Quaternary International 409 (2016) 195–212

Contents lists available at ScienceDirect

Quaternary International

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

Bone retouchers from Lower Palaeolithic sites: Terra Amata, Orgnac 3, Cagny-l'Epinette and Cueva del Angel

Anne-Marie Moigne [a], Patricia Valensi [b], Patrick Auguste [c], José García-Solano [d], Alain Tuffreau [e], Agnès Lamotte [e], Cecilio Barroso [f], Marie-Hélène Moncel [a, *]

[a] UMR 7194 CNRS, Department of Prehistory, National Museum of Natural History, Paris, France
[b] UMR 7194 CNRS, Musée de Préhistoire, 06690 Tourrette-Levens, France
[c] Laboratoire Evo-Eco-Paléo, UMR 8198 CNRS, Université of Lille, Sciences and Technologies, Villeneuve d'Ascq Cedex, France
[d] Departamento de Prehistoria y Arqueología, Universidad de Granada, Spain
[e] UMR 8164 CNRS HALMA, University of Lille, Science and Technologies, France
[f] Fundation Instituto de Investigación de Prehistoria y Evolución Humana, Lucena, Spain

ARTICLE INFO

Article history:
Available online 20 July 2015

Keywords:
Acheulean
Western Europe
Bone retouchers
MIS 11–9
Behaviors

ABSTRACT

Bone retouchers are more common during the Middle Palaeolithic (from MIS 7 to 3) and are now considered as a part of the tool kit of Neanderthals. In Middle Pleistocene and Lower Palaeolithic assemblages, they are few in number and attest to the scarcity of use of bones as material for shaping tools. Some MIS 11 to MIS 9 sites allow the description of the onset of bone use and its multiplication after the MIS 9 attests of another functional relationship between bones and hominins.

Our aim is to provide details about the bone retouchers found in some MIS 11–9 sites with lithic assemblages, often described as late Acheulean, that include handaxes and heavy-duty tools. The sites sampled are Terra Amata (south-east France, MIS 11), Orgnac 3 (south-east France, MIS 9–8), Cagny l'Epinette (Northern France, MIS 9) and Cueva del Angel (Spain, MIS 11–7). The study examined the number of retouchers, their support and type of animal, types of marks, bone sizes, and the lithic and faunal contexts.

While bone retouchers sometimes total several hundreds of pieces in Middle Palaeolithic sites, our Lower Palaeolithic corpus yields generally between 1 and 6 retouchers. Retouchers are always made on fragments of bones from the main hunted species (horses, large bovids and cervids). Marks on bone retouchers indicate specific processes for selecting fragments of bones, and hypotheses are provided on their method of use. Categories may be suggested according to their types of support (diaphysis, epiphysis) as well as their types of marks, and allow us to suggest hypotheses for the retouching of both bifacial tools and flake-tools as well as for direct percussion. The results are compared with other sites from which bone retouchers were already published (Cueva del Bolomor, Gran Dolina TD10 in Spain, and La Micoque in France and Qesem in Israel). They are also compared with younger Acheulean assemblages such as Lazaret cave in France.

1. Introduction

The first records of bone retouchers were made by Leguay (1877), Daleau (1883) and by Henri-Martin (1906, 1907, 1907–1910) at the Middle Palaeolithic site of La Quina (Charente, France). Henri-Martin described "ces os à impressions" and discussed several hypotheses regarding their function according to their support (Baudoin et al., 1906). Recently, Patou-Mathis and Schwab (2002) provided a broader definition for bone retouchers as, "fragments of teeth, long bones, phalanges or ribs of big mammals, which present on their exteriors one or more impressed areas, related to crushing marks, and/or cupules, and/or scores, without modification of initial morphology, made by impact against a sharp and hard artefact with the edge of flake, tool or handaxe".

Bone retouchers are present in various ratios in many Middle Palaeolithic sites from Western and Central Europe and the Levant. They are linked to the Levallois and laminar core technologies and also Micoquian industries in Central Europe (i.e. Vincent, 1993; Auguste, 2002; Valensi, 2002b; Mallye et al., 2012; Jéquier et al., 2012; Guadelli et al., 2013; Daujeard et al., 2014).

* Corresponding author.
E-mail address: moncel@mnhn.fr (M.-H. Moncel).

http://dx.doi.org/10.1016/j.quaint.2015.06.059
1040-6182/

It was often considered that bones were not recovered for use in Lower Paleolithic assemblages in Europe. Nevertheless, discoveries made during recent decades indicate that bones were punctually collected for making heavy-duty tools such as handaxes, for instance on elephant bones at Fontana Ranuccio, La Polledrara di Cecanibbio, Castel di Guido in Central Italy (Segre and Ascensi, 1984; Radmilli and Boschian, 1996; Anzidei et al., 2012; Boschian and Sacca, 2015). Some studies have also pointed out that some bones with marks could be assimilated to bone retouchers (for shaping tools by percussion or pressure) or hammers. They are mainly on herbivore bones, rarely Carnivores or human (Auguste, 2002; Verna and d'Errico, 2011). These bones exhibit pits and scores of varying depths, with a V-section, located on specific areas considered as active. The sites yielding such retouchers are Boxgrove in Great-Britain (MIS 13; Smith, 2013), Caune de l'Arago in France (MIS 12; Moigne, 1996), La Micoque (MIS 12–11; Langlois, 2004; Risco, 2011), Gran Dolina TD10 in Spain (MIS 10–9; Rosell et al., 2011, 2015), Orgnac 3 in France (MIS 9; Sam, 2009; Sam and Moigne, 2011, Moncel et al., 2012), Cagny-l'Epinette in France (MIS 9; Tuffreau et al., 1995), Bolomor Cave in Spain (MIS 9) and Qesem in Israel (400–200 ka) (Blasco and Fernandez Peris, 2012; Blasco et al., 2013b; see Stiner et al., 2009, 2011). These observations have documented some of these bone retouchers dated between MIS 11 and 9, sometimes not related to the bifacial technology. The presence of these bone retouchers indicate that bone recovery has to be considered as part of the behavioral strategies, and are among the modalities of behavioral changes observed in Europe between 400 and 300 ka.

We present in this paper data coming from four sites where bone retouchers were observed, completing evidence of bone uses in MIS 11–9 European sites: Terra Amata (South-East France, MIS 11), Orgnac 3 (South-East France, MIS 9–8), Cagny l'Epinette (North France, MIS 9) and La Cueva del Angel (Southern Spain, MIS 11–7) (Fig. 1). The bone retouchers will be examined through their number, support and type of species, types of traces, sizes, related to the lithic and faunal contexts. While bone retouchers total sometimes several hundreds of pieces in Middle Palaeolithic sites, our Middle Pleistocene corpus only yielded between 1 and 6 retouchers.

2. Sites

2.1. Terra Amata

The site of Terra Amata is an open-air site, situated in Nice, on the western slopes of Mount Boron. The archeological deposits consist of a littoral marine formation at the bottom (stratigraphic unit C1a) composed of a beach of pebbles and silt (M unit) surmounted by a silt level (P4 unit) recovered by a littoral barrier beach made of pebbles (CLs unit), and at the top a large dune of sand (stratigraphic unit C1b). During the excavations in 1966 by H. de Lumley, theoretical levels have been established by the location of each artefact in order to preserve field data (de Lumley et al., 1976). These preliminary levels were questioned by Villa (1978) who suggested recognizing levels by the refitting of artefacts. Recently, archeostratigraphical units were determined underlying phases of human occupations. These units were defined by the vertical and horizontal distribution of the archaeological material and the refittings of lithic pieces and faunal remains (Pollet, 1990; de Lumley, 2013). The taphonomical and archeozoological studies have been performed using six large units (units M, P4, CLs and three units from the dune: DA, DB, DC) (Valensi and El Guennouni, 2004, Valensi et al., 2011). These six units are rather similar to the layers suggested by P. Villa, although more accurately defined and applied to all the material.

The lithic industry, described as Acheulean, is characterized by many products coming from the shaping of pebbles (choppers, chopping-tools, handaxes and cleavers). Flake-tools are composed of a majority of scrapers and secondarily of denticulates and notches. The Levallois core technology does not exist (de Lumley et al., 2008; de Lumley, 2015).

The large mammal corpus consists of 8000 remains, including around 11% which have been determined (Valensi et al., 2011). The faunal remains are composed of eight large mammals with *Palaeoloxodon antiquus*, *Cervus elaphus* and *Sus scrofa* as the most abundant species. The others species are *Bos primigenius*, well represented in the upper levels (dune), *Ursus arctos*, *Hemitragus bonali*, and *Stephanorhinus hemitoechus*, which characterize the Mediterranean population between MIS11 and MIS8 (Lacombat, 2006, 2009). The mammal corpus, similar in the different levels, characterizes a temperate period of the Middle Pleistocene, attributed to the beginning of Aurelian formation (MIS 9 or 11) (Valensi, 2009; Valensi et al., 2011). Geology and general context of the site led to a correlation of Terra Amata to MIS 11 (de Lumley et al., 2001).

The taphonomical study indicates the best preservation for the bone corpus from the beach levels (M, P4 and CLs units). The archeozoological data (Valensi et al., 2011) show hunting of *Cervus* with transportation of the whole carcasses to the habitat, followed by intense treatment for food. Cervid long bones are mainly shafts, intentionally broken for marrow extraction. These results are also confirmed by the fact that 20% of bones exhibit percussion cones, bone flakes, and percussion marks. Deer remains also show a significant number of cut-marks and striations (about 8% of NISP in the different units and more than 20% in CL unit). Hominids also brought portions of carcasses of aurochs and young elephants to the camp. Only cranial fragments and extremities of claws of wild boars were found, which seems to be the result of scavenging. Marks left by carnivores are almost nonexistent on the material (less than 10 remains).

During this period, the site was located at the coast, near a delta in a swamp environment, explaining the recurrence of the human occupations. Distinct Acheulean occupations were observed on the different archaeostratigraphic units (de Lumley, 2015):

- On the beach (P4 unit) and the dune (DA, DB and DC units), occupations are organized with remains of huts with fireplaces, with faunal and lithic remains in situ.
- On the barrier beach (CLs unit), the artefacts are scattered and poor, some of them rolled by the sea. *Cervus* deciduous teeth were recovered from this unit, suggesting late-season use. Occupation differs with many choppers, few flakes, and extensive use of local stones.

2.2. Orgnac 3

The site was at first a cave, then it was transformed into a rock shelter and finally into an open-air site (Combier, 1967; Moncel et al., 2005). The sequence was divided into 10 archaeological levels.

Recent studies of complete lithic and faunal assemblages from the ten archeological levels of Orgnac 3 (1959–1972 excavations) (Combier, 1967; Aouraghe, 1999; Sam, 2009; Moncel et al., 2011, 2012) provide an opportunity to observe the contextual evidence of some behavioural changes and focus that occurred on both technological and subsistence strategies. The site contains records of Upper Acheulean occupations (Combier, 1967), with evidence of Middle Paleolithic behavior at the top of the sequence (Moncel, 1999). This site consequently offers the opportunity to address the question of gradual versus punctuated changes in hominin behavior while the Neanderthal lineage was evolving.

Fig. 1. Location of the Middle Pleistocene sites.

The lower levels (6, 5b and 5a) of Orgnac 3 yielded several hominin teeth attributed to Pre-Neanderthals, similar to the hominin remains discovered in level G at the Caune de l'Arago (south-west France) (de Lumley, 1981). Electron Spin Resonance (ESR) and Uranium/Thorium (U/Th) methods yielded ages of 288 − 45/+82 ka, 309 ± 34 ka, and 374 − 94/+165 ka for these levels (Shen, 1985; Falgueres et al., 1988; Laurent, 1989; Masaoudi, 1995), associated with MIS 9.

Four pure calcite samples from level 5b–6–7 were taken and dated by U/Th using a multicollector (MC)-ICPMS at the High-precision Mass Spectrometry and Environment Change Laboratory (HISPEC, Taiwan). The ages obtained vary between 255 and 319 ka (Michel et al., 2011, 2013).

Fauna is rich and well preserved, with an abundance of cervid bones. Horse represents the second most hunted species. Carnivores are well represented and marks on bones indicate wolf activities after human activities. Fire places are clearly located near the wall of the cave (Moncel et al., 2005, 2011, 2012; Sam and Moigne, 2011).

The upper level 2 contains volcanic minerals, from an eruption of Mont-Dore volcano, which can be attributed to the beginning of MIS 8 (298 000 ± 55 000) (Debard and Pastre, 1988). Direct dating was carried out with $^{40}Ar/^{39}Ar$ on sanidine grains of cineritic material that were recovered from level 2 (Org-C1). The remaining 12 ages are between 276 and 326 ka with a weighted mean age of 308.2 ± 6.8 ka. This age is in agreement with the age of 298 ± 55 ka obtained by fission track dating (FT) on zircons (Khatib, 1994). Based on mineralogical analyses, the tephra from the eruption of the Puy de Sancy is considered to be the same as in Orgnac 3. The age of 275 ± 5 ka may represent the Orgnac 3 date, discarding the furnace age due to mixture of juvenile sanidine phenocrysts and older K-feldspar xenocrysts (Michel et al., 2013).

Combined biostratigraphical studies of mammal remains, microfauna, and fossil pollen suggest that the basal layers of the sequence were deposited in a temperate context, characteristic of an interglacial Middle Pleistocene period (Mourer-Chauvire, 1975; Tillier and Vandermeersch, 1976; Guerin, 1980; Jeannet, 1981; Gauthier, 1992; El Hazzazi, 1998; Aouraghe, 1999; Sam, 2009). The upper level 1 is indirectly attributed to MIS 8, due to the presence of the tahr (*Hemitragus bonali*) and the bear (*Ursus deningeri*), which suggest that this level cannot be more recent than MIS 8. Levels 2 and 1 are mainly characterized by species typical of an open landscape and by the replacement of the equid *Equus mosbachensis* by *Equus steinheimensis* (Forsten and Moigne, 1988).

2.3. Cagny l'Epinette

Excavated since the 1980s, the open-air site of Cagny-l'Epinette belongs to the Somme Valley terraces (Tuffreau et al., 1986, 1995, 1997). Around Amiens, 10 different alluvial sheets were recognized (Antoine, 1994) and designated with a local toponym. The number IV is for l'Epinette system. Each represents an interglacial/glacial cycle; the oldest is the Grâce alluvial sheet with an age older than the Bruhnes–Matuyama palaeomagnetic limit, position supported by the paleontology (Auguste, 1995), the silt cover and different types of dating methods (ESR, U/Th and magnetostratigraphy (Bates, 1993; Laurent et al., 1994)).

At l'Epinette, the thin fluvial deposits were dated by ESR of 296 ka ± 53 (cf. Laurent et al., 1994) which is in agreement with the characteristics of the large mammals (Moigne in Tuffreau et al., 1995) especially red deer and horses, although the microfauna would indicate a younger age (Van Kolfschoten in Tuffreau et al., 1995). The explanation for the problem of the data given by micromammals is the taphonomic situation. Teeth and bones come from holes and are not contemporaneous with lithics and large mammal remains but younger by at least one glacial cycle.

In the thin fluvial deposits of the middle terrace (end of MIS 10, MIS 9), one main level (I1) on a surface of 148 m^2 contains many lithics artefacts (around 3000) associated with teeth and bones of large mammals (2630 elements including 2412 determined remains; Auguste, 2012). The auroch *Bos primigenius* is the main taxa identified in these fluvial levels, and the red deer *Cervus elaphus* is the second species well represented (Table 1). Large caballin horse *Equus cf. mosbachensis* is also present but with fewer remains. The large quantity of bones without external agents of destruction could indicate rapid burial of the site by sediments. Some bones of aurochs and red deer show marks caused by river activity and carnivore gnawing. Nevertheless, many bones exhibit cutting marks indicative of anthropological butchery activities (dismembering, defleshing, tong extraction, removal of tendons) and especially long bones with typical breakage patterns characterizing direct percussion on fresh bone to extract the marrow. In addition, some bones were used as tools and hammers. There are many shed antlers in the fluvial levels of Cagny-l'Epinette, but also some parts of frontals with the antlers unshed. No clear modification is present on these antlers, and no functional aspect can be detected.

The cutting marks were made with flakes, handaxes and fresh gelifracts. They are located in different parts of the skeleton (cranial, axial and limbs). Flint is the only raw material used in Cagny-l'Epinette fluvial deposits. The poor quantity of tested nodules, cores and the great number of parts of handaxes, and bifaces-tools on gelifracts tend to design the site as a quick killing place with extraction of the meat and other faunal material with the use of natural gelifracts (raw material and tools blank) (Lamotte and Tuffreau, 2001).

Other taxa are present, but only with few remains: a large Cervid, probably Megaceros, the Fallow Deer, Steinheim horse but only in post alluvial sediments, the asinid, the steppe rhinoceros, the straight-tusk Elephant, a hyena, and a fox. They exhibit no anthropic modifications and therefore have no clear connection with human activities.

2.4. La Cueva del Angel

The Cueva del Angel archaeological site is an open-air sedimentary sequence (over 5 m deep), a remnant of a collapsed cave that is part of a karst complex (Barroso et al., 2011, 2014). At present day, 8 m^2 were excavated with a high density of archaeological and paleontological material, with more than 5000 lithic and 9000 fossil remains recorded. The stratigraphic sequence is composed of seventeen archaeological levels without hiatus.

Taphonomical characteristics of the herbivore faunal assemblage (dominated by the horse *Equus ferus*, large bovids *Bos*/*Bison* and cervids) indicate the intense fragmentation (95%) of the bones for marrow extraction with a significant number of cut-marks and striations (10%), and the high proportion of burnt elements. About 90% of the faunal bone remains and a third of the lithic artifacts are burnt.

A preliminary $^{230}Th/^{234}U$ date of 121 + 11/−10 ka was obtained in layer VIII (Zouhair, 1996). However, the review of the paleontological evidence favor a chronological positioning of the site in a period stretching from the end of the Middle Pleistocene to the beginning of the Upper Pleistocene, from MIS 11 to MIS 5. Given the latitude of the site and the average size of the species identified, smaller than the same species of northern Europe, this fauna may be correlated with faunal associations of the end of the Middle Pleistocene, and especially to MIS 11–9.

The Cueva del Angel lithic assemblage, dominated by flakes and abundant retouched tools with the presence of 46 handaxes, appears to fit well within the regional diversity of a final Acheulean industry. Knapping patterns reflect exhaustive, well standardized, and economic use of relatively fine quality materials. Early phases of knapping are not represented in the assemblage, as initial shaping was performed outside of the cave. The hominins practiced a core technology based on repeated application of recurrent unidirectional, often radial, knapping from prepared striking platforms. This method sometimes produced cores with morphology close to Levallois forms. Another technological specificity at this site concerns the flakes extracted from retouched tool edges. They make an extraordinary use of small flakes and scrapers, in a great typological diversity. The stratigraphic continuity of the sedimentary sequence without hiatus or interruptions of anthropic presence, low intervention of carnivores, along with continued use of fire and similar processing patterns, suggest a prolonged occupation and persistent subsistence strategies (Garcia Solano, 2014).

3. Material and methods

Bone retouchers of four faunal assemblages have been studied, coming from recent excavations (Cueva del Angel, Cagny l'Epinette) or older excavations (Terra Amata, Orgnac 3) with fieldwork exhaustive enough for a detailed and careful analysis. These assemblages were all analysed through taphonomical and archeozoological analyses published in previous papers. A systematic and detailed observation of the whole faunal material for each site allows us to emphasize bone retouchers. The small quantity of bone retouchers in each assemblage is thus confirmed (Table 1).

Table 1
Type of species in our corpus of sites with NISP (number of identified specimens) and MNI (minimal number of individuals) of the main species with number of bone retouchers (Nr).

	Terra-Amata C1a	Orgnac 3 Level 5a-6	Cagny l'Epinette Level l1	Cueva del Angel Level IX to XIII
Paleoloxodon antiquus	118/7	X	4/2	X
Equus c. mosbachensis and *E. ferus*		728/33 Nr = 1	54/15 Nr = 2	541/14 Nr = 1
Equus hydruntinus			1/1	
Bos primigenius	X	515/32 Nr = 1	1642/61 Nr = 4	178/9 Nr = 1
Cervus elaphus	108/7 Nr = 1	1116/30 Nr = 2	664/35	167/5 Nr = 2
Dama clactoniana	X	316/21	17/6	X
Sus scrofa	11/4	91/13	X	50/13
Megaloceros giganteus		X	2/1	
Capreolus sussenbornensis		X	X	
Stephanorhinus hemitoechus	X	X	2/1	X
Hemitragus bonali	25/11	X		
Ursus arctos	X	X	X	X
Crocuta spelaea		X	1/1	

For selecting our corpus of bone retouchers, we used first the broader definition of Henri-Martin describing pieces with striations at their extremities (Baudoin et al., 1906) and the definition of Patou-Mathis and Schwab (2002) of bones with impressed areas, related to crushing marks, and/or cupules, and/or scores, made by impact against a sharp and hard artifact. Detailed terminology and orientation of areas of stigmata are from papers from "Commission de l'Outillage en os" (Patou-Mathis, 2002 and from Mallye et al., 2012).

The criteria retained to identify the bone retouchers are the following:

1) The large categories of marks are pits and scores, more or less deep.
2) When the scores are not deep, they resemble striations and their edges are irregular with a high magnification
3) When the scores are deep and dense on a same surface, this provides a hatched aspect to the active area.
4) On some retouchers, thin striations can appear perpendicular to the score, due to the contact between the retoucher and the edge of the artefact (Vincent, 1993; Valensi, 2002b).
5) The surface of the fragment of bone is plano-convex, however after much use it is a deep depression.

Moreover, following the various experiments made during the last decade and the numerous publications, retouchers are assimilated to active pieces used for percussion while compressors were used for pressure (Vincent, 1993; Defleur in Valensi, 2002a; Mallye et al., 2012; Daujeard et al., 2014). Active percussion implies a possible standardization of the support and a specific location and orientation of the marks (some distance from the edge for the diaphysis or for the humerus on the mass, Vincent, 1993; Valensi, 2002a). Moreover, the scores are all turned in the same direction and present asymmetrical shapes (Valensi, 2002b; Daujeard et al., 2014).

Through the study of the numerous bone retouchers at Isturitz, Patou-Mathis and Schwab (2002) has observed specificities of the scores (length and orientation) according to the chrono-cultural groups. For the Mousterian, the scores are deep and long, perpendicular to the main length of the bone fragment. For the Aurignacian and Gravettian, scores are shorter, and for the Magdalenian, the scores are parallel to the main length of the bone.

Beside bone retouchers, other categories of "os à impressions", attesting to contact between bone and artefacts, may be mentioned with hypotheses of use (de Beaune, 1997): compressor (active or passive use by pressure), "billot" or anvil (passive use) and in the Upper Paleolithic, "dé" or "cousoir" (active use).

The compressors, handled as the bone retouchers, indicate retouch by pressure. Shchelinskiï (in Plisson, 1988) described in detail stigmata and underlined (among others) parallel striations and short and not deep scores. de Beaune (1997) observed that small pebbles or diaphysis, experimentally used by pressure on the flake cutting edge, result in thin striations without specific orientation. Even if the retouch by pressure is general for the Upper Palaeolithic, use for earlier reduction processes cannot be excluded (Bordes, 1961 in Patou-Mathis and Schwab, 2002).

In contrast, anvils and blocks (« billot ») correspond to passive use as a support for percussion or for cutting. Mark areas are on the centre of the bone rather than near the extremities and edges of the bone fragment. Marks are less asymmetrical than on active retouchers and they do not have a preferential direction (de Beaune, 1997).

For each site, we examined:

1) bone retouchers in their context (levels, faunal data) and number
2) type of support: species, type of bone, bone fragment, sizes
3) active areas: number, localization, morphology, size of the area
4) description of the stigmata (pits and scores)
5) association or not with other traces (fractures, cut-marks, scraping marks, polish, etc.).

We examined and described the active zone, recorded an accurate description of their distribution across the bone surfaces localization area, then photographed each bone retoucher using a stereo-microscope (Vincent, 1993; Fisher, 1995; Armand and Delagnes, 1998; Auguste, 2002; Patou-Mathis and Schwab, 2002; Malerba and Giacobini, 2002; Valensi, 2002a,b; Blasco et al., 2013a; Daujeard et al., 2014).

4. Description of the bone retouchers

4.1. Terra Amata

The only bone retoucher comes from a pebble layer or barrier beach (CLs) attributed to the stratigraphic level C1a (Table 2, Fig. 2).

Table 2
Bone retoucher of Terra Amata: inventory and general data of the support.

References	Level	Taxa	Type of bone	Type of fragment	Length, mm	Width, mm	Thickness, mm
TA-I11-P2-405	CLs	*Cervus elaphus*	femur	Caudal shaft	85	27	20

TA. I11. P2. 405: is a femur shaft of *Cervus elaphus*, one of the hunted animals in Terra-Amata (Valensi et al., 2011). It measures 85 mm in length and 27 mm in width. Thickness of the bone in the active area is 5 mm. The bone surface, as usual in the site, shows weathering cusps. Breakage planes show smooth side edges related to an intentional alimentary breakage, and no specific modifications were done before use.

The active area is lateral, 8 mm near the apical edge. The area, pitted and scaled, is similar, with a crushed area linked to carnivore activity. With magnification ×10, pits are effectively deep scores, V-shaped and oriented perpendicularly to the long bone axis. Location, orientation and morphology are characteristic of the use as a retoucher for lithic tools edges (soft hammer?) (Valensi, 2002b). The proximal edge of deep scores shows many thin cutaways. The distal edge is vertical and stops the cutting edge. These deep scores reach the bone spongiosa to form this crushed area.

4.2. Orgnac 3

The bone retouchers only come from the bottom of the sequence, levels 6 and 5b. They total 4 pieces, 1 unipolar and 3 with bipolar areas (Table 3).

- E16 507 level 6: Metatarsal of *Equus cf. mosbachensis*, intentionally longitudinally fractured. The bone shows long sinuous cutmarks related to butchery activities. The retouch is on one area. Pits are rare, dispersed on a small surface and there are two series of scores. The three initial scores are deep and large

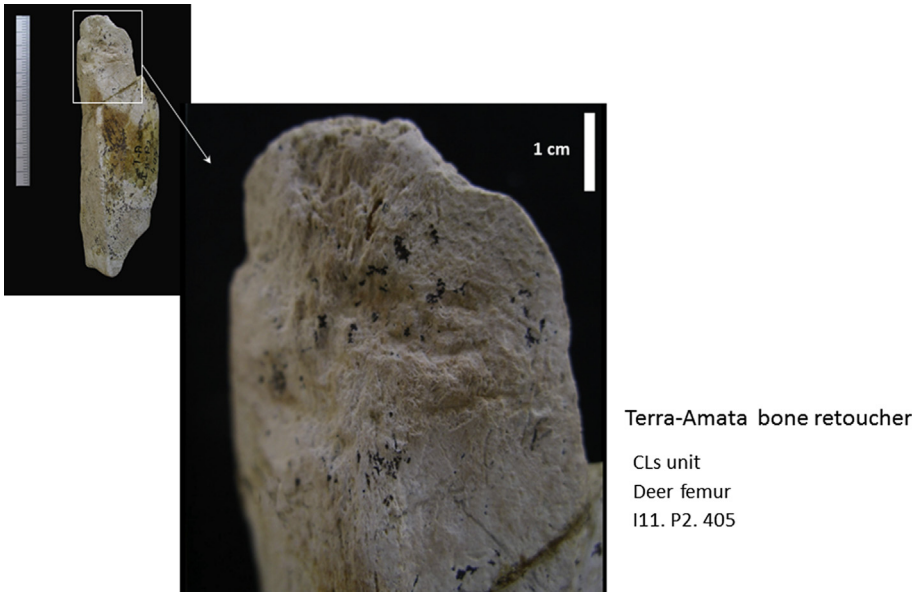

Fig. 2. Terra-Amata. Fragment of left deer femur (85–27 mm) with green fracture. Unipolar area on the distal part with deep transversal marks and cutaways interpreted as soft hammer (photo by Patricia Valensi). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

between 1 and 2.5 mm long with smooth sides and asymmetrical sections, perpendicular to the long bone axis. The second series corresponds to four scores (Fig. 3). They are large, thin V shaped, oblique and characteristic of flint work on fresh bones (according to experimental data from Mallye et al., 2012).

- D14.496, level 6: Tibia diaphysis of *Bos primigenius*. The long bone was previously longitudinally broken. The retoucher presents two active concentrated pitted areas. Pits are triangular, deep, with rough sides. Scores are rectilinear, perpendicular to the long bone axis. Use was intensive (dense and deep pits and scores) when the bone was probably not fresh. The second area is partly covered by calcite (Fig. 4).
- C15.272 level 5b: Tibia diaphysis of *Cervus elaphus* with a percussion cone of intentional green fracture. The active area is concentrated on a 30 × 30 mm^2 area, on a slightly convex surface (Fig. 4). It is not located at the extremity of the diaphyse but on the edge of a fracture. The hatched area presents parallel scores. They are thin and elongated (more than 10 mm in

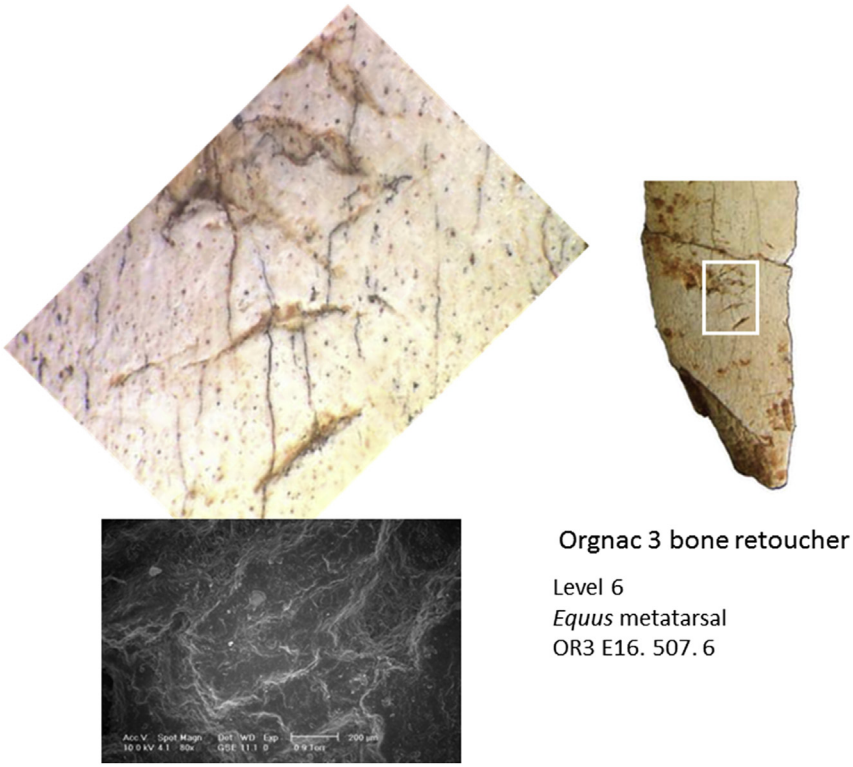

Fig. 3. Bone retoucher on an *Equus* bone fragment from level 6 of Orgnac 3 (photos by Denis Dainat, EPCC CERP Tautavel).

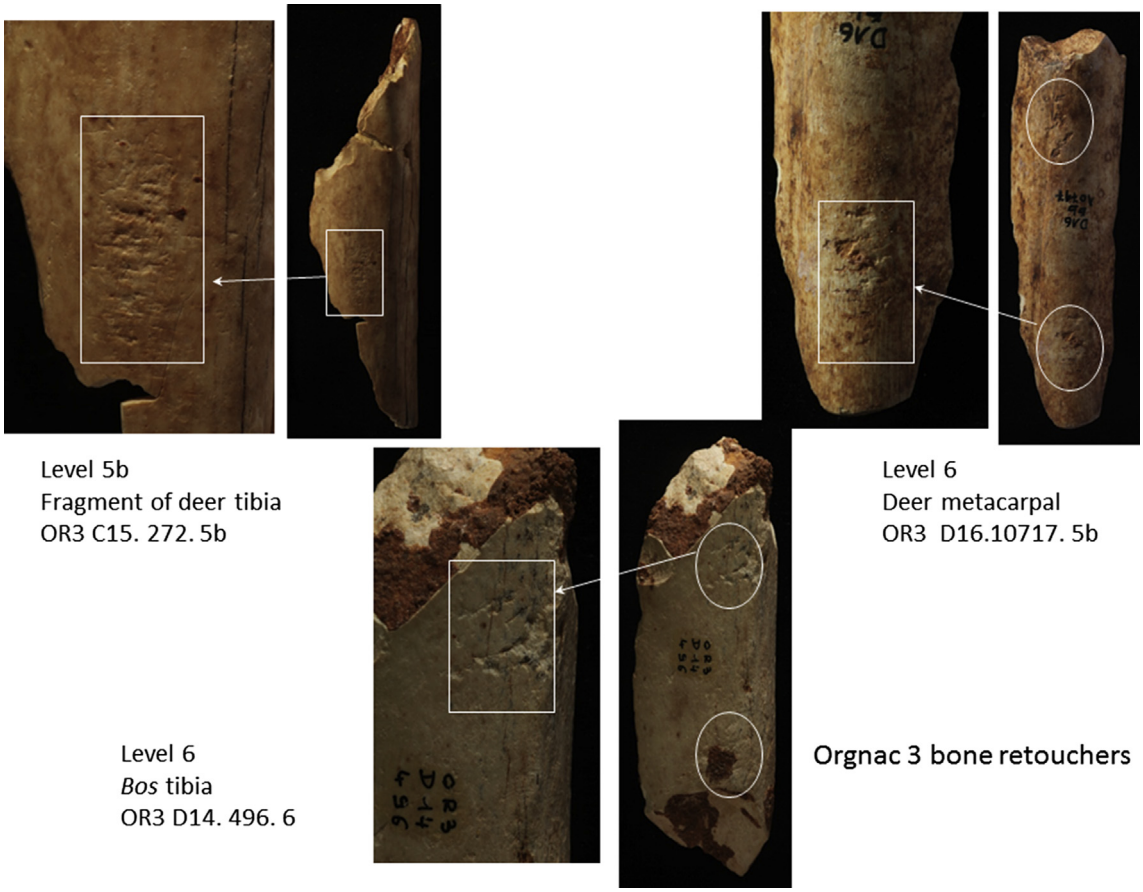

Fig. 4. Three bone retouchers on fragments of deer and Bos from levels 6 and 5b of Orgnac 3 (photos by Denis Dainat, EPCC CERP Tautavel).

length). Thin scores (resembling striations but with irregular edges) are oriented perpendicular to the long bone axis and undulated. This is typical of a hatched area related to the final shaping for a tangential abrasion of the flint edges (cf. Mallye et al., 2012).

this layer. This richness can be related to a use of this retoucher on flint or quartzite.

Table 3
Bone retouchers of Orgnac 3: inventory and general data of the supports.

References	Level	Taxa	Type of bone	Type of fragment	Length, mm	Width, mm	Thickness, mm
OR3-E16-507	6	*Equus mosbachensis*	Metatarsal	Lateral shaft	180	25	10
OR3-D14-494	6	*Bos primigenius*	Tibia	Shaft	120	39	32
OR3-C15-272	5b	*Cervus elaphus*	Tibia	Shaft	115	30	27
OR3-D16-10717	5b	*Cervus elaphus*	Metacarpal	Shaft	82	23	16

- D16.10717 level 5b: Metacarpal bone of *Cervus elaphus*. It presents a green longitudinal fracture and bipolar active area (Fig. 4). Scores are short and deep, parallel, V shaped, and perpendicular to the long bone axis. Analysis of sediment imbedded into the scores revealed a very high level of silica (EDAX-EPCC-CERP Tautavel) compared with the sediment of

4.3. Cagny l'Epinette

The bone tools come only from levels I1A and I1B. Six bone retouchers were identified in these levels (Table 4). Four are made from aurochs bones and two from horse bones; bones of red deer were not used. For the auroch, three humerus and one metatarsal were used. For the horse, one humerus and one metatarsal were used.

Table 4
Bone retouchers at Cagny-l'Epinette: inventory and general data of the supports.

References	Level	Taxa	Type of bone	Type of fragment	Length, mm	Width, mm	Thickness, mm
Ep90-20V-50	I1	*Equus mosbachensis*	Humerus	Lateral shaft Distal articulation	210	90	86
Ep93-22U-39	I1B	*Equus mosbachensis*	Metatarsal	Lateral diaphysis	172	35	20
Ep95-25T-12	I1B	*Bos primigenius*	Metatarsal	Lateral diaphysis	90	26	25
Ep2000-25O-318	I1B	*Bos primigenius*	Humerus	Distal articulation	150	102	95
Ep2007-1647	I1A	*Bos primigenius*	Humerus	Distal articulation	165	90	90
Ep2008-26I/J-2342	I1B	*Bos primigenius*	Humerus	Proximal diaphysis	150	80	40

The main element of these six retouchers from Cagny-l'Epinette is the use of large herbivorous mammals with thick bones, aurochs and horse. Moreover, the "classical" retouchers are made with part of the diaphysis of the same bone (metatarsal) for the two species. The other retouchers use the same part of the same bone, the distal part of the articulation of the humerus, for the two taxa.

The characteristics of these bone tools are:

Ep90.20V-50, I1: Horse distal humerus with a classical spiral fracture to obtain marrow (Fig. 5). It was then used with two areas of stigmata. On the lateral view, the active part is concentrated and superposed on a 70 × 35 mm pitted to scaled area. It is a retoucher with large pits, ovoid and triangular, and the general orientation is perpendicular to the long bone axis, but the intensity of blows was really hard and some irregular fissures occur with a heavily scaled area. On this scaled area, some large scores are also noted, oblique and rectilinear. These scores with rough sides seem to have been done after the initial intensive retoucher utilization.

The second area is located on the mesial part of epiphysis, as noted in the La Quina historical collection. The use hypothesis is now related to the shaping of handaxes or bifacial tools and for retouch (Vincent, 1993). However, at Cagny l'Epinette, the humerus does not indicate particular management: the distal part is always present. The bone fragment could not have been put on the ground as an anvil because the stigmata are clearly located on the distal part of the trochlea and not on the cranial face. The area, located on the trochlea, is 30 × 30 mm. The pits, triangular, deep and at least n = 12, superposed, are all oriented perpendicularly to the main axis of the articulation (Fig. 5). The active part has the same characteristics as the retouchers, but the blows on the articulation modified its original convexity (Moigne in Tuffreau et al., 1995).

Ep 2007.1647-I1A: Auroch distal humerus with no clear breakage pattern of the shaft. The area is in the same location as for the previous bone tool, and is characterized by a lack of bone indicative of hard and/or long use, perhaps due to the disappearance of organic elements in the bone, meaning it was not fresh (Fig. 6). The area, on the trochlea, is 40 × 40 mm and is both hatched and pitted near the edge. The pits are triangular rather than ovoid. The scores are rectilinear and smooth.

Ep 2000.25O-318, I1B: Auroch distal humerus with a classical spiral fracture to obtain marrow. The area of stigmata is located on the mesial part of the articular trochlea in dorso-distal position, as was noted in the La Quina historical collection and from a humerus of a horse. The area is 29 × 22 mm and hatched. The pits are triangular, deep and at least n = 19, superposed, all oriented perpendicular to the main axis of the articulation (Fig. 7). The scores are rectilinear and generally smooth. The active part has the same characteristics as the retouchers, but the blows on the articulation are heavier with a lack of bone. This bone must have been used when it was fresh. According to the results from Vincent (1993), the best efficiency of the retoucher is a green bone, no older than 2–4 days. As in the other retouchers on the distal extremity of a humerus at Cagny-l'Epinette, the trochlea is the active part. That suggests that the capitulum was taken in hand by the user. The fact that the diaphysis still exists does not help either to grip the bone, or a good rotation of the wrist by the user. However, use of the bone fragment as a retoucher is feasible (Vincent, 1993).

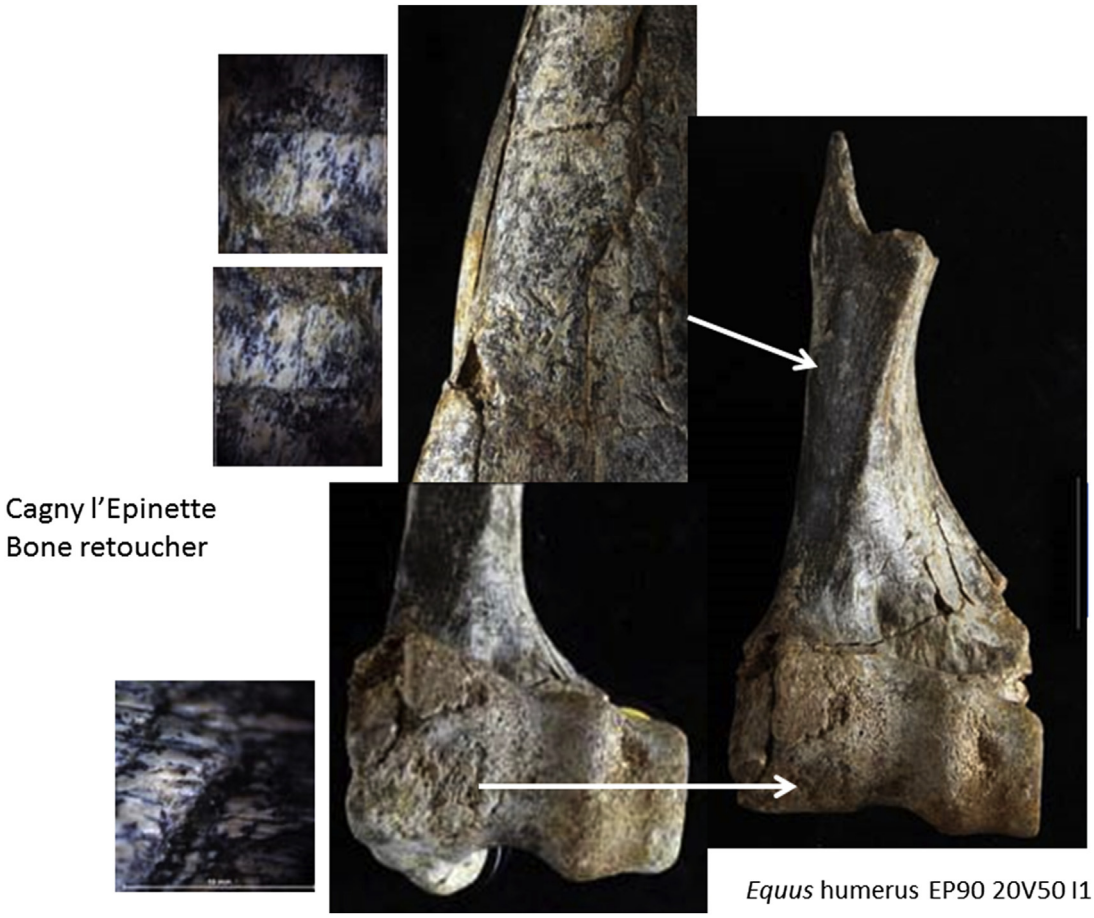

Fig. 5. Cagny-l'Epinette, left *Equus* humerus (Ep90.20V-50, I1), cranial view (photos by Anne-Marie Moigne and Denis Dainat, EPCC CERP Tautavel) (Anatomical position).

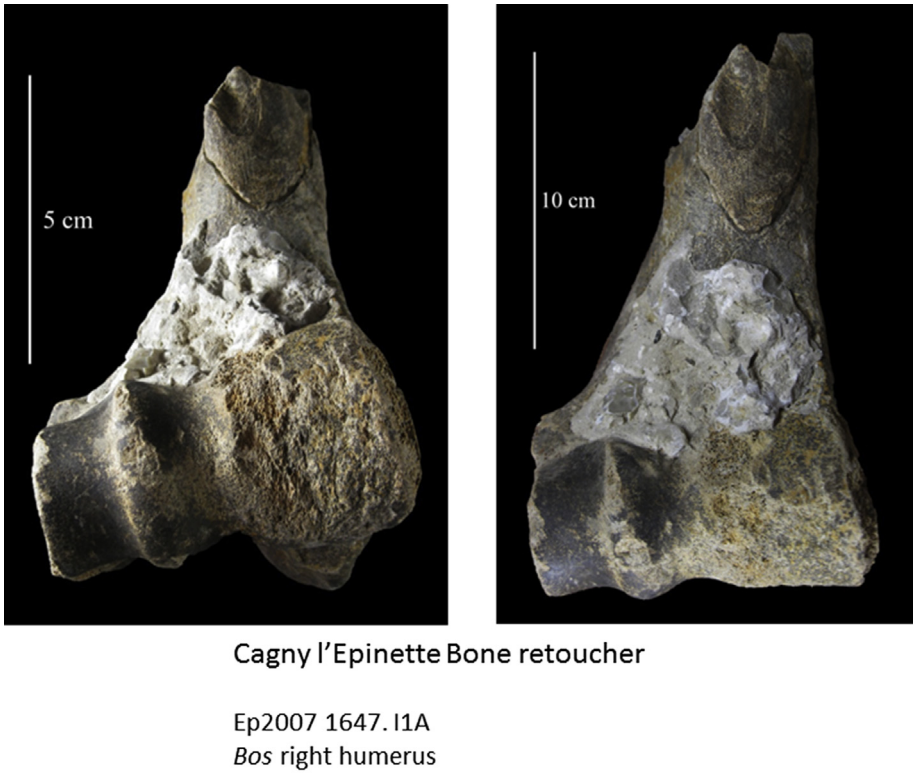

Fig. 6. Cagny-l'Epinette, right Aurochss humerus (Ep 2007.1647-I1A), cranial view (photos by Noémie Sévêque) (Anatomical position).

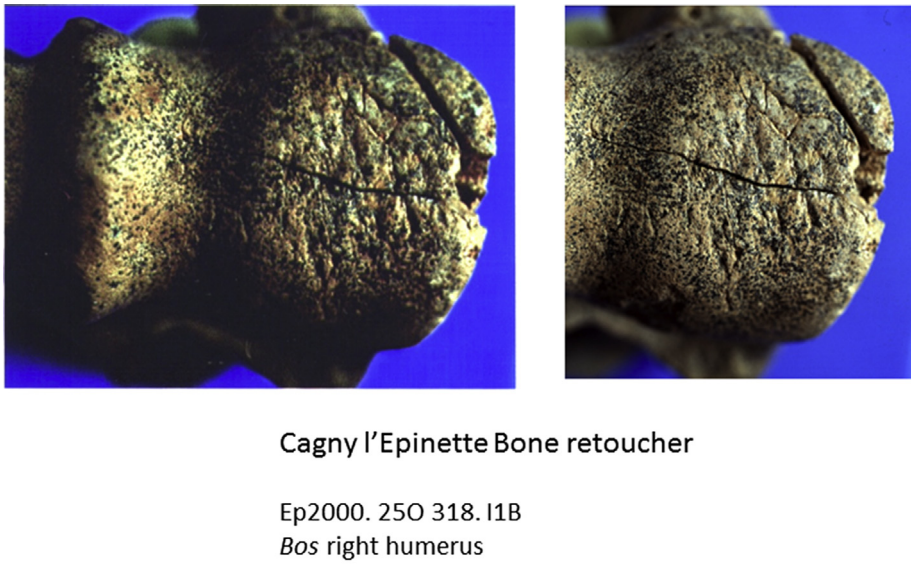

Fig. 7. Cagny-l'Epinette, Aurochss right humerus (Ep 2000.25O-318, I1B), distal view (photos by Patrick Auguste) (Anatomical position).

Ep 93.22U-39, I1B: Horse metatarsal diaphysis with a longitudinal fracture. The active part is 50 × 22 mm, from hatched to pitted area. It is located on the lateral side, on a broad and slightly convex surface. It is a retoucher with many deep, rectilinear scores with rough and asymmetrical sides. These scores are sometimes covered by deep triangular pits (Fig. 8, left). This may correspond to the retouch of a flint edge with a bone of intermediary freshness (Mallye et al., 2012). The originality of the active area is the location centered on the diaphysis rather than on an extremity. The scores show a regular orientation (perpendicular to the length of the bone) and they are asymmetrical. That confirms that the bone has not been used as an anvil but as a retoucher (active use with the piece taken in hand).

Ep 95.25T-12, I1B: Aurochs metatarsal diaphysis with spiral intentional fragmentation. The active area is located on the lateral face. It is a characteristically hatched 36 × 18 mm rectangular and flat area. Scores are concentrated, thin, sinuous, 6 mm long, around 25 striae, parallel, perpendicular to the long axis of the metatarsal. Microscopic view presents a V-shaped section of the marks. This hatched area is correlated with the retouching of flint flakes (Mallye et al., 2012).

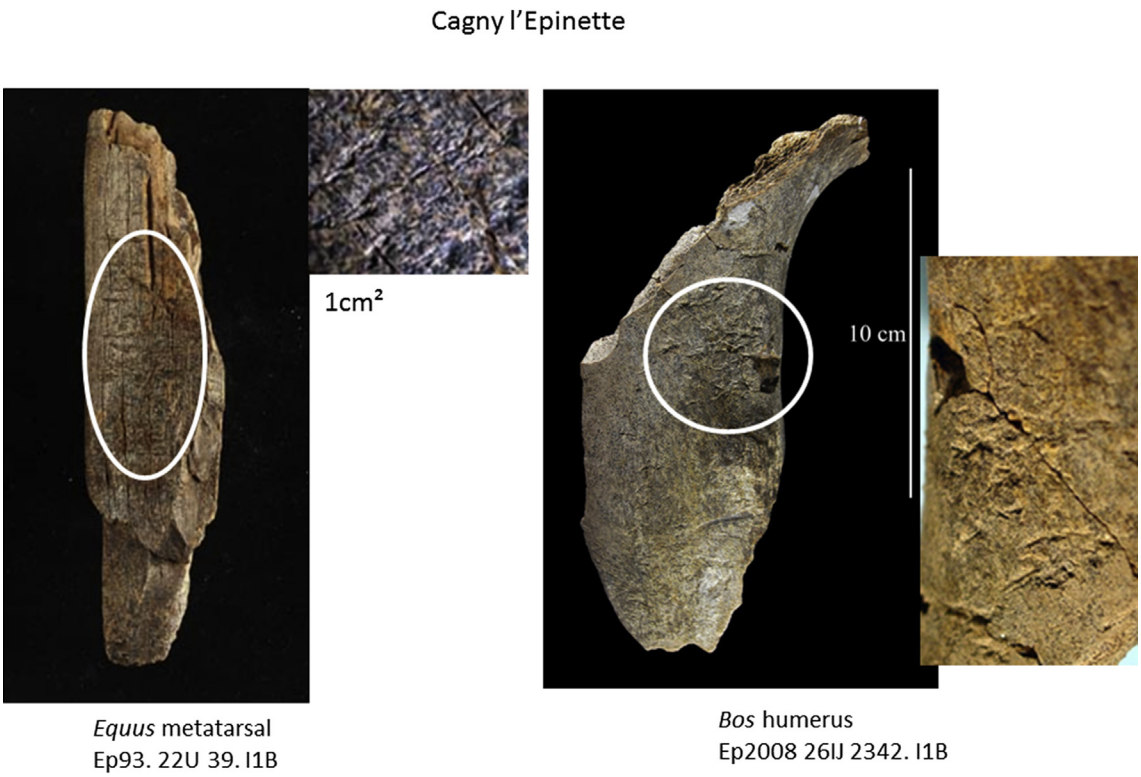

Fig. 8. Left: Cagny-l'Epinette, *Equus* metatarsal (Ep 93.22U-39, I1B), lateral view (photos by Denis Dainat, EPCC CERP Tautavel). right: Cagny-l'Epinette, Aurochss right humerus (Ep 2008.26I/J-2342, I1B), cranio-medial view (photos by Noémie Sévêque).

Ep 2008.26I/J-2342, I1B: Aurochs shaft humerus, proximal part of the diaphysis in cranial location with a clear breakage pattern upon fresh bone with one notch corresponding to the percussion point. The area, located just above the "tuberosity of the large round" is clearly hatched, 50 × 40 mm, with at least 21 stigmata (Fig. 8, right). The pits are also clearly triangular. The scores are rectilinear and smooth, obliquely oriented with an angle of 45° to the main axe of the bone. The active zone is dispersed from the edge of the fracture to the center of the fragment. This retoucher can be considered as a typical flint edge retoucher (Mallye et al., 2012).

4.4. La Cueva del Angel

The bone retouchers only come from the bottom of the sequence, levels IX and XIII. At least 8 bones have marks that could be related to a bone tool (Garcia Solano, 2014) (Table 5). To compare and use the same methodology, at this state of the art, 4 retouchers are observed, 3 unipolar and 1 with bipolar areas. They come from unit II and are associated with assemblages including handaxes and Middle Pleistocene species.

- CA-K7-204-level IX: Large Bovid vertebra spine. The single active area (24 × 18 mm) is located on the lateral face of the spine, and is centered. It is a concentrated and superposed area with curved and parallel deep scores (Fig. 9, left). Many blows formed a depressed area, probably made with a flint tool on fresh bone. No antagonist of teeth marks could be detected on the other site of the vertebra *spinae*. This retoucher is considered as passive area and could be called a compressor. This term may be understood in a general meaning, i.e. a bone being in contact with a cutting edge by pressure.
- CVA-K7-532 level XIII: *Equus ferus* metatarsal, with a longitudinal intentional fracture and percussion cone (Fig. 9, right). The single active zone is located on the lateral face, on a broad slightly convex area on the center of the bone. A concentrated area (25 × 30 mm) contains at least 6 deep and crushed asymmetrical grooves (Daujeard et al., 2014), perpendicular to the bone axis. The direction of violent blows was from the proximal to the distal part of the metatarsal bone. It could have been made by a heavy tool.
- CVA-J7-511 level IX: *Cervus elaphus* tibia with a single active area (26 × 28 mm) located on the proximal part of the shaft. The active zone is dispersed, with ovoid pits and large, rectilinear and smooth side scores. It can be considered as a pitted area (Fig. 10, left). The retoucher was used to deliver a limited number of blows but with high intensity. We could consider, following Mallye et al. (2012), that it was used to retouch quartzite pebble tools. Quartz and quartzite raw-material is rare in Cueva del Angel but is collected from Guadalquivir terraces and partly manufactured in the cave. This observation is rather important, as typologists believe that the retouch was mostly done with a hard hammer, and it seems strange that a *Cervus* tibia was used, rather than a larger bone from *Equus* or *Bos*.
- CA-K6-904-level XIII: *Cervus elaphus* metatarsal lateral shaft with two active zones, proximal and distal side (Fig. 10, right). The shaft exhibits long thin and sinuous cut marks from previous nutritional activities and longitudinal fractures to recover the marrow, as usually on this site. This bone exhibits cracks corresponding to alteration by heat but it was not burnt. This is exceptional in this site where 90% of bones show fire alteration. The first proximal area is concentrated in 38 × 12 mm. It is a pitted area with triangular pits, convex with asymmetrical cross section and thin rectilinear scores. On the second distal area, scores are longer, deep and convex. Many thin convex marks form a hatched area, covered with scores. According to Mallye et al. (2012), the retoucher was probably used as a fresh bone on flint.

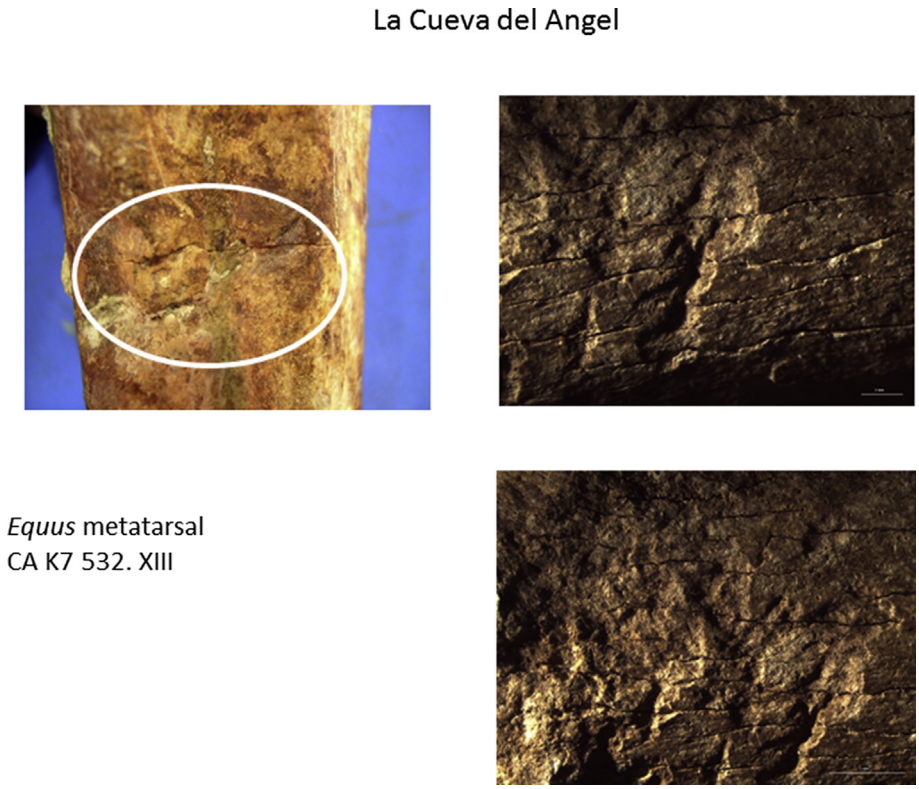

Fig. 9. Bone retoucher (CA K7 532. XIII) from La Cueva del Angel on *Equus* metatarsal (photos by Anne-Marie Moigne).

Table 5
Bone retouchers at the Cueva del Angel: inventory and general data of the supports.

References	Level	Taxa	Type of bone	Type of fragment	Length, mm	Width, mm	Thickness, mm
CVA-K6-904	XIII	*Cervus elaphus*	Metatarsal	Lateral shaft	90	16	10
CVA-K7-532	XIII	*Equus ferus*	Metacarpal	Proximal end	116	36	18
CVA-J7-511	IX	*Cervus elaphus*	Tibia	Caudal shaft	110	30	15
CVA-K7-204	IX	*Bos/Bison*	Thoracic vertebra	Spine	90	35	10

5. Discussion

5.1. Comparison of species, type of bone, bone fragment, sizes

The bone retouchers from our Middle Pleistocene corpus are made in general on bone fragments of the main hunted species, large herbivores such as *Equus* (Cueva del Angel, Orgnac 3, Cagny l'Epinette), *Bos/Bison* (Orgnac 3, Cagny-l'Epinette) and *Cervus* (all sites) (Table 1). The exception is Cagny-l'Epinette, where red deer, second in number of remains and individuals, was not selected.

Bone fragments are generally thick and flat. The most frequent bones are humerus, tibia and metatarsal fragments. In this paper, "classical retouchers" are those made on diaphysis, which are the most frequent in the Palaeolithic. At Cagny-l'Epinette, three retouchers made on a distal epiphysis of a humerus have also been identified. Moreover, the use of a large spine of thoracic vertebra at Cueva del Angel is surprising.

The size of these retouchers mainly varies from 80 to 100 mm, with some longer exceptions. This indicates selection among the longest shafts. Supports are varied and of various weights. The heaviest supports are the humerus of Cagny l'Epinette; they may work with more strength and speediness than the fragments of diaphysis (Vincent, 1993, p. 233).

They seem to be fragments resulting from butchery activity. They were used green or dry. Prior preparation was not observed. We have to mention in particular the use of distal extremities of humerus at Cagny l'Epinette, without removal of the diaphysis, unlike retouchers discovered in the Mousterian levels at the Quina site.

5.2. Active areas: number, localization, morphology, size of the area

Apart from their little numbers in the collections, what characterizes bone retouchers before MIS 9 is the great variability of the type of fragment, the form and especially the kind of traces, greater than for the Middle Palaeolithic sites (Malerba and Giacobini, 1996; Giacobini and Patou-Mathis, 2002; Mozota, 2009; Jéquier et al., 2012). Depending on the sites, there are one or two active areas composed of pits and/or scores. The traces are centered except for some cases where they are near one extremity (Terra Amata, Orgnac 3) or lateral (one piece from Cueva del Angel). The active areas are mainly concentrated or concentrated and superposed, although they are dispersed in a few cases (cf. Mallye et al., 2012). In general, the retouchers have been intensively used. The location of the active areas on the diaphysis of our corpus is different from those observed on Middle Palaeolithic bone retouchers where

Fig. 10. Bone retouchers (CA J7 511. IX and CA K6 904.XIII) from La Cueva del Angel on a Cervus metatarsal and tibia (photos José Solano).

stigmata are generally located ~10 mm from the edge of the fracture (Patou-Mathis and Schwab, 2002).

The morphology of the active areas and their size are diversified depending on the degree of use. These characteristics do not indicate specificities with the Middle Palaeolithic bone retouchers.

5.3. Description of the stigmata (pits and scores)

The marks are variable in size and depth, and some active areas present similarities with carnivore activity. This confusion could reduce the number of retouchers in Lower Palaeolithic sites, but not for our corpus (Binford, 1981; Blumenshine and Selvaggio, 1991; Clark, 1991; Lyman, 1994).

There are a high diversity of pits and scores despite the little number of retouchers. We can observe the variability of traces obtained during experiments (see Tartar, 2002; Mallye et al., 2012). We explain this diversity by the use of green, non-greasy, and moderately fresh bones but also by the use of these retouchers on various raw materials such as flint, quartzite, and others. That can be related in part to the Acheulean behaviour, especially in southern Europe with the use of various materials.

5.4. Association or not with other marks

Bone retouchers correspond to food wastes. Some have cutmarks such as at Orgnac 3. Some indicate fractures on green bones (according to criteria of Villa and Mahieu, 1991) and percussion notches indicate marrow extraction.

According to the kind and position of the marks, most of our retouchers could be grouped in the category of bone retouchers used for active percussion (soft hammer). That may be proposed in relation to the experimental data published, although bone retouchers described as “billots” by Henri-Marin at La Quina were finally considered as retouchers for active percussion for bifacial pieces (Vincent, 1993; Valensi, 2002a). The soft hammer could be used for flaking, shaping and scratching by using a frontal percussion on the flake edge according to the experiments (Blasco et al., 2013a,b).

Categories of bone retouchers and hypotheses of use (Table 6):

1) “Classical” bone retouchers on a diaphysis, with pits and scores on the edge of the fragment. This type is largely identified in the sites younger than MIS 9 (Lazaret, Biache-Saint-Vaast and most of the Mousterian sites).

In our corpus, the “classical retouchers” with triangular pits and rectilinear scores with smooth edges are the most abundant. They are related in the experiments to flint work on green bones.

Other retouchers of this category carry deep, short, rough pits and scores with the same orientation (Terra Amata, Cueva del Angel, Orgnac 3 and Cagny l'Epinette). They exhibit different stages of freshness and could be linked to work on flint and quartzite.

2) The distal articulation of humerus at Cagny-l'Epinette show the area of work located at the same place, the distal articular surface, meaning probably the beginning of standardized work with these bones. They are similar to the experimental bone retouchers (Valensi, 2002a,b), but with no preparation as in Middle Palaeolithic sites. The diaphysis is present for a large part. There are no other marks on the bone, except another retoucher for one piece. Used as soft hammers, from an ergonomic point of view these bones are not really adapted to good prehension. They could not be "billots" or anvils because of the location of the active area in the distal position on the epiphysis, inconsistent with a large part of the diaphysis. Moreover, the microscopic traces reject the hypothesis of "billot" because traces are similar to the use as a soft hammer to retouch the bifacial pieces (Vincent, 1993; Valensi, 2002a,b).
3) The third category groups the bone retouchers with centered and hatched active areas (scratching). They exhibit only superposed thin and slightly sinuous scores with smooth and U-shaped morphology. There is only one piece at Cagny-l'Epinette, one piece at Orgnac 3 and one area of a bipolar piece at Cueva del Angel. When the flint tool edge is sharp during experiments, a simple abrasion is useful and the action of scratching allows the improvement of the cutting edge (Rigaud, 2007).
4) For the two retouchers with deep and centered traces at Cueva del Angel, two possibilities exist: 1) a "billot", but traces are possibly too organized, 2) a compressor, and in this case, all traces would be well oriented.

5.5. *Particularities of the Lower Palaeolithic bone retouchers: a broader perspective*

Sites earlier than MIS 9, with or without handaxes, yielded bone retouchers. At the Caune de l'Arago (level G, unit III, 450 ka), there is already some evidence of bone use. Large and very large mammal teeth and mandibles carry traces and can be considered as "billots". Traces are deep with scars (Moigne, 1996). At Boxgrove at 500 ka, there are also some bone retouchers (Roberts and Parfitt, 1999; Smith, 2013). In the MIS 11–9 sites, such as Gran Dolina TD10, level H La Micoque, Bolomor or Qesem Caves, with or without handaxes, contemporaneous to innovative behaviours, the bone retouchers are on long and thick fragments collected from the main hunted and eaten species (Langlois, 2004; Risco, 2011; Blasco et al., 2013a,b, 2014; Ollé et al., 2013; Rosell et al., 2015).

The state of freshness is varied, fractured when fresh at Bolomor or Gran Dolina, semi-fresh at Qesem. At Bolomor, we see the elimination of the periosteum to be effective with traces of scraping when it was fresh.

At Gran Dolina TD10-1, one bone retoucher is mentioned (Rosell et al., 2015). It is a shaft from a medium-sized animal with oblique, short, and deep scores and pits on the center of the cortical surface, related to a retouching activity during a short time.

At Bolomor, the bone retoucher belongs to the level XVIIa (MIS 9) and in an assemblage without handaxes (Fernández Peris, 2003; Blasco et al., 2013a,b; Rosell et al., 2015). It is a fragment of a right femur of *Cervus elaphus*. There are oblique, short and deep striations with the V-shaped bottom and percussion pits, typical of retouching activities. There are also parallel *striae* to the bone axis from scratching, similar to those observed at Orgnac 3 and Cagny-l'Epinette. Hominins selected flat and broad surfaces such as flat pebbles.

At Qesem, the retoucher published by Blasco et al. (2013a,b) is a long bone shaft of a medium-sized animal with soft hammer damage. In the middle of the fragment, short, deep overlapping pits with thin, elongated scores are preserved, with V-shaped asymmetrical and long parallel striations preceding the pits and scraping of the bone. It can be classified as a "classical retoucher". More retouchers are described as soft retouchers in Rosell et al. (2015). Some show burning damage. They are mainly from fragments of medium-sized and large-sized animals, while the small-sized hunted species predominate.

For younger sites including handaxes, such as the Lazaret cave (South-East France), in younger levels (MIS 6), retouchers appear different (Table 6). In this site, 18 bone retouchers are counted (0.2% of the determined material) (Michel et al., 2009, 2011; Valensi et al., 2013). Selective hunting of *Red deer* and ibex characterizes the occupations (Valensi and Psathi, 2004; Valensi, 2009; Hanquet et al., 2010) with handaxes in the lower unit CII while they disappeared in the upper unit CIII at around 130 ka (de Lumley et al., 2008; Cauche, 2012). In addition, there are retouchers on small and flat limestone pebbles (Darlas, 1994; Cauche, 2012). Four bone retouchers come from CIII and fourteen from CII (Valensi, 2000; de Lumley et al., 2004) (Table 6).

Table 6
Bone retouchers: number of active areas and hypothesis of use.

	Localisation Unipolar/bipolar Areas	On diaphysis (or lateral edge*)	Distal epiphysis of humerus	Centered on diaphysis	Centered on diaphysis
Type of marks		Pits and unsymmetrical scores	Unsymmetrical scores	Unsymmetrical scores Centered and hatched active area	Poorly individualized scores + crushed marks
Terra Amata	1/0	1			
Orgnac 3	1/3	3		1	
Cagny l'Epinette	5/0	1*	3	1	
La Cueva del Angel	3/1	1,5		0,5	2
Type of retoucher		"Classical retoucher" with pits and scores	Retoucher type "Soft hammer" with heavy percussion	Retoucher	Bone retoucher type « Compressor »? Anvil?
Possible use		Retouches by percussion	Shaping or retouched (bifacial tools) + retouches by percussion	Scratching	Retouches by « pressure » on lithic piece or passive piece type anvil ?

Table 7
Data on the bone retouchers at the Lazaret cave.

Number	Stratigraphical unit	Level	Taxa	Type of bone	Type of fragment	il	ic	Length, mm	Width, mm	Thickness, mm	Nb of active areas
laz01	CIII	4	*Cervus elaphus*	Metacarpal	Shaft + distal epiphysis	2	3	110	30	30	1
laz02	CIII	6	*Cervus elaphus*	Metacarpal	Shaft	2	1	84	22	12	2
laz03	CIII	8	*Bos/Bison*	Metacarpal	Shaft	1	1	68	30	26	1
laz04	CIII	11	Medium size	Long bone	Shaft	–	–	66	20	10	1
laz05	Upper CII	20	*Cervus elaphus*	Tibia	Shaft	2	1	96	24	15	1
laz06	Upper CII	25	*Cervus elaphus*	Tibia	Shaft	2	1	90	25	20	1
laz07	Upper CII	25	*Cervus elaphus*	Femur	Shaft	2	1	90	27	14	2
laz08	Upper CII	–	*Bos/Bison*	Tibia	Shaft	1	1	110	40	40	1
laz09	Lower CII	26	Small/medium size	Long bone	Shaft	–	–	35	16	6	1
laz10	Lower CII	28	*Cervus elaphus*	Metacarpal	Shaft	2	1	105	24	9	1
laz11	Lower CII	28	*Cervus elaphus*	Humerus	Shaft	3	2	90	26	20	1
laz12	Lower CII	28	*Capra ibex*	Femur	Shaft	2	2	70	20	18	1
laz13	Lower CII	28	*Cervus elaphus*	Tibia	Shaft	1	1	70	20	9	2
laz14	Lower CII	28	*Cervus elaphus*	Femur	Shaft	1	1	75	25	–	2
laz15	Lower CII	28/29	Small/medium size	Long bone	Shaft	–	–	60	23	14	1
laz16	Lower CII	29	Small/medium size	Long bone	Shaft	–	–	54	16	5	1
laz17	Lower CII	–	*Cervus elaphus*	Tibia	Shaft	2	1	80	26	13	2
laz18	Lower CII	–	Medium size	Long bone	Shaft	–	–	60	23	11	1

« il » et « ic » correspond to the length size and circumference attesting the degree of fragmentation face to the entire bone (see Villa and Mahieu, 1991; Valensi et al., 2013).

All the retouchers are made on long bones of the main large herbivores (mainly *Cervus*), parts of diaphysis. Sizes vary between 35 and 110 mm, the smallest one being possibly longer during its use. They are wide and elongated.

Bones carry cut-marks, scratching marks and percussion notches due to the carcass management (Valensi, 2000; Valensi et al., 2013), prior to the use of bone as a retoucher. Preparation is attested. A large proportion of retouchers made on *Cervus* bones is burnt (7/18, 39%).

Stigmata are grouped in areas, more or less large and dense, centered or located on the edge, and 13 of them have only a single active area. Most of them have less than 30 scores for each area. It is, however, impossible to determine the intensity of use, as experiments indicate either that each impact could have left a mark on the cortical bone surface (Mallye et al., 2012), or repeated and strong gestures are necessary for leaving marks (Armand and Delagnes, 1998; Daujeard et al., 2014) (Fig. 11).

Referring to data published by Mallye et al. (2012), the form of stigmata is linked to the material worked and the state of freshness of the bone. At the Lazaret, there are mainly rectilinear striations parallel to the bone axis and rare pits, and therefore retouchers could have been used.

Other younger sites such as Biache-Saint-Vaast (beginning of MIS 7; Auguste, 2009) also show more regular marks on retouchers, although there are no handaxes in the assemblages. At Biache, the early phase of the Middle Palaeolithic at the end of the Middle Pleistocene, the retouchers are typically Middle Palaeolithic and are distinct from the less regular and less standardized bone retouchers of the MIS 11–9 sites. An important data for the site of Biache-Saint-Vaast with one of the largest collections of retouchers for the Early Middle Palaeolithic is that there is a large proportion of bones showing stigmata of retouches contrasting with the number of retouched lithic artefacts. For example, for level IIa, there are 303 retouchers for only 449 retouched artefacts (Auguste, 2002). This notable disproportion is not yet explained.

In summary, the bone retouchers of MIS 11–9 present some characteristics already recognized in more recent sites:

- Species selected for the retoucher correspond (mostly) to the main hunted species.
- Retouchers, that we name “classical”, exist from MIS 11–9.

However, some particularities of the bone retouchers of our sites may be mentioned:

- Preparation of the support is lacking.
- Supports are diversified and not standardized as for the younger sites.
- The active areas show diverse locations (centered or on an extremity of an edge).

6. Conclusion

Bone retouchers existed before the Middle Palaeolithic and before MIS 9, where they became systematic tools among the tool kit. They may be considered as one of the most relevant criteria to examine the onset of new behaviors that mark the Early Middle Palaeolithic (Moncel et al., 2012). This type of bone tools appears in relation to new technological behaviors, land-uses and subsistence strategies in Europe before MIS 9. It has its roots as soon as 500 ka, apart from some rare cases (D'Errico and Backwell, 2009).

The MIS 11–9 bone retouchers resemble younger Acheulean/Middle Palaeolithic bone retouchers (later than MIS 9) in term of kinds of support (diaphysis, main hunted species), and position of the marks (on the center of the fragment and not at the extremity excluding “billots”). Orientations (oblique) and types of scores are similar as well. Preparation of the support before use is rare before MIS 9. The bones retouchers seem to be however more varied in one site between MIS 11 and 9, due perhaps to their small number (absence of regularity of use) or the large diversity of uses and materials. The various states of freshness of the bone retouchers suggest an immediate selection among the longest butchery shafts or recovery of discarded bone fragments rejected during long-term or recurrent short-term occupations.

Relationships with the lithic artefacts are commonly made for the Middle Paleolithic, even though it is not obvious for all the series. Some sites yielded a high number of retouchers and few flake-tools (see the French sites of Saint-Marcel or Biache-Saint-Vaast, Auguste, 2002; Daujeard and Moncel, 2010; Daujeard et al., 2014).

For our period of time, handaxes and other large tools belong to the tool kit, with flake-tools which are often thick and modified by invasive retouches, perhaps explaining the diversity of bone

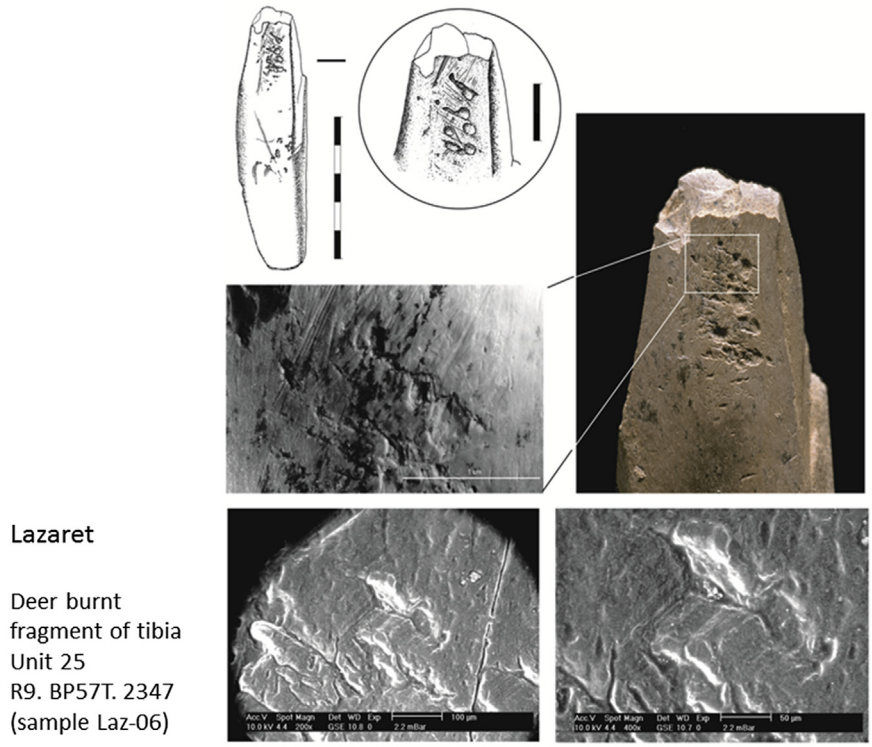

Fig. 11. Lazaret. Retoucher on Deer burnt tibia (R9-BP57T-2347) (sample Laz-06). Details (×80) of the scores by environmental SEM (CERP Tautavel, photographies B. Deniaux).

retouchers in this period. The ratios of flake-tools differ among sites. It is high (15–20%) at Cueva del Angel and in the lower levels of Orgnac 3 that include bone retouchers, and low at the bottom level without bone retouchers. At Cagny l'Epinette, flake-tools are composed of scrapers, denticulates and notches (between 10 and 20% according to the levels). The ratio is low at Terra Amata (less than 5%). Handaxes in our corpus of sites indicate that both hard and soft hammers could have been used to shape them. Our bone retouchers described as soft hammers and classical retouchers could have been used for shaping, retouching, and regularizing the tool edges. For Cagny-l'Epinette, besides the bone retouchers, the presence of many deer antlers, shed and unshed, is noted. No clear stigmata can be observed on those bones, but we may imagine a probable use as soft hammers as in Boxgrove (Tuffreau et al., 1995; Roberts and Parfitt, 1999; Smith, 2013; Stout et al., 2014). At Terra Amata, Orgnac 3, and Cueva del Angel, wild boar canines have been intentionally fractured, indicating that the bone use is much more varied than commonly admitted for this period (Sam, 2009; Valensi et al., 2011; Barroso et al., 2011). Moreover, the bifacial tools on elephant bones of the Latium sites such as Castel di Guido, is evidence of a broader use of bone than expected (Boschian and Sacca, 2015). Bone tools are similar to stone tools (handaxes, scrapers), sometimes recycled (Gaudzinski et al., 2005; Boschian and Sacca, 2015).

The raw material used for the artefacts is also of interest. At Cagny-l'Epinette, all the lithic tools are made on flint (Lamotte and Tuffreau, 2001). At Orgnac 3 and Cueva del Angel, flint is dominant but some large flake tools are made on quartzite, basalt, millstone, and quartz (Barroso et al., 2011; Moncel et al., 2011, 2012). At Terra Amata, limestone is dominant, associated with flint. According to experiments, most of our thin traces should be related to work on flint, while the deep scores and pits should be related to flint or quartzite (Mallye et al., 2012). One retoucher at Orgnac 3 yielded traces of silica in the scores, allowing the suggestion that it was used for working on flint or quartzite.

Why, although in some sites such as Cagny-l'Epinette flint is the only raw material used, do observe the same diversity of traces as in other sites? Perhaps the intensity of activities and the strength of knappers on tools could explain the greater or lesser intensity of marks, regardless of the raw materials and the freshness of bone. The interaction between the kind of bone tool (large herbivorous and notably thick cortical diaphysis and the articulation) and lithic industries have to be considered.

If these bone retouchers were reliable and useful for retouching and managing tools, how can the limited numbers be explained?

1) The bone retouchers should be more numerous due to the quantity and the technology of tools. According to the sites, the number of handaxes differs, as does the mode of shaping, hard and soft percussion. The current core technologies produce thick flakes that have often to be retouched in order to modify the cutting edges, in contrast to Levallois core technology which provides thin flakes that could be directly used and does not need retouch. This technology is very rare before MIS 9.
2) The bone retouchers should be more numerous due to the kind of retouches which are commonly invasive and abrupt, as with some tools from younger sites. Bone retouchers consequently could have been useful.
3) Few bone retouchers existed because other types of retouchers were used, such as vegetal retouchers, antlers (Boxgrove) or small and flat pebbles (Terra Amata and Lazaret). These types of material, although always available in the environment of the sites after MIS 9, would be rarely used in the Mousterian sites. This could be explained by a shift in the hominids' perception that occurred from MIS 9, and included the widespread diffusion of bone retouchers in parallel to technological and behavioural changes.

No clear explanation may be given at present. The recovery of fragments of bones (not only from solid fragments of bones of some

species such as auroch) for bone retouchers would not have been among the habits of MIS 11–9 hominin groups or would have been a minor solution among a large diversity of items useful for retouching.

Acknowledgements

This work has been made through fieldworks financially supported by the French Ministry of Culture. The English editing has been made by Cedric Fontaneil. We would like to thank the two reviewers who helped us to improve the paper.

References

Antoine, P., 1994. The Somme valley terrace system (Northern France): a model of river response to Quaternary climatic variations since 800 000 BP. Terra Nova 6, 453–464.
Anzidei, A.P., Bulgarelli, G.M., Catalano, P., Cerilli, E., Gallotti, R., Lemorini, C., Milli, S., Palombo, M.R., Pantano, W., Santucci, E., 2012. Ongoing research at the late Middle Pleistocene site of La Polledrara di Cecanibbio (central Italy), with emphasis on human-elephant relationships. Quaternary International 255, 171–187.
Aouraghe, H., 1999. Reconstitution du paléoenvironnement par les grands mammifères: les faunes du Pléistocène moyen d'Orgnac 3 (Ardèche, France). L'Anthropologie, Paris 103 (1), 177–184.
Armand, D., Delagnes, A., 1998. Les retouchoirs en os d'Artenac (couche 6c): perspectives archéozoologiques, taphonomiques et expérimentales. In: Brugal, J.-P., Meignen, L., Patou-Mathis, M. (dirs.), Économie préhistorique: les comportements de subsistance au Paléolithique, 18°rencontres internationales d'archéologie et d'histoire d'Antibes, APCDA-CNRS, pp. 205–214.
Auguste, P., 1995. Révision préliminaire des grands mammifères des gisements du Paléolithique inférieur et moyen de la vallée de la Somme. Bulletin de la Société Préhistorique Française 92, 143–154.
Auguste, P., 2002. Fiche éclats diaphysaires du Paléolithique moyen: Biache-Saint-Vaast (Pas-de-Ca1ais) et Kulna (Moravie, République tchèque). In: Patou-Mathis, M. (Ed.), Industrie de l'os préhistorique: compresseurs, percuteurs, retouchoirs, vol. X. Société Préhistorique Française, pp. 39–57.
Auguste, P., 2009. Évolution des peuplements mammaliens en Europe du Nord-Ouest durant le Pléistocène moyen et supérieur. Le cas de la France septentrionale. Quaternaire 20 (4), 527–550.
Auguste, P., 2012. L'homme et l'animal au Pléistocène en France septentrionale. In: Un quart de siècle de recherches paléontologiques et archéozoologiques dans le nord de la France, 2 vols.. Habilitation à Diriger des Recherches, Université Lille 1, p. 251.
Barroso, R.C., Ortega Botella, D., Moigne, A.-M., Riquelme Cantal, J.-A., Caparros, M., et al., 2011. The cueva del Angel (Lucena, Spain). An Acheulean hunter's habitat in the South of the Iberian peninsula. Quaternary International 243, 105–126.
Barroso, C., Moigne, A.-M., Caparros, M., Celiberti, V., García-Solano, J., Monge, G., Monclova, A., 2014. El Achelense de la Cueva del Ángel (Lucena, Córdoba). In: Sala, R. (Ed.), Los cazadores recolectores del Pleistoceno y el Holoceno en Iberia y el estrecho de Gibraltar, Estado actual del conocimiento del registro arqueológico. Universidad de Burgos, Fundación Atapuerca, Burgos, pp. 451–463.
Bates, M.R., 1993. Quaternary aminostratigraphy in Northwestern France. Quaternary Science Reviews 12, 793–809.
Baudoin, M., Chauvet, G., Henri-Martin, L., Hue, E., Taté, E., de Mortillet, A., 1906. Discussion à propos de la communication du Dr Henri-Martin sur les maillets ou enclumes en os de la Quina, époque moustérienne. In: Bulletin de la Société préhistorique française, séance du 31 mai 1906.
de Beaune, S.A., 1997. Les galets utilisés au Paléolithique supérieur. In: XXXIIe supplément à Gallia Préhistoire. CNRS Éditions, p. 298.
Binford, L.R., 1981. Bones: Ancient Men and Modern Myths. Academic Press, New York.
Blasco, R., Fernandez Peris, J., 2012. A uniquely broad spectrum diet during the middle Pleistocene at Bolomor Cave (Valencia, Spain). Quaternary International 252, 16–31.
Blasco, R., Rosell, J., Fernandez Peris, J., Arsuaga, J.L., Bermudez de Castro, J.M., et al., 2013a. Environmental availability, behavioral diversity and diet: a zooarchaeological approach from the TD10-1 sublevel of Gran Dolina (Sierra de Atapuerca, Burgos, Spain) and Bolomor Cave (Valencia, Spain). Quaternary Science Review 62, 629–639.
Blasco, R., Rosell, J., Cuartero, F., Fernandez Peris, J., Gopher, A., Barkai, R., 2013b. Using bones to shape stones: MIS 9 bone retouchers at both edges of the Mediterranean sea. PLoS One 8 (10), e76780.
Blasco, R., Rosell, J., Gopher, A., Barkai, R., 2014. Subsistence economy and social life: a zooarchaeological view from the 300 kya central hearth at Qesem Cave, Israel. Journal of Anthropological Archaeology 35, 248–268.
Blumenshine, R.J., Selvaggio, M.M., 1991. On the marks of marrow bone processing by hammerstones and hyenas: their anatomical patterning and archaeological implications.
Boschian, G., Sacca, D., 2015. In the elephant, everything is good: carcass use and re-use at Castel di Guido (Italy). Quaternary International 361, 288–296.
Cauche, D., 2012. Productions lithiques et comportements techno-économiques de groupes humains acheuléens et moustériens en région liguro-provençale. Comptes Rendus Palevol 11, 519–527.
Clark, J.D. (Ed.), 1991. Cultural Beginnings e Approaches to Understanding Early Hominid Life-ways in the African Savanna, Forschunginstitut fur Vor- und Fruhgeschichte. Monographien, vol. 19. Romisch-Germanisches Zentralmuseum, Bonn, pp. 17–32.
Combier, J., 1967. Le Paléolithique de l'Ardèche dans son cadre paléoclimatique. In: Mémoire n°4, Bordeaux, Delmas, p. 462.
D'Errico, F., Backwell, L., 2009. Assessing the function of early hominin bone tools. Journal of Archaeological Science 36, 1764–1773.
Daleau, F., 1883. Sur des lésions que présentent certains os de la période paléolithique. In: Congrès de l'Association Française pour l'Avancement des Sciences, 12e session, Rouen, pp. 600–602.
Darlas, A., 1994. L'Acheuléen final des couches supérieures de la grotte du Lazaret (Nice, Alpes-Maritimes). L'Anthropologie 98, 267–304.
Daujeard, C., Moncel, M.H., 2010. On Neanderthal subsistence strategies and land use: a regional focus on the Rhone Valley area in southeastern France. Journal of Anthropological Archaeology 29, 368–391.
Daujeard, C., Moncel, M.-H., Fiore, I., Tagliacozzo, A., Bindon, P., Raynal, J.-P., 2014. Middle paleolithic bone retouchers in southern France: variability and functionality. Quaternary International 326–327, 492–518.
Debard, E., Pastre, J.F., 1988. Un marqueur chronostratigraphique du Pléistocene moyen à la periphérie du Massif Central: la retombée à clinopyroxène vert du Sancy dans le site acheuléen d'Orgnac III (Bas-Vivarais, SE France). Comptes Rendus de l'Académie des Sciences 306, 1515–1520.
El Hazzazi, N., 1998. Paléoenvironnement et chronologie des sites du Pleistocène moyen et supérieur, Orgnac 3, Payre et Abri des Pêcheurs (Ardèche, France) d'après l'étude des rongeurs. Phd unpublished. Museum National d'Histoire Naturelle, Paris.
Falgueres, C., Shen, G., Yokoyama, Y., 1988. Datation de l'aven d'Orgnac III: comparaison par les méthodes de la resonnance de spin électronique (ESR) et du déséquilibre des familles de l'Uranium. L'Anthropologie, Paris 92 (2), 727–730.
Fernández Peris, J., 2003. Cova del Bolomor (La Valldigna, Valencia). Un registro paleoclimático y arqueologicó en un medio kárstico. Boletín, 4 Sedeck. Sociedad española de Espeleología y Ciencias del karst, pp. 34–47.
Fisher, J.W., 1995. Bone surface modifications in zooarchaeology. Journal of Archaeological Method and Theory 2, 7–68.
Forsten, A., Moigne, A.-M., 1988. The horse from the Middle Pleistocene of Orgnac 3 (Ardèche-France). Faune et Archéologie. Quaternaire 9 (4), 315–323.
Garcia Solano, J., 2014. La persistencia en las estrategias de subsistencia de los groupos humanos del Pleistoceno medio iberico, a partir del registro fosil de la Cueva del Angel (Lucena, Cordoba) (Thesis doctoral-Universidad de Granada), p. 627.
Gaudzinski, S., Turner, E., Anzidei, A.P., Alvarez-Fernandez, E., Arroyo-Cabrales, J., Cinq-mars, J., Dobosi, V.T., Hannus, A., Johnson, E., Münzel, S.C., Scheer, A., Villa, P., 2005. The use of proboscidean remains in every-day Palaeolithic life. Quaternary International 126–128, 179–194.
Gauthier, A., 1992. Paléoenvironnement du Pléistocène moyen dans le sud de la France. Apport et limite de l'analyse pollinique de trois sites préhistoriques: Caune de l'Arago, Orgnac 3, grotte du Lazaret. Phd unpublished. Muséum National d'Histoire Naturelle, Paris.
Giacobini, G., Patou-Mathis, M., 2002. Fiche rappels taphonomiques. In: Patou-Mathis, M. (Ed.), Industrie de l'os préhistorique: compresseurs, percuteurs, retouchoirs, vol. X. Société préhistorique française, pp. 21–28.
Guadelli, A., Fernandez, P., Guadelli, J.-L., Miteva, V., Sirakov, N., 2013. The Retouchers from the Gravettian Levels in Kozarnika Cave. In: Archaeo Plus, – Schriften zur Archäologie und Archäometrie an der Paris Lodron-Universität Salzburg, Band 5, pp. 155–162.
Guerin, C., 1980. Les Rhinocéros (Mammalia, Perissodactyla) du Miocène terminal au Pléistocène supérieur en Europe occidentale. In: Comparaison avec les espèces actuelles, Documents du laboratoire de géologie de Lyon, 79, 3 vols..
Hanquet, C., Valensi, P., Bailon, S., Desclaux, E., El Guennouni, K., Roger, T., de Lumley, H., 2010. Caractérisation du climat et de la biodiversité au Pléistocène moyen final, d'après les faunes de vertébrés de la grotte du Lazaret (Nice, France). Quaternaire 21 (3), 215–226.
Henri-Martin, L., 1906. Maillets ou enclumes en os provenant de la couche moustérienne de la Quina (Charente). Bulletin de la Société Préhistorique Française, III 233–239.
Henri-Martin, L., 1907. Présentation d'ossements utilisés à l'époque moustérienne. Bulletin de la Société Préhistorique Française, IV 269–277.
Henri-Martin, L., 1907-1910. Recherches sur l'évolution du Moustérien dans le gisement de la Quina (Charente). Premier volume: industrie osseuse, Paris, Schleicher.
Jeannet, M., 1981. Les rongeurs du gisement acheuléen d'Orgnac 3 (Ardeche). Bulletin de la Société Linnéenne de Lyon 50 (2), 49–71.
Jéquier, C.A., Romandini, M., Peresani, M., 2012. Les retouchoirs en matières dures animales: une comparaison entre Moustérien final et Uluzzien. Comptes Rendus Palevol 11 (4), 283–292.
Khatib, S., 1994. Datation des cendres volcaniques et analyses géochimiques du remplissage d'Orgnac 3 (Ardèche, France). Quaternaire 5 (1), 13–22.
Lacombat, F., 2006. Pleistocene Rhinoceroses in Mediterranean Europe and in Massif Central (France), vol. 256. Cour. Forsch.-Inst. Senckenberg, pp. 57–69.

Lacombat, F., 2009. Biochronologie et grands mammifères au Pléistocène moyen et supérieur en Europe occidentale: l'apport des Rhinocerotidae (genre *Stephanorhinus*). Quaternaire 20 (4), 429–435.
Lamotte, A., Tuffreau, A., 2001. Les industries lithiques de la séquence fluviatile fine de Cagny-l'Epinette (Somme). In: Tuffreau, A. (dir.), L'Acheuléen dans la vallée de la Somme et Paléolithique moyen dans le Nord de la France: données récentes, Publications du CERP, 6, pp. 113–134.
Langlois, A., 2004. Au sujet du Cheval de La Micoque (Dordogne) et des comportements humains de subsistance au Pléistocène moyen dans le Nord-Est de l'Aquitaine (Phd thesis). University of Bordeaux 1.
Laurent, M., 1989. Etude paléoclimatique du gisement d'Orgnac III: premiers résultats, mémoire de DEA (unpublished). Muséum National d'Histoire Naturelle, Paris.
Laurent, M., Falguères, C., Bahain, J.-J., Yokoyama, Y., 1994. Géochronologie du système des terrasses fluviatiles du bassin de la Somme par datation RPE sur quartz, déséquilibres des familles de l'uranium et magnétostratigraphie. Comptes Rendus Académie des Sciences Paris, série II 318, 521–526.
Leguay, L., 1877. Les procédés employés pour la gravure et la sculpture des os avec les silex. Bulletin de la Société d'Anthropologie de Paris, 2ème série 12, 280–296.
de Lumley, M.A., 1981. Les restes humains d'Orgnac 3. In: Les premiers habitants de l'Europe (1 5000 000–1000 000 ans), Paris. Catalogue de l'exposition du Laboratoire de Préhistoire du Musée de l'Homme, pp. 143–145.
de Lumley, H., 2013. Terra Amata, Nice, Alpes-Maritimes, France. In: Individualisation des unités archéostratigraphiques et description des sols d'occupation acheuléens, Tome III. Editions CNRS, Paris, p. 476.
de Lumley, H., 2015. Terra Amata, Nice, Alpes-Maritimes, France. In: Fascicule 1. Les industries acheuléennes, Tome IV. Editions CNRS, Paris, p. 806.
de Lumley, H., de Lumley, M.A., Miskovsky, J.C., Renault-Miskovsky, J., 1976. Le site de Terra Amata. In: de Lumley, H., Barral, L. (dirs.), Sites paléolithiques de la région de Nice et grottes de Grimaldi, IX° Congrès UISPP, Livret-guide Excursion B1, Nice, pp. 15–49.
de Lumley, H., Khatib, S., Echassoux, A., Todisco, D., 2001. Les lignes de rivage quaternaires en relation avec les sites paléolithiques des Alpes-Maritimes et de la Ligurie occidentale. Revue d'Archéométrie 25, 125–134.
de Lumley, H., Echassoux, A., Bailon, S., Cauche, D., de Marchi, M.-P., Desclaux, E., El Guennouni, K., Khatib, S., Lacombat, F., Roger, T., Valensi, P., 2004. Le sol d'occupation acheuléen de l'unité archéostratigraphique UA 25 de la grotte du Lazaret, Nice, Alpes-Maritimes. Edisud, p. 493.
de Lumley, H., Arroba, D., Cauche, D., Desclaux, E., Echassoux, A., Khatib, S., Ricci, M., Roussel, B., Simon, P., Tozzi, C., Valensi, P., Vicino, G., 2008. Les cultures acheuléennes et moustériennes dans les Alpes-Maritimes et en Ligurie. Bull. Mus. Anthropol. Préhist. Monaco, suppl. n°1, pp. 203–212.
Lyman, R.L., 1994. Vertebrate Taphonomy. Cambridge University Press, Cambridge, MA.
Malerba, G., Giacobini, G., 1996. Les retouchoirs sur éclats diaphysaires du Paléolithique moyen et supérieur de trois sites de l'Italie nord orientale (Grotte de San Bernardino, Abri de Fumane et Abri Tagliente). In: Forli Atti XIII Congresso UISPP, vol. 6, pp. 167–171.
Malerba, G., Giacobini, G., 2002. Fiche d'éclats diaphysaires avec marques transversales d'utilisation. In: Patou-Mathis, M. (Ed.), Industrie de l'os préhistorique: compresseurs, percuteurs, retouchoirs, vol. X. Société préhistorique française, pp. 29–37.
Mallye, J.B., Thiébaut, C., Mourre, V., Costamagno, S., Claud, E., Weisbecker, P., 2012. The Mousterian bone retouchers of Noisetier Cave: experimentation and identification of marks. Journal of Archaeological Science 39, 1131–1142.
Masaoudi, H., 1995. Application des méthodes du déséquilibre des familles de l'uranium (230TH/234U) et de la résonance de spin électronique (ESR) à la datation des sites d'Orgnac 3, de Payre et de l'abri des Pêcheurs (Ardèche) (Thèse de Doctorat). Muséum National d'Histoire Naturelle, Paris, p. 155.
Michel, V., Shen, G., Valensi, P., de Lumley, H., 2009. ESR dating of dental enamel from Middle Palaeolithic levels at Lazaret cave, France. Quaternary Geochronology 4, 233–240.
Michel, V., Shen, G., Shen, C.-C., Fornari, M., Vérati, C., Gallet, S., Sabatier, D., 2011. Les derniers *Homo heidelbergensis* et leurs descendants les néandertaliens: datation des sites d'Orgnac 3, du Lazaret et de Zafarraya. Comptes Rendus Palevol 10, 577–587.
Michel, V., Shen, G., Shen, C.-C., Wu, C.-C., Vérati, C., Gallet, S., Moncel, M.-H., Combier, J., Khatib, S., Manetti, M., 2013. Application of U/Th and $^{40}Ar/^{39}Ar$ dating to Orgnac 3, a Late Acheulean and Early Middle Palaeolithic site in Ardèche, France. PLoS One 8 (12), e82394. http://dx.doi.org/10.1371/journal.pone.0082394.
Moigne, A.-M., 1996. Utilisation des ossements de grands herbivores au Paléolithique inférieur. In: Peretto, C. (Ed.), Forli Atti XIII Congresso UISPP W 4–6, p. 31.
Moncel, M.-H., 1999. Les assemblages lithiques du site Pléistocène moyen d'Orgnac 3 (Ardèche, Moyenne vallée du Rhône, France). In: ERAUL 89. Univ. Liège, p. 446.
Moncel, M.H., Moigne, A.M., Combier, J., 2005. Pre-Neandertal behaviour during isotopic stage 9 and the beginning of stage 8. New data concerning fauna and lithics in the different occupation levels of Orgnac 3 (Ardèche, south-east France): occupation types. Journal of Archaeological Science 32, 1283–1301.
Moncel, M.H., Moigne, A.M., Sam, Y., Combier, J., 2011. The emergence of Neanderthal technical behavior: new evidence from Orgnac 3 (Level 1, MIS8), Southeastern France. Current Anthropology 52 (1), 37–75.
Moncel, M.H., Moigne, A.M., Combier, J., 2012. Towards the Middle Palaeolithic in western Europe: the case of Orgnac 3 (southeastern France). Journal of Human Evolution 63, 653–666.
Mourer-Chauvire, C., 1975. Les Oiseaux du Pléistocène moyen et supérieur de France, 2 vols.. Documents Laboratoire Faculté des Sciences de Lyon 64.
Mozota, M., 2009. El utillaje óseo musteriense del nivel « D » de Axlor (Dima, Vizcaya): análisis de la cadena operativa. Trabajos de Prehistoria 66, 28–46.
Ollé, A., Mosquera, M., Rodriguez, X.P., de Lombera-Hermida, A., Garcia-Anton, M.D., Garcia-Medrano, P., Pea±a, L., Menendez, L., Navazo, M., Terradillos, M., Bargalla, A., Marquez, B.N., Sala, R., Carbonell, E., 2013. The Early and Middle Pleistocene technological record from Sierra de Atapuerca (Burgos, Spain). Quaternary International 295, 138–167.
Patou-Mathis, M., Schwab, C., 2002. Fiche générale. In: Patou-Mathis, M. (dir.), Retouchoirs, compresseurs, percuteurs... Os à impressions et éraillures. Editions S.P.F., Cahier X, Paris, pp. 11–19.
Plisson, H., 1988. Technologie et tracéologie des outils lithiques moustériens en Union soviétique: les travaux de V.E. Scchelinskiï. In: L'Homme de Néandertal. La Technioque, Liège, vol. 4, pp. 121–168.
Pollet, G., 1990. Contribution à l'individualisation des sols d'habitat de Terra Amata. In: Elaboration de lexiques de correspondance, sols d'habitat-couches-objets coordonnés. Diplôme d'Etudes Doctorales, Muséum national d'Histoire naturelle, Paris (Unpublished).
Radmilli, A., Boschian, G., 1996. Gli scavi a Castel di Guido. Instituto Italiano di Preistoria e Protostoria, ETS, Firenze.
Rigaud, A., 2007. Retouchoirs sur éclats diaphysaires ou "affutoirs" de Labastide (Hautes-Pyrénées). Archéologie des Pyrénées occidentales et des Landes 26, 193–200.
Risco, A., 2011. Analyse techno-économique de la couche E de la Micoque: histoire d'une transformation (Master 2 dissertation). University Bordeaux 1 (unpublished).
Roberts, M., Parfitt, S., 1999. Boxgrove. A Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex. In: London English Heritage Monograph, vol. 17, p. 456.
Rosell, J., Blasco, R., Campeny, G., Carlos Díez, J., Alonso Alcalde, R., Menéndez, L., Luis Arsuaga, J., Bermúdez de Castro, J.M., Carbonell, E., 2011. Bone as a technological raw material at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). Journal of Human Evolution 61, 125–131.
Rosell, J., Blasco, R., Fernández Peris, J., Carbonell, E., Gopher, A., Barkai, R., 2015. Recycling bones in the Middle Pleistocene: some reflections from Gran Dolina TD10-1 (Spain), Bolomor Cave (Spain) and Qesem Cave (Israel). Quaternary International 361, 297–312.
Sam, Y., 2009. Etude paléontologique, taphonomique et archéozoologique des grands mammifères du site Pléistocène moyen d'Orgnac 3 (Ardèche, France) (PhD thesis). University of Perpignan.
Sam, Y., Moigne, A.-M., 2011. Rôles des Hommes et des Carnivores dans l'accumulation osseuse des niveaux profonds d'Orgnac 3 (Ardèche, France). Exemple des niveaux 7–8. In: Prédateurs dans tous leurs états, évolution, biodiversité, interactions, Mythes, Symboles XXXI rencontres internationales d'archéologie et d'histoire d'Antibes. Ed. APDCA, Antibes, pp. 351–367.
Segre, A., Ascensi, A., 1984. Fontana Ranuccio: Italy's earliest Middle Pleistocene hominid site. Current Anthropology 29, 230–233.
Shen, G., 1985. Datation des planchers stalagmitiques de sites acheuléens en Europe par les méthodes des déséquilibres des familles de l'Uranium et contribution méthodologique (Phd unpublished). Université de Paris VI.
Smith, G.M., 2013. Taphonomic resolution and hominin subsistence behaviour in the Lower Palaeolithic: differing data scales and interpretive frameworks at Boxgrove and Swanscombe (UK). Journal of Archaeological Science 40, 3754–3767.
Stiner, M.-C., Barkai, R., Gopher, A., 2009. Cooperative hunting and meat sharing 400–200 ka at Qesem Cave Israel. Proceedings of the National Academy of Sciences 106, 13207–13212.
Stiner, M.-C., Gopher, A., Barkai, R., 2011. Hearth-side socioeconomics, hunting and paleoecology during the late Lower Paleolithic at Qesem Cave, Israel. Journal of Human Evolution 60, 213–233.
Stout, D., Apel, J., Commander, J., Roberts, M., 2014. Late Acheulean technology and cognition at Boxgrove, UK. Journal of Archaeological Science 41, 576–590.Tartar, 2002 Tartar, E., 2002. Etude fonctionnelle d'os à impressions de Starocele et Kabazi V (Crimé). Université Paris 1, p. 148.
Tillier, A.-M., Vandermeersch, B., 1976. Les cynomorphes. La Préhistoire Française 367–370.
Tuffreau, A., Bouchet, J.P., Moigne, A.-M., Munaut, A.-V., 1986. Les niveaux acheuléens de la moyenne terrasse de la vallée de la Somme à Cagny-l'Epinette. L'Anthropologie 90, 9–27.
Tuffreau, A., Antoine, P., Chase, Ph., Dibble, H.-L., Ellwood, B.B., van Kolfschoten, Th., Lamotte, A., Laurent, M., McPherron, Sh. P., Moigne, A.-M., Munaut, A.-V., 1995. Le gisement acheuléen de Cagny-l'Epinette. Bulletin de la Société Préhistorique Française 92, 169–191.
Tuffreau, A., Lamotte, A., Marcy, J.-L., 1997. Land-use and site fonction in Acheulean complexes of the Somme Valley. World Archeology 29, 225–241.
Valensi, P., 2000. Archaeozoology of Lazaret cave faunal remains (Nice, France). International Journal of Osteoarchaeology 10 (5), 357–367.
Valensi, P., 2002a. Fiche Extrémités distales d'humérus de grands ongulés. In: Patou-Mathis, M. (Ed.), Retouchoirs, compresseurs, percuteurs...Os à impressions et à éraillures, Cahier X, Commission de Nomenclature de l'Industrie osseuse préhistorique. Editions Société préhistorique française, pp. 75–85.

Valensi, P., 2002b. Fiche phalanges d'Ongulés. In: Patou-Mathis, M. (Ed.), Industrie de l'os préhistorique: compresseurs, percuteurs, retouchoirs, vol. X. Société préhistorique française, pp. 87–97.
Valensi, P., 2009. Evolution des peuplements de grands mammifères en Europe méditerranéenne occidentale durant le Pléistocène moyen et supérieur. Un exemple régional: les Alpes du Sud françaises et italiennes. Quaternaire 20 (4), 551–567.
Valensi, P., El Guennouni, K., 2004. Comportements de subsistence et structures d'habitat sur le site de plein air de Terra Amata (Paléolithique inférieur, France). In: British Archaeological Reports International Series, vol. 1272, pp. 75–85.
Valensi, P., Psathi, E., 2004. Faunal exploitation during the Middle Palaeolithic in South-Eastern France and North-Western Italy. International Journal of Osteoarchaeology 14, 256–272.
Valensi, P., de Lumley, H., Beden, M., Jourdan, L., Serre, F., 2011. Les faunes de grands mammifères des formations du Pléistocène moyen du site acheuléen de Terra Amata. In: de Lumley, H. (Ed.), Terra Amata, Nice, Alpes-Maritimes, France, Tome II. Edition CNRS, Paris, pp. 41–290.
Valensi, P., Michel, V., El Guennouni, K., Liouville, M., 2013. New data on human behavior from a 160,000 year old Acheulean occupation level at Lazaret cave, south-east France: an archaeozoological approach. Quaternary International 316, 123–139.
Verna, C., d'Errico, F., 2011. The earliest evidence for the use of human bone as a tool. Journal of Human Evolution 60, 145–157.
Villa, P., 1978. Terra Amata and the Middle Pleistocene Archaeological Record of Southern France (Ph. D. dissertation). University of California, Berkeley.
Villa, P., Mahieu, E., 1991. Breakage patterns of human long bones. Journal of Human Evolution 21, 27–48.
Vincent, A., 1993. L'outillage osseux au Paléolithique moyen: une nouvelle approche, 2 tomes. University Paris X – Nanterre (PhD thesis).
Zouhair, S., 1996. Intérêt de la datation des planchers stalagmitiques par les méthodes fondées sur le déséquilibre de l'Uranium (230TH/234 U). Application à quelques sites préhistoriques (unpublished Master's thesis). Museum National d'Histoire Naturelle, Paris.