the archaeological sites. There is a predominance of adults, but also some juveniles and infants are present in the faunal assemblages (Tables 1 and 2) (Yravedra Sainz de los Terreros, 2001a,b, 2008; Manne, 2010, 2012; Villaverde Bonilla et al., 2012).

Fig. 8. Antler debris with traces of direct percussion, Ambrosio cave. The arrows indicate the location of the impacts. (Photo by ME).

There is a certain preference for a specific taxon, but it is dependent on the environmental constraints. In Andalucía, the archaeological sites are located in mountain areas (Yravedra Sainz de los Terreros, 2001a,b), and in Portugal, Vale Boi is located near a fluvial valley (Fig. 1). At Vale Boi site, in southwestern Portugal, during the Gravettian the most hunted species was rabbit, followed by ungulates, red deer and horse (Manne, 2010). In the Solutrean, the ungulate species most hunted continued to be red deer, horse, and also auroch (Manne, 2010). There was a decrease in the hunting of red deer and horse during the Magdalenian, as well as rabbit (Manne, 2010). The goat was present during the Gravettian and Solutrean, but always in lower frequencies (Manne, 2010) (Fig. 2).

Table 1
Vale Boi horse and red deer age profile; a indicates that the sample size is too small for a reliable calculation (following Manne, 2010).

Assemblages/ taxon	Total MNE	Juveniles (%)	Prime adults (%)	Old adults (%)
Red deer				
Gravettian	8a	12.5	75	12.5
Solutrean	13	15	85	0
Horse				
Gravettian	4a	25	50	25
Solutrean	12	25	67	8

Table 2
Ambrosio cave faunal assemblage age profile (following Yravedra, 2008).

Assemblage taxon	Middle Solutrean			Upper Solutrean		
	MNI	A-J-I	%	MNI	A-J-I	%
Bos sp	1	1-0-0	0.1			
Equus caballus	14	11-1-1	1.6	11	7-4-0	2.6
Cervus elaphus	5	3-1-1	0.6	3	2-1-0	0.7
Sus scrofa	1	1-0-0	0.1	2	1-1?-0	0.5
Capra pyrenaica	31	28-2-1	3.6	14	11-2-1	3.2
Capreolus capreolus	1	1-0-0	0.1	1	1-0-0	0.2
Felix silvestris	2	2-0-0	0.2	1	1-0-0	0.2
Lynx pardina	2	1-0-1	0.2	1	1-0-0	0.2
Canis lupus	1	1-0-0	0.1	1	1-0-0	0.2
Vulpes vulpes	1	1-0-0	0.1	2	1-0-1	0.5
Lagomorfos indet	795	793-1-1	93.3	395	392-2-1	91.6
Total	852	842-5-5		431	418-10-3	

The sites from Southern Iberia that were used in this study are those that have their bone tools assemblages published and the raw material discriminated: Vale Boi (Évora, 2008), Nerja (Aura Tortosa, 1995), El Pirulejo (Cortés-Sánchez et al., 2008), Cueva Ambrosio (Ripoll López, 1988), Cueva de los Mejillones (García del Toro, 1985) and Les Cendres (Villaverde and Roman, 2004)

Fig. 9. Double grooving on antler blank, Ambrosio cave. (Photo by ME).

Fig. 10. Double grooving on antler blank (×10 magnification), El Pirulejo. (photo by ME).

(Tables 3, 4 and 5). Parpalló is an exception: although Aura Tortosa (1995) published an extensive analysis of its Magdalenian bone industry, the raw material used to manufacture that industry is not discriminated. The Gravettian and Magdalenian bone industries from Parpalló are presently under reanalysis (M. Borao, personal communication), the osseous industry from El Pirulejo and C. Ambrosio are being reviewed, and the bone industry from Vale Boi is presently under study. In the discriminated tools present at Tables 3, 4 and 5, the item "debris" includes debitage debris, blanks and preforms, because, with the exception of Magdalenian bone industry from Cendres and the bone industries from Vale Boi, from the reports of the other archaeological sites, there is no discrimination of these artefacts, so they are all included in the same item.

Table 3
Gravettian bone tools (Villaverde and Roman, 2004; Évora, 2008).

Vale Boi			Cendres		
Tool	Antler	Bone	Tool	Antler	Bone
Projectile	9	10	Projectile	1	14
Baguette	0	0	Baguette	0	0
Handle	0	0	Handle	0	0
Spatula	0	0	Spatula	0	0
Needle	0	0	Needle	0	0
Awl	2	1	Awl	0	0
Harpoon	0	0	Harpoon	0	0
Fishhook	0	1	Fishhook	0	0
Tube	0	0	Tube	0	0
Wedge	0	1	Wedge	0	0
Debris	7	11	Debris	n.i.	n.i.

Note: n.i. = not indicated.

Table 4
Solutrean bone tools (Ripoll, 1988; Évora, 2008).

Vale Boi			Cueva Ambrosio		
Tool	Antler	Bone	Tool	Antler	Bone
Projectile	3	3	Projectile	1	12
Baguette	0	0	Baguette	0	0
Handle	0	1	Handle	0	0
Spatula	0	1	Spatula	0	3
Needle	0	0	Needle	0	2
Awl	0	0	Awl	0	13
Harpoon	0	0	Harpoon	0	0
Fishhook	0	0	Fishhook	0	0
Tube	0	0	Tube	0	0
Wedge	0	0	Wedge	0	1
Debris	14	14	Debris	2	4

Table 5
Magdalenian bone tools (García del Toro, 1985; Aura, 1995; Cortés et al., 2008; Borao, 2010)

Nerja			Cendres			Pirulejo			Mejillones		
Tool	Antler	Bone	Tool	Antler	Bone	Tool	Antler	Bone	Tool	Antler	Bone
Projectile	10	24	Projectile	35	0	Projectile	13	5	Projectile	4	0
Baguette	1	1	Baguette	6	0	Baguette	6	3	Baguette	0	0
Handle	0	0	Handle	0	0	Handle	1	0	Handle	0	0
Spatula	0	0	Spatula	0	0	Spatula	0	0	Spatula	0	0
Needle	0	14	Needle	0	9	Needle	0	0	Needle	0	0
Awl	0	2	Awl	0	2	Awl	0	0	Awl	0	0
Harpoon	3	0	Harpoon	10	1	Harpoon	0	0	Harpoon	3	0
Fishhook	0	2	Fishhook	0	0	Fishhook	0	0	Fishhook	0	0
Tube	0	1	Tube	0	2	Tube	0	0	Tube	0	0
Wedge	0	0	Wedge	0	0	Wedge	0	0	Wedge	0	0
Debris	n.i.	n.i.	Debris	109	5	Debris	7	2	Debris	n.i.	n.i.

Note: n.i. = not indicated.

The faunal assemblages from Vale Boi, Ambrosio and El Pirulejo are highly fractured. This characteristic makes the identification of the original mammal bone from which the osseous artefact was made almost impossible. The completed modified artefacts have lost all the bone diagnostic features that could indicate its origin.

The acquisition of mammal bone as raw material is related to food activities, resulting from bone fracturing for marrow extraction. Hunter-gatherers could choose to collect some bone splinters after the butchering of the animal carcasses, modifying them into different shapes and sizes, until the desired tool was made (Évora, 2013). This is corroborated by the faunal analysis from some of the archaeological sites where bone greasing was practiced, such as Vale Boi (Manne et al., 2003, 2010, 2012) and Cendres (Villaverde et al., 1998; Aura Tortosa et al., 2002; Borao Alvarez, 2010). At those sites, there is an intensive large game carcass fragmentation, and most of the mammal bones were fractured by direct percussion to extract bone marrow (Yravedra Sainz de los Terreros, 2001a,b; Hockett and Haws, 2009; Manne and Bicho, 2009).

The exploitation of the cortical tissue by prehistoric hunter-gatherers was directly related with the manufacture of their tool-kits and to the economic activities they performed, including hunting medium and small mammals, fishing and other daily tasks. As can be seen in Fig. 3, in the Gravettian layers from Vale Boi and

Fig. 11. Bone tools from Vale Boi. (Photo by ME).

Cendres sites the preference in the raw material was mammal bone for the manufacture of pointed tools including projectiles and spearheads (Table 3). Bone was also preferable to antler in the manufacture of projectiles, spearheads, and awls during the Solutrean, even more in Ambrosio than in Vale Boi, for here bone and antler were used almost in the same quantities (Fig. 4 and Table 4). This is probably due to the fact that the most hunted species were the wild goat, and female and juvenile red deer. The mechanical properties of the mammal bone makes it a preferred raw material to manufacture tools that are intended to be used with the application of pressure, including awls and needles. The reduced amount of other types of tools does not allow further conclusions. Antler, however, is present as debitage debris, which indicates that hunter-gatherers used it to manufacture some of their toolkit. On the other hand, in Magdalenian layers from Cendres, Pirulejo and Mejillones sites, antler was the preferred raw material (Fig. 5) to manufacture pointed tools such as harpoons, projectile and spearheads. Due to its mechanical properties, it resists direct impacts better than mammal bone. Mammal bone continued to be used in the manufacture of needles, awls and fishhooks (Table 5).

The low frequency of bone tools in some of Southern Iberian archaeological sites, when compared with archaeological sites from the north, is likely not related to bone preservation, as most of the sites have faunal assemblages. This is not the reason for lower bone tool frequency at a site. One reason may be that not all sites are residential sites, but logistical. Thus, hunter-gatherers may not manufacture bone tools at the site, but rather carry them

Fig. 12. Awl (mammal bone),Vale Boi. (Photo by ME).

Fig. 13. Awl (mammal bone), Ambrosio cave. (Photo by ME).

in their toolkit to the site (Évora, 2013). Some of the osseous projectiles recovered in these residential and logistical sites could have been brought inside the animal carcasses that were then processed in the site and the projectiles discarded. Another reason for the low frequency is that it could be a conscious choice from these hunter-gatherer groups in the selection of the raw material for the production of their daily tools, as another kind of raw material that was available at all times was wood. Apart from lithics, wood was most certainly used to produce tools, but as it is an organic material, its survival in archaeological assemblages is very rare (Bicho, 1994; Évora, 2013). Wood is easier to acquire, rapidly and easily to work and transform than bone or antler, and was present in the regions of Southern Iberia during the Gravettian, the Solutrean, and the Magdalenian periods, although in different frequencies and species.

4. Discussion

A problem when comparing information on bone assemblages is the fact that most reports about Upper Paleolithic sites only refer to the typology of the artefacts, and not to the technology, as it happens with the description of lithic industry. This information of typology alone does not allow making conclusions about means of acquisition of bone or antler, or information about the *chaîne operatoire* of producing the utensils.

However, the archaeological sites revisited and analysed for the first time have registered the presence of different debitage and manufacturing methods and techniques in the production of the utensils. In Vale Boi, some debris resulted from segmentation followed by flexion of antler tines, and bipartition of mammal bones is also present (Fig. 6). Ambrosio cave has debris resulting from direct percussion and flexion of mammal ribs (Fig. 7), direct percussion traces on antler (Fig. 8), and traces of double grooving on antler (Fig. 9). In El Pirulejo, double grooving on antler (Fig. 10) and segmentation by direct percussion and flexion traces on antler tines were registered in this assemblage. The tools are diversified, including projectile points, awls, handle, fishhooks, *baguettes*, wedges and retouchers (Figs. 11–18).

Fig. 14. Fishhook (?) indeterminate raw material, Ambrosio cave. (Photo by ME).

Fig. 15. Antler *baguette*, El Pirulejo. (Photo by ME).

Fig. 16. Wedge (mammal long bone), Ambrosio cave. (Photo by ME).

Fig. 17. Retoucher (mammal long bone), Ambrosio cave. (Photo by C. Gonçalves).

In Southern Iberia, there are similarities among the bone tools assemblages from these archaeological sites. As a raw material, mammal bone was much used during the Gravettian and Solutrean, and that seems to be a characteristic in Southern Iberia archaeological sites with bone industry (Aura Tortosa, 1995; Román Monroig and Villaverde, 2011). During the Solutrean in Vale Boi and Ambrosio, the preference for raw material was mammal bone, as it was more available than red deer antler. This availability is not due to a change in the climate, as red deer was hunted throughout the Upper Paleolithic, but rather to hunting choices. One reason for this fact is that hunter-gatherers were choosing to hunt female and infant red deer that do not have antlers. Thus, this raw material would not be as available as was mammal bone, which could be used after the butchering process and bone fracturing to marrow extraction. During the Magdalenian, the preference changed, and antler became more frequent in sites located both near the coast and inland. Another characteristic that this region shares is the decreased in the quantity and typology of osseous tools that occur in the Final Magdalenian: for example, in Vale Boi they are absent so far. Their presence decreased in El Pirulejo, Nerja, Cendres and Parpalló where harpoons are missing along with burins during the Epimagdalenian, a cultural period characterized by the continuity of the Magdalenian lithic assemblage but with the absence of harpoons and a decrease in other bone and antler implements (Villaverde Bonilla et al., 2012). Could this decrease in osseous artefacts be related to the use of wood as raw material? Some species in particular could have been used, including *Alnus*, *Betula* and *Ulmus* present in the pollen record from El Pirulejo during the Magdalenian. These woods are easy to work and most importantly rot proof in water (Carrión Marco, 2005). This characteristic could permit their use as a substitute to mammal bone or antler in the manufacture of projectiles used for fishing and other tools, such as wedges, for collection of shellfish in the coastal and intertidal zones.

Typologically, there are similarities too. A Gravettian bipointed bone tool from Vale Boi (Fig. 11) (Bicho et al., 2004; Évora, 2008, 2013) is similar in morphology to some Magdalenian bone points from Cueva de Nerja that are classified as fishhooks (Aura Tortosa and Pérez Herrero, 1998). Another tool from Vale Boi is similar to a robust point also from Nerja (Aura Tortosa et al., 2006), both recovered from Solutrean levels. From Parpalló, there is a Magdalenian robust bone point similar to a Gravettian bone point, also robust, from Vale Boi (Aura Tortosa, 1995; Évora, 2008). These examples of typological similarities, although not all coincident in chronology, reflect a continuity over time for the same morphology of bone points and other utensils, becoming stereotypes, probably due to the functionality and hafting of these tools. This may also reflect the fact that the use of this industry is adapted to a variety of environments. Upper Paleolithic hunter-gatherers exploited different habitats as sites are located near the coast, including Vale Boi, Nerja, Mejillones and Cendres, and inland, including Pirulejo, Ambrosio and Parpalló. These three are also close to the major rivers Guadalquivir, Jocar, Segura and affluents as Genil, Guadajoz, Guadalentin, Cañoles and Serpis. In the case of Vale Boi, with a small river close to the archaeological site, bones from *Mustela* sp. were recovered from Gravettian and Solutrean levels. Therefore, hunting-gatherers exploited coastal,

Fig. 18. Antler handle (?), El Pirulejo. (Photo by ME).

fluvial and terrestrial resources (Aura et al., 2002; Cortés-Sanches et al., 2008; Manne and Bicho, 2009; Bicho and Haws, 2012; Villaverde et al., 2012). They used more of this industry in sites located near the coast, where the frequency of bone tools is higher than in sites located inland, and this is a constant feature along the Upper Paleolithic in Southern Iberia. The difference remains in the choice of the raw material, which changes from the Solutrean to the Magdalenian, with a preference from mammal bone to red deer antler. This higher frequency of bone tools in sites located near the coast, and in particular the projectiles, is because these are suitable for fishing, besides hunting. They do not get easily lost, because an osseous projectile hafted to a wooden shaft fluctuates better than a lithic projectile, and so hunter-gatherers would easily recover a projectile after missing a shot. Besides fishing and hunting, hunter-gatherers used other types of tools made out of this raw material for other daily tasks, including awls for piercing shells for adornments and needles for piercing hides, as *Oryctolagus cuniculus*, *Linx pardinus*, *Felix sylvestris* and *Vulpes vulpes* were hunted during the Upper Paleolithic in Southern Iberia, and their fur was certainly used.

The climate change during the Upper Paleolithic did not seem to interfere with the use of this industry by hunter-gatherers. Southern Iberia is located south of 40°N, and during Heinrich Events 3 and 2 the Sea Surface Temperature (SST), increased, reaching gradients between 4 and 14°C between 43-12°N and 37-48°N, which caused the icebergs to melt south of 39.6°N (Salgueiro et al., 2010). In the beginning of Heinrich 1, the SST decreased, but the ice sheet did not reach Southern Iberia, making it subject to less severe climate changes than those that occurred in northern latitudes. An example of this is the *Cervus elaphus*, always present in the faunal record, even during the LGM, in sites located near the coast and inland. *Eqqus caballus* is also present in the faunal record: as a species more adapted to grassland and open areas, along with *Capra pyrenaica* adapted to rocky mountains, they were hunted mostly during the Gravettian and Solutrean when the climate was colder. Antler during this cold period was replaced by mammal bone as raw material, something that changed in the beginning of the Magdalenian when the climate began to ameliorate and the landscape changed to woodland, more suitable to *Cervus elaphus* and also *Sus scrofa*, mostly hunted during this period. Mammal bone or antler, this raw material was always available to hunter-gatherers during the Upper Paleolithic in Southern Iberia.

There are other cultural and environmental traits in common between the Algarve region and Southern Spain. The location of the sites near the coast during the Gravettian and the Magdalenian, taking advantages of marine resources like fish, sea mammals, and shellfish as happened in Nerja (Aura Tortosa et al., 2002), and at the same time fluvial and terrestrial resources, with the hunting of gregarious ungulates, is a common feature to this vast region (Aura Tortosa et al., 2002; Cortés-Sánchez, 2008; Manne and Bicho, 2009; Manne, 2010; Cortés-Sánchez et al., 2011). Hunter-gatherers had preferences for the same kind of game prey, wild goat, red deer, horse and wild boar; rabbit has the highest frequency in faunal assemblages from Southern Iberia archaeological sites. Both shellfish, especially limpets, and hunting of aquatic resources played an extremely important role in the diet of hunter-gatherers of the Upper Paleolithic (Fig. 2) (Aura Tortosa et al., 2002; Cortés-Sánchez et al., 2008; Manne and Bicho, 2009; Manne, 2010; Bicho and Haws, 2012; Villaverde Bonilla et al., 2012).

5. Conclusion

The bone tools industries used in this study allow some inferences about raw-material choices. Southern Iberia was outside of the glacial zone that extended over most of the European continent during the Last Glacial Maximum, but did not reach low latitudes (Aura et al., 1998). This permitted the presence of refuge areas for animals and plants during the Upper Paleolithic. Due to different landscapes in this region, that provide different microclimates and different habitats for animals, and thus several kinds of resources were available for hunter-gatherers. From the archaeological record, climate changes during the Upper Paleolithic in this region did not have much influence on the use of osseous industry by hunter-gatherers. People used it in their toolkits during the Gravettian, Solutrean and Magdalenian in sites located near the coast and inland, in a variety of economic activities: fishing, hunting, in the treatment of hides and adornments and possibly in the collection of shellfish. The difference remains in the raw material from the Solutrean to the Magdalenian, and this is due to hunting choices and not to changes in climate causing a displacement of taxa. The faunal analysis from some of the Spanish sites and from Vale Boi in Portugal shows that red deer, horse and wild goat were the most hunted prey, with the exception of rabbit, the most hunted animal which is present in higher frequencies in the faunal assemblages since the Gravettian. Although red deer is one of the most hunted species, red deer antler is scarce as raw material in the bone tools industries in Southern Iberia during the Gravettian and the Solutrean. This is because the hunted animals were female and infant red deer that do not possess antlers. Likely, this is one of the reasons that bone tool industry is dominated by mammal bone tools instead of antler tools, in contrast to the Northern Iberia archaeological sites.

Another conclusion that is important to outline is the decrease of osseous artefacts by the Final Magdalenian in the Southern Iberia archaeological assemblages.

Bone tool industry is now being studied with a different perspective. Most of the earlier published articles from Portuguese and Spanish archaeological sites that have osseous industries only mention its presence, and may present a typological and morphological analysis. Today, the approach is beyond these two analysis, and technological and use-wear analysis are important and much needed. They can give us indications of preference of raw material choices, why they were chosen, for what kind of tools and how they were made and used, and the evolution of techniques and procedures.

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