SANDRINE COSTAMAGNO · LAURENCE BOURGUIGNON · MARIE-CÉCILE SOULIER
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BONE RETOUCHERS AND SITE FUNCTION IN THE QUINA MOUSTERIAN: THE CASE OF LES PRADELLES (MARILLAC-LE-FRANC, FRANCE)

Abstract

The over-representation of faunal remains, the particularity of the carcass processing and the lithic industry suggest that the Les Pradelles Mousterian site was used as a task specific location dedicated to the exploitation of reindeer, killed in large number during their migrations. This study focuses on Facies 4a, where almost 500 retouchers were recovered. We discuss the place of retouchers in the technical equipment of the hunter-gatherers of Les Pradelles and the significance of their abundance in the context of a site involving short-term occupations for secondary butchery activities. The relatively stringent selection of blanks is most likely related to constraints caused by the use of reindeer bones whose intrinsic qualities were not necessarily optimal for use as retouchers. Despite the high number of available bone remains, some types of bones were routinely exploited, which leads us to suggest a selection of some blanks during the butchery stage rather than a selection of appropriate remains among the butchery waste. Based on comparisons with published experimental data, three major groups of retouchers have been identified and their roles in the preparation of lithic equipment have been established. The over-representation of retouchers compared to the number of abandoned scrapers in the cave attests to the exportation of a significant proportion of the scrapers. The "exported" tools were used either for activities carried out near the site or were part of the toolkit taken away during travel to other locations. These results demonstrate how retouchers help in characterizing the interconnections between the animal exploitation and the lithic tool production technical sub-systems.

Keywords

Middle Palaeolithic; Bone retouchers; Blank selection; Lithic tool exportation; Quina type Mousterian; Site function

Introduction

Retouchers are among the oldest bone tools that exist, recovered from the faunal assemblages at Boxgrove (Roberts and Parfitt, 1999; Smith, 2013); Caune de l'Arago (Moigne, 1996); Gran Dolina (Rosell et al., 2011); Bolomor, Qesem Cave (Blasco et al., 2013); La Micoque (Langlois, 2004); Schö-

ningen (Julien et al., 2015; Serangeli et al., 2015; van Kolfshoten et al., 2015); Terra Amata, Orgnac 3, Cagny l'Epinette and Cueva del Angel (Moigne et al., 2016). Prior to the Upper Palaeolithic in Europe, retouchers are the only bone tools that are found with relative consistency and in appreciable quantities, for example, at Artenac (Armand and Delagnes, 1998); Espagnac (Jaubert, 2001); Biache-Saint-Vaast, Kůlna (Auguste, 2002); Grotta della Fatte (Valensi and Psathi, 2004); Saint-Marcel (Daujeard, 2007); Jonzac (Beauval, 2004; Jaubert et al., 2008; Niven et al., 2012); Axlor (Mozota, 2009); Fumane (Jéquier et al., 2012); Le Noisetier (Mallye et al., 2012); La Quina (Malerba and Giacobini, 2002; Valensi, 2002a, 2002b); and, Scladina (Abrams et al., 2014a, 2014b). Identified beginning in the late nineteenth century (Leguay, 1877; Daleau, 1884; Henri-Martin, 1906, 1907, 1907-1910; Bourlon, 1907; Giraux, 1907; de Mortillet and de Mortillet, 1910), retouchers have given rise to numerous studies, mostly focused on the characterization and/or function of the pieces, notably through an experimental approach (Henri-Martin, 1906; Siret, 1925; Semenov, 1964; Feustel, 1973; Lenoir, 1973; Dauvois, 1974; Rigaud, 1977; Leonardi, 1979; Vincent, 1988; Boëda and Vincent, 1990; Chase, 1990; Vincent, 1993; Bourguignon, 1997; Armand and Delagnes, 1998; Bourguignon, 2001; Valensi, 2002a;

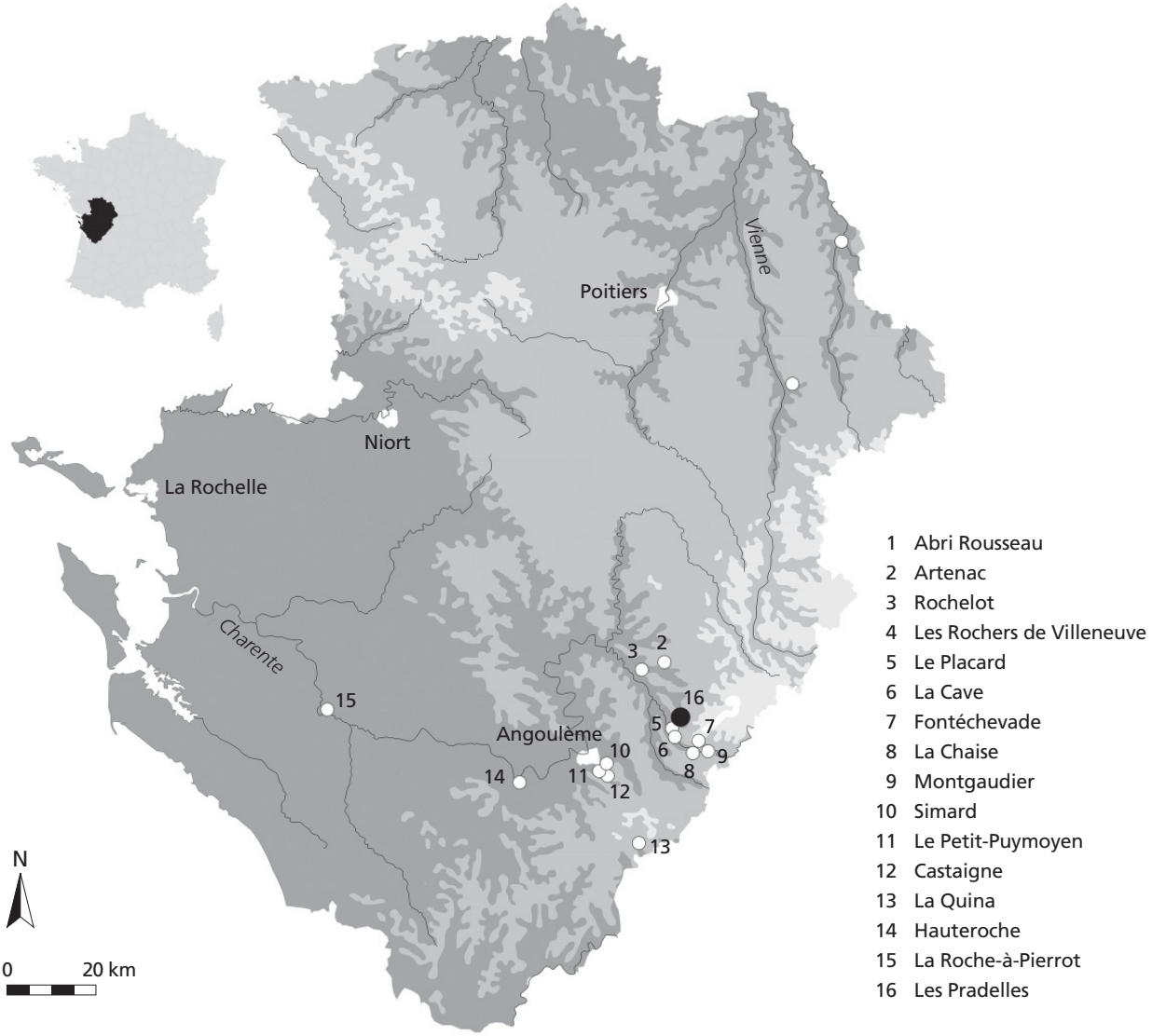

Figure 1 Location of Les Pradelles and other Mousterian sites in the Charente region (image by Lacrampe-Cuyaubère).

Karavanic and Sokec, 2003; Schwab, 2009; Mallye et al., 2012; Mozota, 2012, 2013, 2014; Tartar, 2012). Studies concerning the role of these tools in the technical systems of Palaeolithic human groups (Vincent, 1993; Mallye et al., 2012; Mozota, 2012, 2015; Rosell et al., 2015), or within the different lithic technocomplexes (Jéquier et al., 2012; Daujeard et al., 2014), are less common. Retouchers stand at the interface between the technical subsystems of animal exploitation and lithic production, and can be a valuable source of information if addressed in their multiple dimensions.

At the Quina Mousterian site of Les Pradelles, interpreted as a hunting camp focused on the killing of reindeer (Costamagno et al., 2006; Meignen et al., 2007; Rendu et al., 2011, 2012), a large number of retouchers have been identified. Given the relatively short duration of the occupations, this abundance seems somewhat disproportionate, and this article aims to explore this apparent incongruity. In other words, is this abundance of retouchers compatible with the supposed function of the site? In order to answer this question, we begin by carrying out a detailed study of a representative sample of retouchers from Facies 4a in which we examine the selection of blanks and their possible uses. We then look for their role in lithic production and other activities carried out on the site. These data are finally compared with lithic and faunal data in order to gain a better understanding of the site function.

Les Pradelles

The site of Les Pradelles, also known as Marillac (David, 1935; Vandermeersch, 1971; Maureille et al., 2010), is located near the village of Marillac-le-Franc, in the Charente department of southwest France, near a rivulet (Ligonne) tributary of the Tardoire River (**Figure 1**). Originally open karst, the site has been dramatically altered and today consists of a large depression about 20 m long, 11 m wide and 7.5 m deep.

Known since the late nineteenth century (Vincent, 1898), the site was first excavated by B. Vandermeersch between 1967 and 1980. The site had become a wide shaft, which experienced a steady accumulation punctuated by a rapid filling caused by the collapse of the roof and walls. Eighteen lithological strata and sixteen archaeological levels were identified, all containing Mousterian lithic material and numerous faunal remains. Of outstanding importance are Levels 9 and 10, which contain Quina assemblages (Meignen and Vandermeersch, 1987; Meignen, 1988; Bourguignon 1996, 1997) with abundant cold-climate fauna (particularly *Rangifer, Equus* and *Bison*) and 30 Neanderthal remains (Vandermeersch, 1965, 1971, 1976, 1986).

Table 1 Correspondance between the Vandermeersch and the Maureille and Mann stratigraphies.

Vandermeersch	Maureille and Mann
Levels 5 to 3 (upper)	Facies 5
Levels 6 to 8 (middle)	Facies 4
Levels 9 to 10 (lower)	Facies 2

A new series of excavations was conducted between 2001 and 2013 under the supervision of B. Maureille and A. Mann. The studies published to date (Maureille et al., 2007, 2010; Costamagno et al., 2005) have succeeded in correlating the levels identified by Vandermeersch with eight sedimentary facies (**Table 1; Figure 2**). All the geological, archaeological, and faunal data indicate a chronology corresponding to the end of MIS 4 or the beginning of MIS 3 for Facies 2b and 2a, while the upper levels are assigned to MIS 3 (Maureille et al., 2010; Royer, 2013; Royer et al., 2013; Frouin, 2014). Facies 2b, representing one of the major Neanderthal occurrences, has been dated by thermoluminescence on a burned flint to 57.6 ± 4.6 ka (Maureille et al., 2010). During the more recent phase of fieldwork, almost 100 new hominin remains were recovered throughout the sequence. The remains belong to immature individuals and adults, and include cranial and mandibular fragments, isolated teeth, and post-cranial skeletons, all broken and incomplete. Many of the Neanderthal bones show traces of perimortem manipulations (cut-marks and

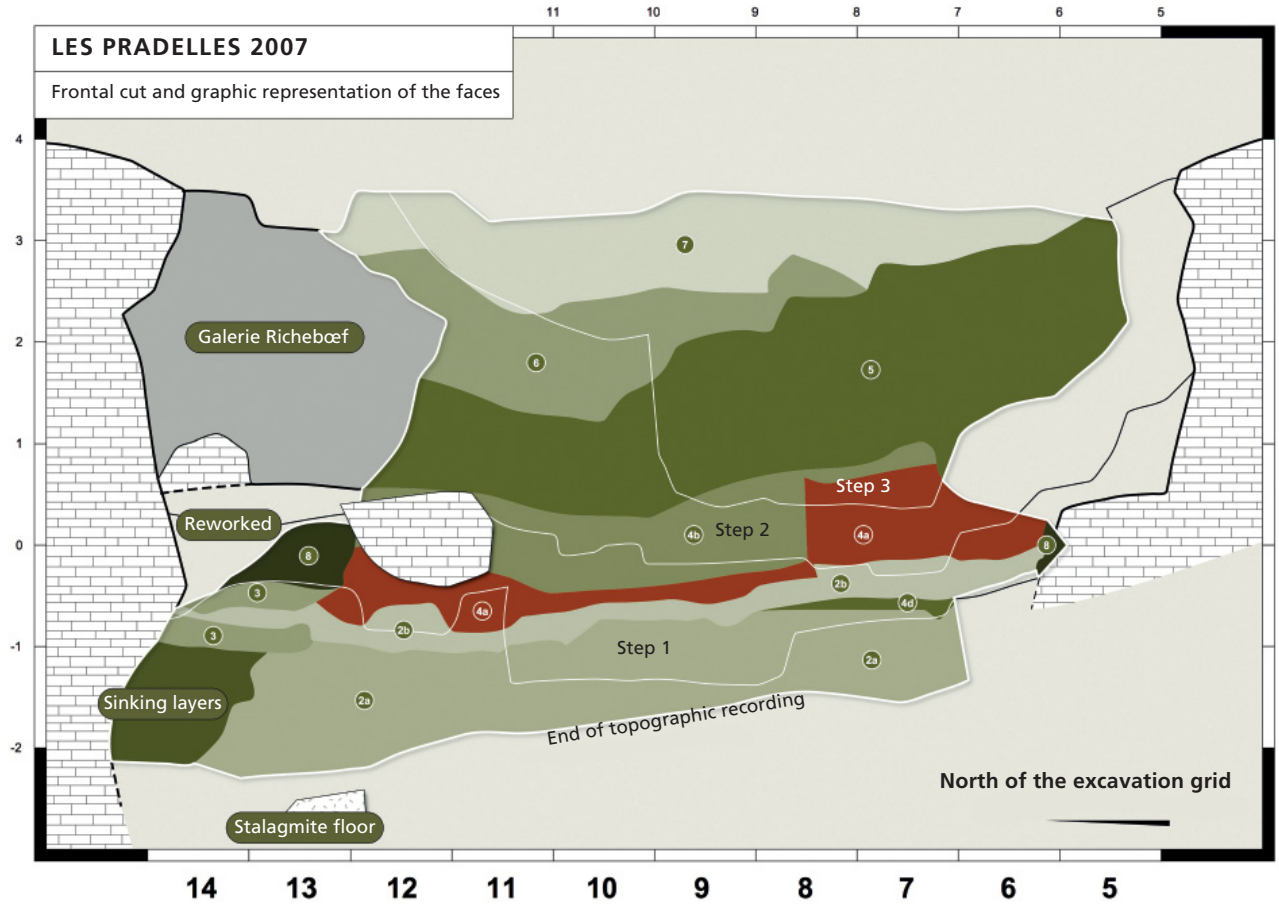

Figure 2 Lithostratigraphy of Les Pradelles (after Maureille et al., 2010; image by Lacrampe-Cuyaubère).

strong percussion impacts with conchoidal scars) reflecting cannibalism (Garralda et al., 2005; Mussini, 2011 but see also Garralda, 2008; Maureille et al., 2010), as well as carnivore consumption/scavenging activities. Moreover, a left Neanderthal femur diaphysis fragment in Facies 2a has been used as a retoucher (Mussini, 2011).

Previous taphonomic analysis of the bone assemblages has shown that the upper levels (Levels 6 to 3) only contain evidence of animal occupations, whereas the faunal remains from the lower levels (Levels 9 and 10 from Vandermeersch fieldwork, and Facies 2a and 2b from Maureille-Mann fieldwork) are of anthropic origin (Costamagno et al., 2005). The lithic technology and zooarchaeological analyses of the lower levels show that Quina Mousterian groups used the site as a hunting camp. There, they processed parts of their prey, especially reindeer *(Rangifer tarandus)*, which had previously been disarticulated (Costamagno et al., 2006). The Neanderthal occupations were short and possibly limited to the time of reindeer migrations (Costamagno et al., 2006; Meignen et al., 2007; Soulier, 2008).

Following these first analyses, which mainly focused on the material from the lower levels (Levels 9 and 10, Vandermeersch excavations), studies carried out on the material collected during recent excavations showed that the occupations of the middle stratigraphic units (Facies 4, Maureille-Mann excavations) present the same characteristics as the lower ones (Facies 2a and 2b) and could be interpreted in the same way (see Rendu et al., 2011, 2012 for Facies 2; work is in progress for Facies 4).

Facies 4a

In this article, we focus our study on the retouchers from Facies 4a (thickness = 20 cm), the richest level

Table 2 Main characteristics of the facies 4a lithic assemblage. Q = Quina.

	N	% retouched tools	% scrapers	% notches / denticulates	% Q and 1/2 Q scrapers	% resharpening / recycling flakes
@xogenous flints	183 (15.4%)	43.2	51.3	22.4	38.5	35.0
Local flints	1008 (84.6%)	14.8	36.2	28.3	16.4	4.9

and the most recent with a clear Neanderthal occupation. We describe here the main characteristics of this level, which are hitherto unpublished.

Just like the lower levels, the lithic assemblages identified in Facies 4a are characteristic of the Quina Mousterian in their production system and tool management (Meignen and Vandermeersch, 1987; Meignen, 1988; Bourguignon, 1996, 1997). Less abundant than the bone remains, these tools have been made mainly on local raw material of relatively poor quality, but also on material imported from distances of 10-15 km away, and even from as far as 30 km (**Table 2**). In this level, the proportion of imported material (15.4%), mainly good-quality Cretaceous flint, is greater than in the lower levels, and in general, more abundant than in other Mousterian industries. This lithic material on exogenous flint involves a high proportion of retouched tools (43.2%), mainly scrapers (51.3% of the tools), usually single-edged or transverse and often refined by Quina and half-Quina retouch (38.5%). The presence of numerous small sharpening flakes characteristic of Quina retouch (type 0 to III; Bourguignon, 1997, 2001), as well as recycling flakes (type IV; Bourguignon, 1997, 2001) (35% of imported products), indicates the sharpening/resharpening/recycling process of the imported tools. The recycling flakes have occasionally been transformed into retouched tools, illustrating the branched reduction process of the Quina matrix (Bourguignon et al., 2004).

In this exogenous lithic assemblage, the blanks underwent special maintenance, whether already retouched or not, having been sharpened/used/resharpened, then recycled in some cases and finally abandoned or transported away from the site.

The treatment of local raw materials was different. Flint nodules, present in the surrounding area and within the limestone host rock of the cave, were knapped on site (presence of cores and debitage products, cortical or not) using the Quina flaking method. A small proportion of these blanks (14.8%) were transformed into tools, mostly scrapers, but also notches and denticulates. Denticulates are more frequent than in the exogenous raw material assemblage. These tools complemented the range of imported tools to ensure the ability to carry out the necessary activities at the site. Here again, small sharpening flakes, and even recycling flakes, reflect this process. But, this phenomenon is much less marked than for the exogenous, primary raw material (4.9% *versus* 35%). It also seems that some of the cortical flakes produced during this on-site knapping were taken away. This type of cortical blank was, in fact, often selected for the production of tools in the Quina Mousterian or to be used as a production matrix (Bourguignon, 1997; Bourguignon et al., 2006).

The bones are particularly well preserved (% number of specimens with more than 75% of the cortical surface preserved [NISPo] = 97.7) and exhibit very few natural alterations, such as root marks and manganese deposits. As in the lower levels, reindeer largely dominates the faunal remains, representing 98.4% of the identified specimens (**Table 3**). Large bovids and horse *(Equus caballus)* are the second and third most abundant taxa. Carnivore tooth marks are present on only 3.3% of the NISPo (reindeer = 3.1%; bovid = 13.8%; horse = 21%), together with 0.8% digested bones. The frequent occurrence of hominid modifications on reindeer specimens (33.8% of the NISPo) shows that this prey was first hunted by Neanderthals and then occasionally scavenged by carnivores. Hominin modifications are less frequent on bovid (27.5% of the NISPo) and horse specimens

(10.5% of the NISPo); thus, their origins could be mixed.

Though not very extensive (8 m^2, ca. 1.6 m^3), the excavated area for Facies 4a yielded a minimum of 58 reindeer individuals. The mortality profile falls into the Juvenile-Prime-Old zone (**Figure 3**), which is usually characteristic of an L-shaped or catastrophic mortality profile (Discamps and Costamagno, 2015). This indicates a non-selective slaughter in terms of the age of the individuals with the reindeer herds.

In terms of %MAU (minimum animal units), the long bones of the hind limbs (tibia and femur) are the most common elements, followed by the humeri and the metatarsals (**Table 4**). Carpals, tarsals and phalanges are largely under-represented. The ribs (10.3%), crania (28%) and mandibles (29%) are more frequent than the vertebrae (< 4%). This skeletal representation appears more likely to result from transport decisions favouring marrow-rich elements (Jones and Metcalfe, 1988; %MAU/marrow cavity volume: $r_s = 0.955$; $p < 0.001$) than from taphonomical bias (Lam et al., 1999; %MAU/density: $r_s = 0.298$; $p = 0.07$).

Cutmarks, which are particularly abundant on the bone remains, indicate intensive defleshing of the meaty limb bones. At the same time, the numerous marks found on the metapodials reflect skinning of the reindeer carcasses and extraction of the tendons. No long bone is complete; the epiphyses are absent and most (85.2%) of the diaphysis fragments preserve fresh bone fractures. Together with percussion marks, this fracturing reflects a particularly intensive retrieval of bone marrow (Costamagno et al., 2006; Rendu et al, 2012); phalanges and the calcaneus were also systematically broken.

The site was located near several rivers that may have constituted a major migration corridor for reindeer populations between the Massif Central and the Aquitaine Basin (**Figure 1**). This passageway must have offered a strategic location for Neanderthal groups to carry out large-scale seasonal hunts. In addition, several minor topographic features around the site offer good views of the surrounding area and may have been used as look-

Table 3 **Les Pradelles Facies 4a large mammals faunal spectrum in NISP (number of identified specimens) and MNI (minimum number of individuals).**

Taxa	NISP	%NISP	MNI	%MNI
Bovinae	39	0.7	2	2.9
Equus caballus	38	0.6	2	2.9
Rangifer tarandus	5871	98.4	58	85.3
Cervus elaphus	1	0.02	1	1.5
Crocuta spelaea	4	0.1	1	1.5
Canis lupus	4	0.1	1	1.5
Vulpes sp.	8	0.1	1	1.5
Mustelidae	1	0.02	1	1.5
Lepus sp.	3	0.1	1	1.5
Total	5969	100	68	100

Table 4 **Reindeer skeletal part representation in NISP (number of identified specimens), MNE (minimum number of elements) and %MAU (minimum animal units). (–) = not calculated.**

Skeletal Part	NISP	MN@	MAU	%MAU
Skull	96	14	14	28.2
Mandible	213	29	14.5	29.3
Atlas	1	1	1.0	2.0
Axis	1	1	1.0	2.0
Other cervical vertebra	17	6	1.5	3.0
Thoracic vertebra	31	13	1.0	2.0
Lumbar vertebra	14	11	1.8	3.7
Sacrum	3	1	1.0	2.0
Rib	262	133	5.1	10.3
Scapula	67	-	-	-
@umerus	300	64	32.0	64.6
Radius	465	-	-	-
Carpals	12	11	0.9	1.8
Metacarpal	199	49	24.5	49.5
Pelvis	67	-	-	-
Femur	438	95	47.5	96.0
Tibia	723	99	49.5	100.0
Calcaneus	16	12	6.0	12.1
Talus	9	6	3.0	6.1
Other tarsals	18	18	6.0	12.1
Metatarsal	486	52	26.0	52.5
Phalanx 1	59	34	4.3	8.6
Phalanx 2	24	17	2.1	4.3
Phalanx 3	8	-	-	

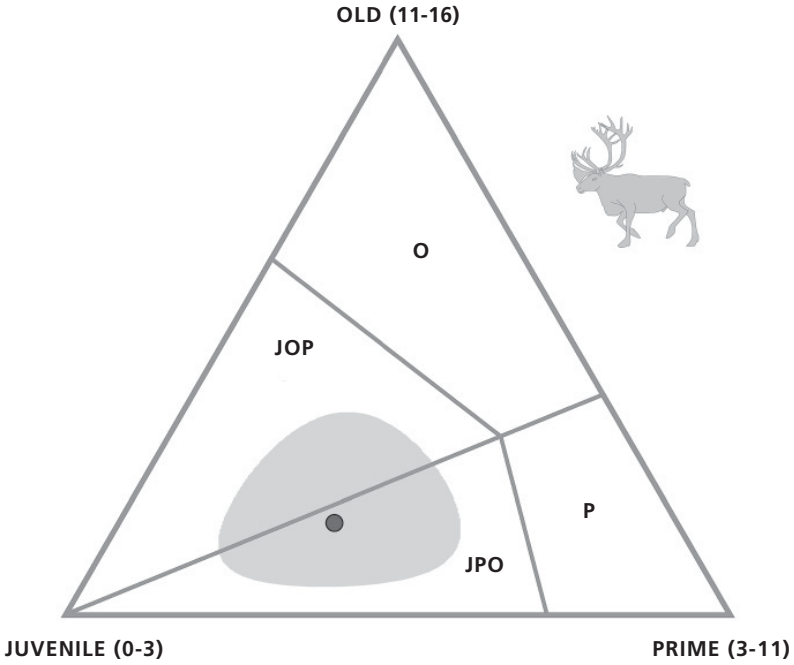

Figure 3 Mortality profile for Les Pradelles reindeer using a ternary diagram modified after Discamps and Costamagno (2015).

out stations by reindeer hunters. The reindeer may therefore have undergone initial butchery at kill locations near the site, with subsequent transport of the nutritionally richest parts back to the cave for more intensive butchery.

At the same time, the lithic data clearly suggest that the cave was occupied for relatively short periods. In the context of brief occupations, transported toolkits (i.e., the exogenous flint component) constitute a substantial portion of the lithic assemblage recovered on the site. On the contrary, in prolonged stays (e.g., base camps), extensive *in situ* manufacture activities on local raw material produce vast amounts of debris that quickly overwhelms the imported artefacts (Kuhn, 1995). Thus, in the case of Les Pradelles Facies 4a, the high proportions of exogenous raw material observed (15.4%), together with the low density of lithics as compared to bone remains (16.6%, a ratio close to those encountered in Mousterian sites considered as "hunting camps"; Rendu et al., 2011) clearly sustained short-term occupations. Moreover, the introduction of ready-made and highly curated tools (Binford, 1979) goes hand in hand with short stays during which limited time was spent manufacturing tools (Meignen et al., 2007).

So, the Neanderthals travelled around and arrived at the site with a toolkit ready for use and versatile blanks with a high functional potential (Bourguignon et al., 2006). During these short stays, tools manufactured on site from local raw materials completed the imported tool kits; these were also retouched and sometimes recycled to suit the intended activities. Part of this production (cortical blanks, Kombewa-type flakes, and tools) was taken away for activities outside the cave, to nearby or more distant areas. The fragmentation of the lithic reduction sequence in time and space is often observed in Mousterian sites (Turq et al., 2013). This division is particularly well represented at Les Pradelles and developed in parallel to that perceived with the animal carcasses. Indeed, the short occupation periods suggest that some of the animal resources obtained during hunts were taken away to other sites and kept for later consumption (see Costamagno et al., 2006, for Levels 9 and 10 of Vandermeersch excavation; Rendu et al., 2011, 2012, for Facies 2 of Maureille and Mann excavation).

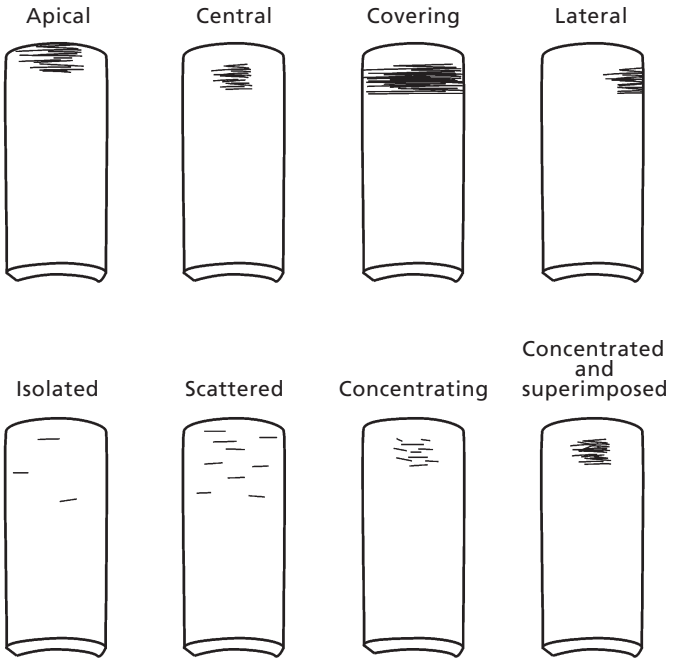

Figure 4 Nomenclature used for the Active Percussion Zone (APZ) description (after Mallye et al., 2012).

Materials and methods

This paper focuses on Facies 4a; it is the richest anthropogenic assemblage of the sequence excavated by Maureille and Mann, the only one in which the MNE (minimum number of elements) have been calculated (except for the scapula, the radius and the pelvis) and the anthropogenic marks are reported on bone templates. Facies 4a yielded 497 retouchers. Mussini (2011) conducted a preliminary analysis of 35 of the retouchers from Facies 4, which discussed the characteristics of the retoucher made on a Neanderthal bone.

In order to set apart the retouchers, all the skeletal remains, whether identifiable or not, were observed under x30 magnification with a hand lens. The retoucher blanks were identified with as much precision as possible from a taxonomic and anatomical point of view. When the level of precision was relatively high, the remains were drawn using *Adobe Illustrator* software onto anatomical charts in order to observe the aggregated locations of retoucher areas. The length and width of the blanks were systematically measured to the nearest millimetre. For pieces with recent fractures, dry bone fractures and flexion fractures, the length was recorded and noted as a minimum length. These pieces were not taken into account for the evaluation of overall blank length. The presence of scraping marks in relation to the retoucher use area was noted, as were the number of retoucher use areas present on the pieces.

A sample of 408 retouchers was studied in detail. Each of the use areas (N = 530; 83% of the use area sample) was described using most of the terminology proposed by Mallye et al. (2012). Other criteria that we considered important for an effective description of the retouchers at Les Pradelles were included. For each area, eight mainly qualitative criteria were selected. The length (1) and width (2) of the use areas were measured to the nearest tenth of a millimetre. The length always corresponded to the long axis of the use area, defined as its greatest length (Mozota, 2012). The localization (3) was divided into four categories: apical, central, covering and lateral (Figure 4). As recommended by Mallye et al. (2012), four trace distribution (4) types were distinguished: isolated, scattered, concentrated, and concentrated and superimposed traces. Together with the dimensions of the use area, this allowed us to assess the use intensity of the retouchers (Mallye et al., 2012). For the orientation of the marks relative to the long axis (5), three categories were

distinguished: longitudinal, transverse, and oblique. The presence of stigmata with different orientations within the same use area, indicating a change of gesture or a different use of the retoucher, was systematically noted. The sixth criterion records the presence or absence of fine bone scales (6). According to Mallye et al. (2012), the detachment of fine bone scales can reflect the use of retouchers with an intermediary freshness. Similarly, "widespread chipping" has also been documented on experimental dry bones used as retouchers (Mozota, 2012). In terms of the morphology of the stigmata (7), we distinguished between short (pits) and elongated (scores). The depth of the stigmata (8) was recorded as superficial, intermediary or deep (**Figure 5**). As these last two criteria were used post-analysis once we had defined the types of retouchers, quantified data are not currently available.

Table 5 Number of bone retouchers and NISP (number of identified specimens) by species.

Taxa	Retoucher	% Retoucher	NISP	%NISP
Reindeer	473	95.2	5871	97.5
Red deer	1	0.2	1	0.02
Bison	8	1.6	39	0.6
Horse	5	1.0	38	0.6
Large ungulates	10	2.0	75	1.2
Total	497	100	6024	100

Results

The bone blanks

Facies 4a yielded 497 bone retouchers, principally made on reindeer bone (N = 473) and on bovids and horse in lesser abundance (**Table 5**). Large ungulates represent 2.4% of the NISP and 4.6% of the blanks used as retouchers. Thus, based on the relative contribution of the different taxa to the faunal spectrum, it appears that large ungulates were preferentially selected ($\chi^2 = 33.569$, $df = 1$, $p << 0.001$).

The length of the blanks ranged between 27 and 154 mm. Although predominant in the overall assemblage (53.2%), only 2.7% of bone fragments under 40 mm in length were used (**Figure 6**). Conversely, 46.2% of the retouchers were made on bone fragments over 70 mm in length, while such large fragments only constitute 5.7% of the total assemblage. The average length of the blanks used as retouchers is 73.2 mm, while the average length in the total assemblage of limb shaft fragments is 40.2 mm (**Table 6**). Longer blanks were clearly preferred.

Most of the retouchers (N = 479; %NISP = 96.4%) were made on limb bone fragments (humerus, radius, femur, tibia and metapodial) (**Table 7**). The mandible, scapula, pelvis and ribs were also used but to a far lesser extent, constituting only 2.6% of the retouchers. Among the limb bones, only shaft

Figure 5 Depth of the stigmata: a. deep; b. superficial; c. intermediary (photographs by Beauval).

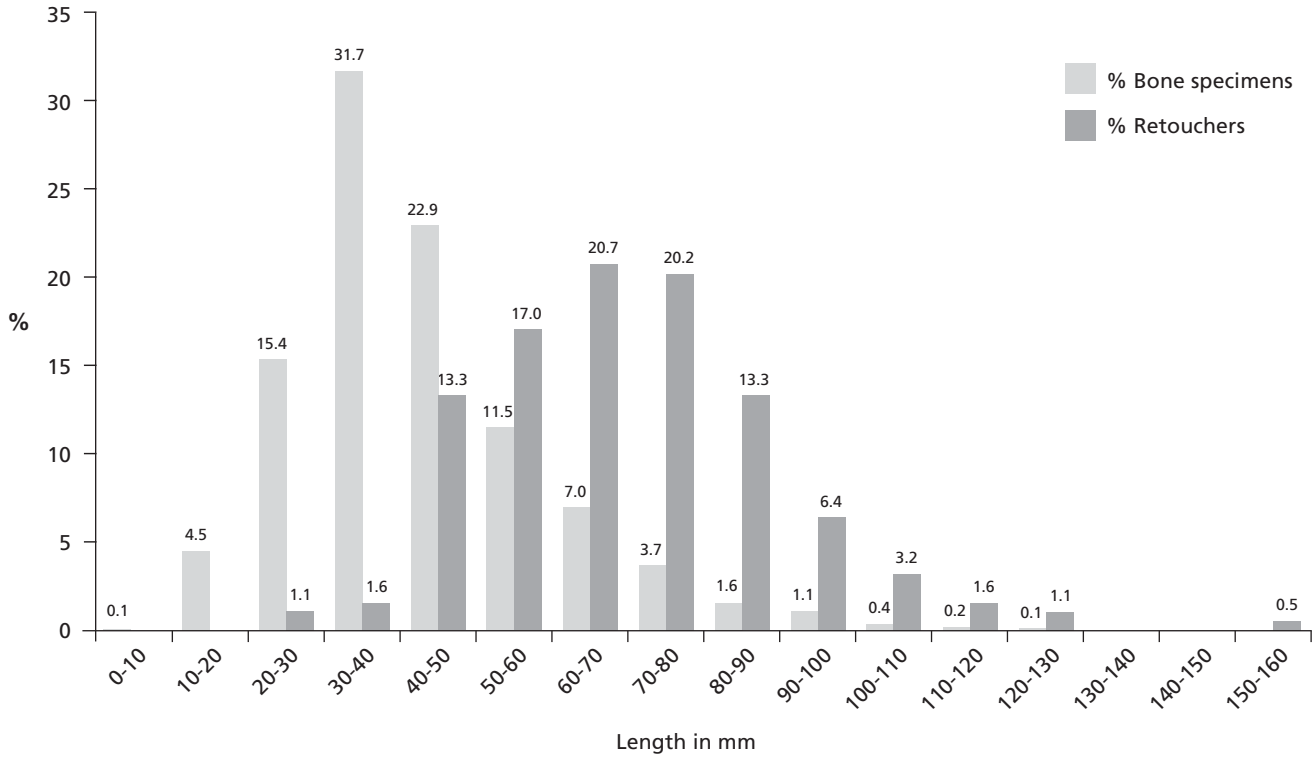

Figure 6 Proportion of bone retouchers and all bone specimens by size classes. Only complete fragments are taken into account.

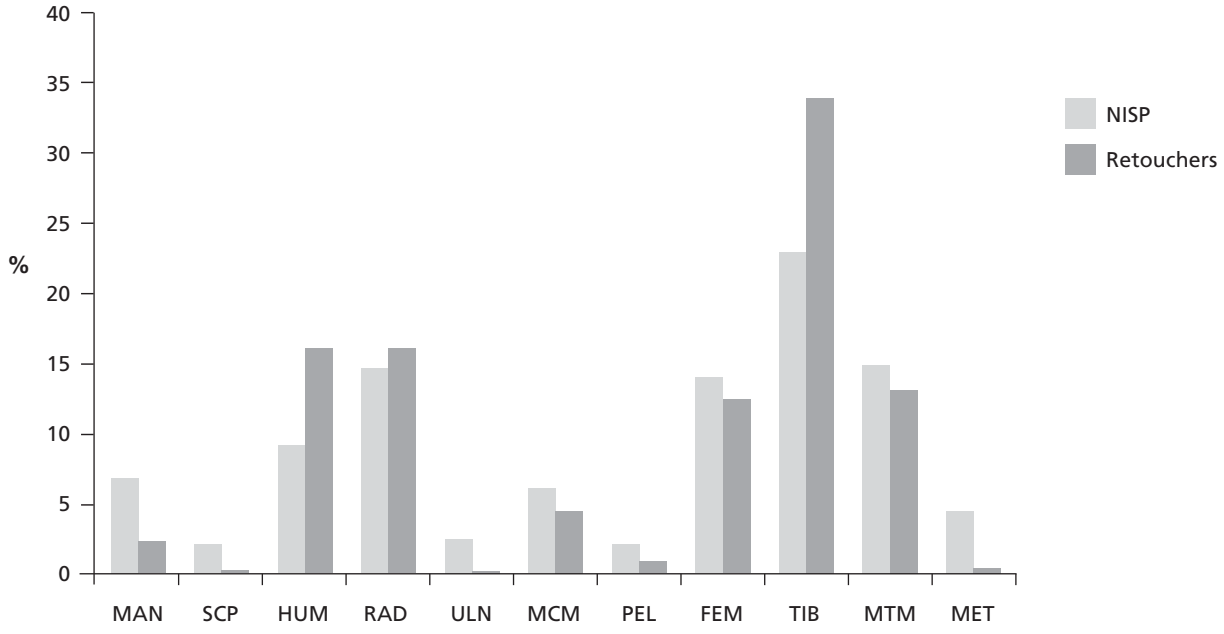

Figure 7 Proportion of bone retouchers and of bone specimens by skeletal parts for the reindeer (NISP = 2919; N retouchers = 473). MAN = mandible; SCP = scapula; HUM = humerus; RAD = radius; ULN = ulna; MCM = metacarpal; PEL = pelvis; FEM = femur; TIB = tibia; MTM = Metatarsal; MET = metapodial.

fragments were used and, for the reindeer, the tibia appears to have been preferentially selected – 35% of the reindeer limb bone retouchers were on the tibia. The humerus (16%), radius (16%) and metatarsals (13.6%) were also frequently used. Compared to their relative abundances in Facies 4a, the tibia and humerus were used more frequently than expected, whereas the radius, femur and metapodials were used in proportion to their overall abundance in the assemblage (**Figure 7**).

Figure 8 displays the use areas for retouchers identified on reindeer mandibles and limb bones. Flat and plano-convex surfaces were preferentially selected: the anterior side of the radius and femur, the medial and posterior sides of the tibia, the anterior side of the mid- and distal shaft of the tibia, and the lateral and medial sides of the metatarsal. However, convex surfaces were also used, such as the inferior part of the horizontal ramus of the mandible, the lateral side of the proximal radius, the anterior part of the metacarpal and humerus, and the posterior face of the distal humerus just above the olecranon fossa.

In 18% of cases (N = 71), the combination of retoucher use areas and scraping marks (see **Figure 5b**) indicates the use of fresh blanks. At the same time, fine cortical scales, which are evidence of the use of defatted bone, are rare (< 3%).

The use areas

Most of the retouchers have only one use area (78.5%); only 17.3% have two use areas. In the most extreme cases, four or even five use areas were observed (**Table 8**). The large ungulate remains include multiple use areas more frequently (39.1%) than the reindeer remains (20.7%) (**Table 9**), but the difference is not statistically significant ($\chi^2 = 3.764$, $df = 1$, $p > 0.05$). Multiple use areas have been identified on almost one-third (31.2%) of the retouchers made on reindeer tibia shafts, 26.2% of the humeri and 18.6% of the femurs. The percentage is less for the metatarsals (14.5%) and metacarpals (4.8%). This dichotomy between the reindeer tibia and the other limb bones is even more striking if we take into account the pieces with three or more use areas – 63.2% of these multiple retouchers have been made on tibia shafts.

As shown in **Figure 9**, large blanks do not systematically have a greater number of use areas. On the other hand, retouchers smaller than 60 mm rarely present more than one use area. These short fragments seem to have been quickly abandoned

Table 6 Length of bone retouchers and other bone specimens in millimetres.

	Retouchers	Bone specimens
Number	256	5641
Mean	73.2	40.2
Standard Deviation	21.7	17.4
Minimum	27	4
Maximum	154	154

Table 7 Skeletal parts used as retouchers.

	Reindeer	Bison	Horse	Red deer	Large ungulates
Mandible	11	-	-	-	-
Rib	-	-	-	-	2
Scapula	1	-	-	-	-
Humerus	76	2	1	1	-
Radius	76	1	3	-	-
Ulna	1	-	-	-	-
Metacarpal	21	1	-	-	-
Pelvis	4	-	-	-	-
Femur	59	1	-	-	-
Tibia	160	2	1	-	-
Metatarsal	62	1	-	-	-
Metapodial	2	-	-	-	-
Limb bone	-	-	-	-	8

Table 8 Number of use areas per retoucher.

Number of use areas	Number of retouchers	%
1	390	78.5
2	86	17.3
3	13	2.6
4	5	1.0
5	3	0.6

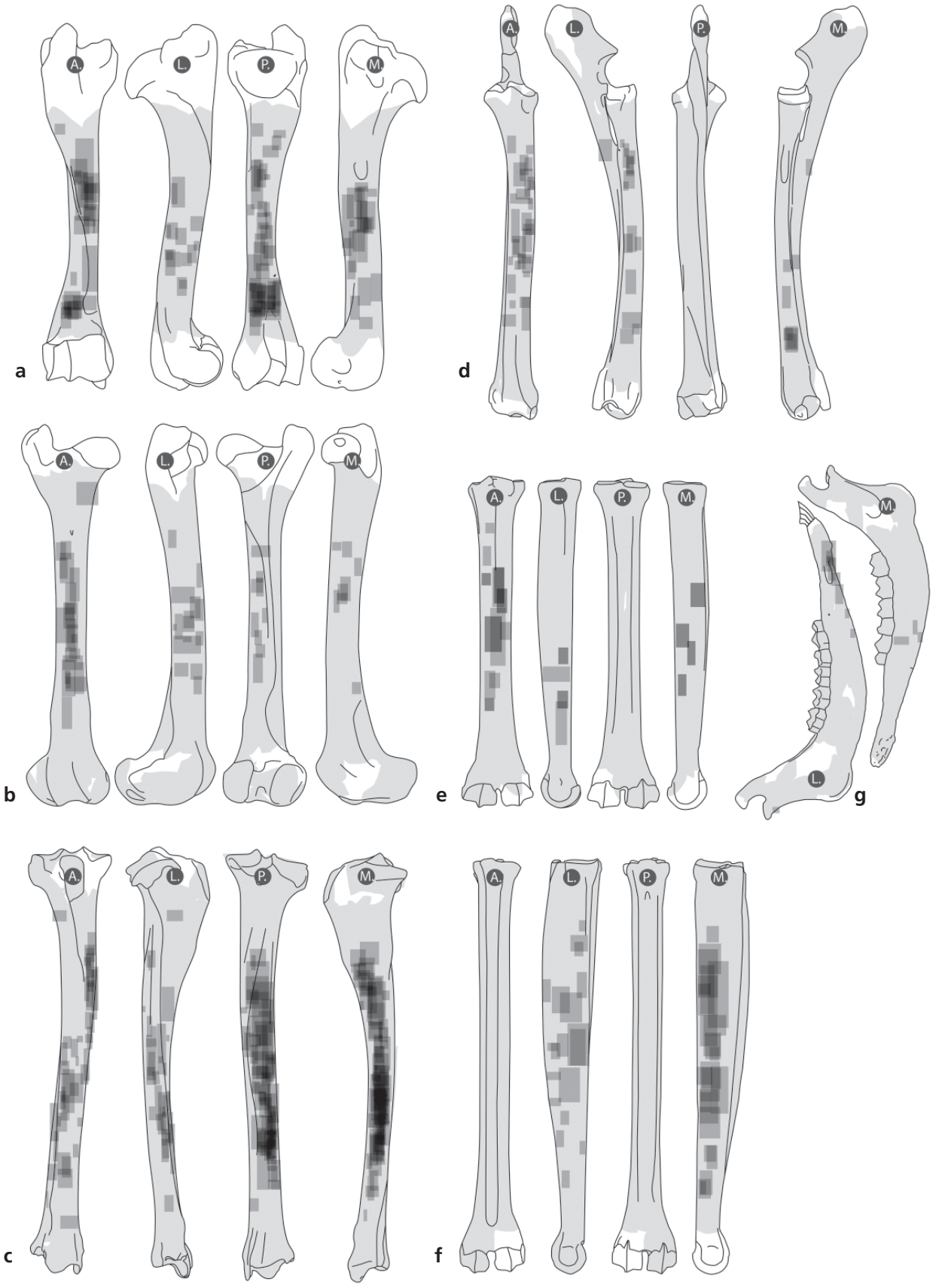

Figure 8 Location of the use areas on reindeer skeletal parts: a. humerus; b. femur; c. tibia; d. radio-ulna; e. metacarpal; f. metatarsal; g. mandible. A. = anterior face; L. = lateral; P. = posterior; M. = medial.

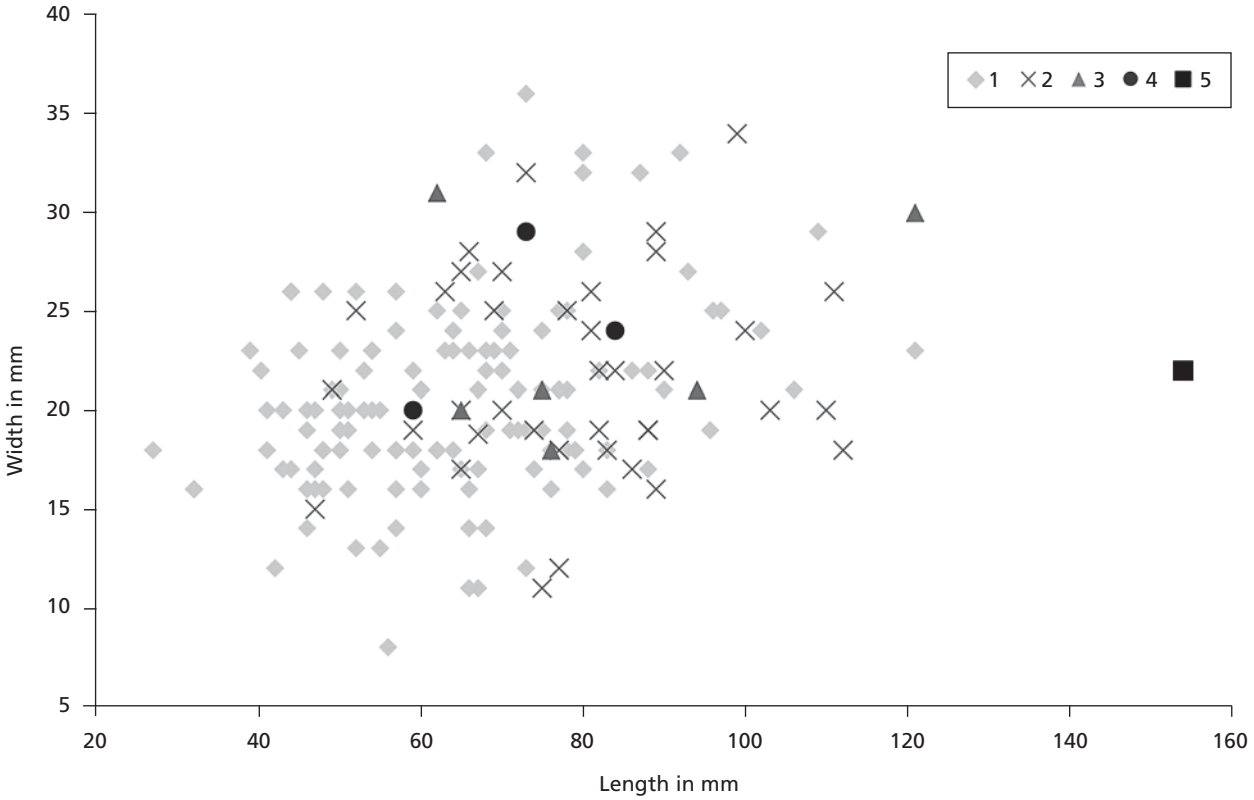

Figure 9 Number of use areas per blank relative to length and width dimensions.

after their first use. For the retouchers that were repeatedly used, it is not the length that is the decisive factor, but the skeletal element.

The length of the use areas ranges from 1.2 mm to 47 mm and the width from 0.5 mm to 28 mm (**Table 10**). Less than 4% of the use areas exceed 30 mm in length. The length of the use area is not linked to the skeletal part (**Figure 10**). Use area length is significantly and positively correlated with the length of the blanks, but the coefficient is low ($r_s = 0.262$, $p < 0.001$). In most cases (87%), the use areas are longer than they are wide (see **Table 10**).

Only six use areas have an apical localization, half of which are on large ungulates. Otherwise, the use areas have a central location (*sensu* Mallye et al., 2012). Most of the time (52.5%), the marks are obliquely oriented relative to the long axis of the bone, but a continuum exists from longitudinal (1.6%) to a sub-transversal (43.3%) orientation. In some cases (4.2%), the same use area presents marks in different directions, showing that the blanks were used in different ways. Depending on the skeletal element, the orientation of the marks shows different patterns. For the tibias and metatarsals, the orientation is mostly oblique (61.8% and 62.2%), whereas for the humerus and the metacarpals, orientations are mostly transverse (59.1% and 55.6%). The femurs, metacarpals and to a lesser extent metatarsals, show different orientations in the same use area. In contrast, this is relatively rare for the humerus and the tibias.

The different types of use trace distributions identified by Mallye et al. (2012) are all present (**Table 11**). For the retouchers on reindeer bone, use areas with scattered marks are the most frequent (38.3%), closely followed by areas with concentrated marks (34.1%). Retouchers on reindeer bones with concentrated and superimposed marks are scarcer (14.4%). On the fragments from large mammals, in contrast, concentrated marks (41.2%) and concentrated and superimposed marks (29.4%) are predominant. The bones of large ungulates reflect a more intense use than reindeer bones ($\chi^2 = 6.168$, $df = 1$; $p < 0.01$).

For the reindeer bone retouchers, the distribution of use traces depends on the anatomical part considered. The mandible usually exhibits isolated impacts, while the metacarpals have no superimposed used areas (**Figure 11**). Except for metatarsals and tibias, the frequency of use areas with concentrated and superimposed marks, which correspond to prolonged use, never exceed 20% of the studied cases.

Discussion

Selection of retouchers

BLANK CHOICE In Facies 4a of Les Pradelles, retoucher blanks are mainly on reindeer bone; however, Neanderthals also used the bones of large ungulates. If the reindeer bones were gathered from butchery remains, we might reasonably question the origin of the retoucher blanks made on large ungulate bones. Assuming the blanks were brought to the site for use as retouchers, it would be reasonable to expect that the majority of pieces were used as retouchers. Moreover, we might expect to observe an almost exclusive presence of anatomical elements suitable for blanks. Although proportionally used more than reindeer bone, not all the potentially suitable large ungulates remains have been used as retouchers. If we consider, for example, the limb bone diaphysis fragments over 40 mm in length, more than half of these fragments have not been used. Furthermore, the skeletal elements of these large ungulates are not exclusively fragments that potentially could be used as retouchers (e.g., teeth, short bones and vertebrae). Thus, the retouchers appear to have come from food resources present at the site, as is usually the case at Palaeolithic sites (e.g., Armand and Delagnes, 1998; Auguste, 2002; Jéquier et al., 2012; Mallye et al., 2012; Tartar, 2012; Daujeard et al., 2014; Rosell et al., 2015).

Almost 97% of the reindeer retouchers are on limb bone diaphysis fragments. Other types of blanks have occasionally been used: limb bone epiphyses from La Quina (Henri-Martin, 1910; Valensi, 2002a, 2002b), Kůlna (Auguste, 2002), Payre and Baume des Peyrards (Daujeard 2014); ribs from Isturitz (Schwab, 2002; Soulier et al., 2014), Saint-

Table 9 Number of use areas by taxa and skeletal parts in NISP (number of identified specimens) and %NISP. The unique retoucher on a red deer fragment is excluded.

	Large mammals				Reindeer				
	1	2	3	4	1	2	3	4	5
Mandible	-	-	-	-	10 (90.9%)	1 (9.1%)	-	-	-
Rib	2	-	-	-	-	-	-	-	-
Scapula	-	-	-	-	1 (100%)	-	-	-	-
Humerus	2	1	-	-	56 (73.7%)	17 (22.3%)	2 (2.6%)	1 (1.3%)	-
Radius	3	-	1	-	70 (92.1%)	5 (6.6%)	1 (1.3%)	-	-
Ulna	-	-	-	-	1 (100%)	-	-	-	-
Metacarpal	1	-	-	-	20 (95.2%)	1 (4.8%)	-	-	-
Pelvis	-	-	-	-	4 (100%)	-	-	-	-
Femur	-	1	-	-	48 (81.3%)	9 (15.2%)	2 (3.4%)	-	-
Tibia	1	1	-	1	110 (68.8%)	38 (23.7%)	7 (4.4%)	3 (1.9%)	2 (1.2%)
Metatarsal	-	1	-	-	53 (85.5%)	8 (12.9%)	-	-	1 (1.6%)
Metapodial	-	-	-	-	2 (100%)	-	-	-	-
Limb bone	5	3	-	-	-	-	-	-	-
Total	14	7	1	1	375	79	12	4	3

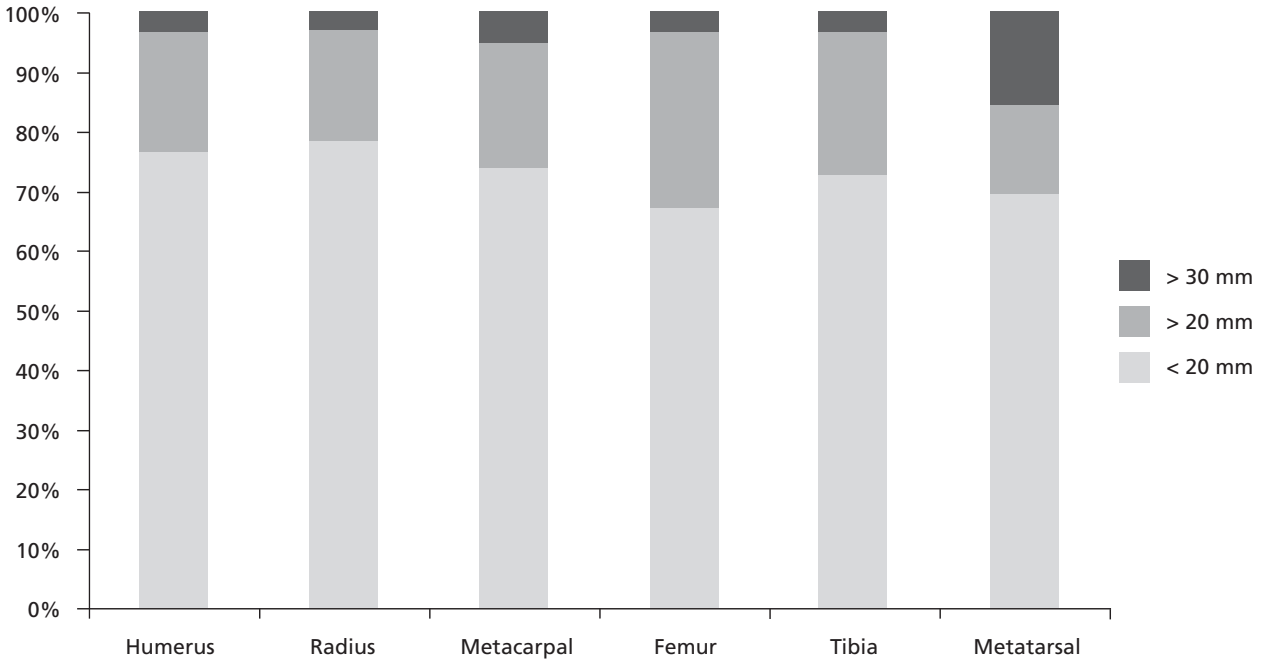

Figure 10 Length of the use areas by skeletal part.

Marcel and Saint-Anne (Daujeard et al., 2014); and carnivore canines in the Upper Palaeolithic (Leroy-Prost, 2002; Castel et al., 2003; Camarós et al., 2016). Nevertheless, limb bone diaphysis fragments, or complete limb bones from earlier periods (van Kolfschoten et al., 2015), are the blanks most often used for retouchers throughout the Palaeolithic (e.g., Vincent, 1993; Malerba and Giacobini, 2002; Schwab, 2009; Mallye et al., 2012; Tartar, 2012; Daujeard, 2014; Rosell et al., 2015). Les Pradelles is no exception to this pattern.

A preference for long blanks is perceptible in Facies 4a and is also identified at other Mousterian sites, including La Quina, Hauteroche, Combe-Grenal (Vincent, 1993), Roc de Marsal (Soulier, 2007; Castel et al., 2017), Fumane (Jéquier et al., 2012) and Le Noisetier (Mallye et al., 2012). This preference for long blanks (> 50 mm according to Vincent, 1993) facilitates an adequate grip on the retoucher and allows a certain flexibility of the wrist, which is indispensable for the "rolled" gesture of these bone retouchers when used as soft hammers (Vincent, 1993).

Owing to the large number of retouchers identified in Facies 4a, it is possible to examine the selection of blanks in more detail. Among the reindeer retouchers, the tibia and, to a lesser extent, the humerus, seem to have been the preferred limb bones. While the tibia was frequently used at Palaeolithic sites (e.g., Vincent, 1993; Jéquier et al., 2012; Soulier, 2013; Daujeard et al., 2014), this is rarely the case for the humerus (see Soulier, 2013, for use of humerus during the early Aurignacian at Isturitz,). For the tibia, it is the plano-convex areas with thick cortical bone that were generally selected (**Figure 8c**), particularly the middle portion of the medial surface. For the humerus, the preferred use areas were the most frequent parts in the assemblage, which raises the possibility for intentional selection (**Figure 8a**). Nevertheless, it is interesting to note

Table 10 Dimensions of the use areas in millimetres.

	Lenght	Width	Lenght / Width
N	466	451	421
Mean	14.6	8.6	1.8
Standard Deviation	8.0	3.9	0.8
Minimum	1.2	0.5	0.2
Maximum	47	28	7.4

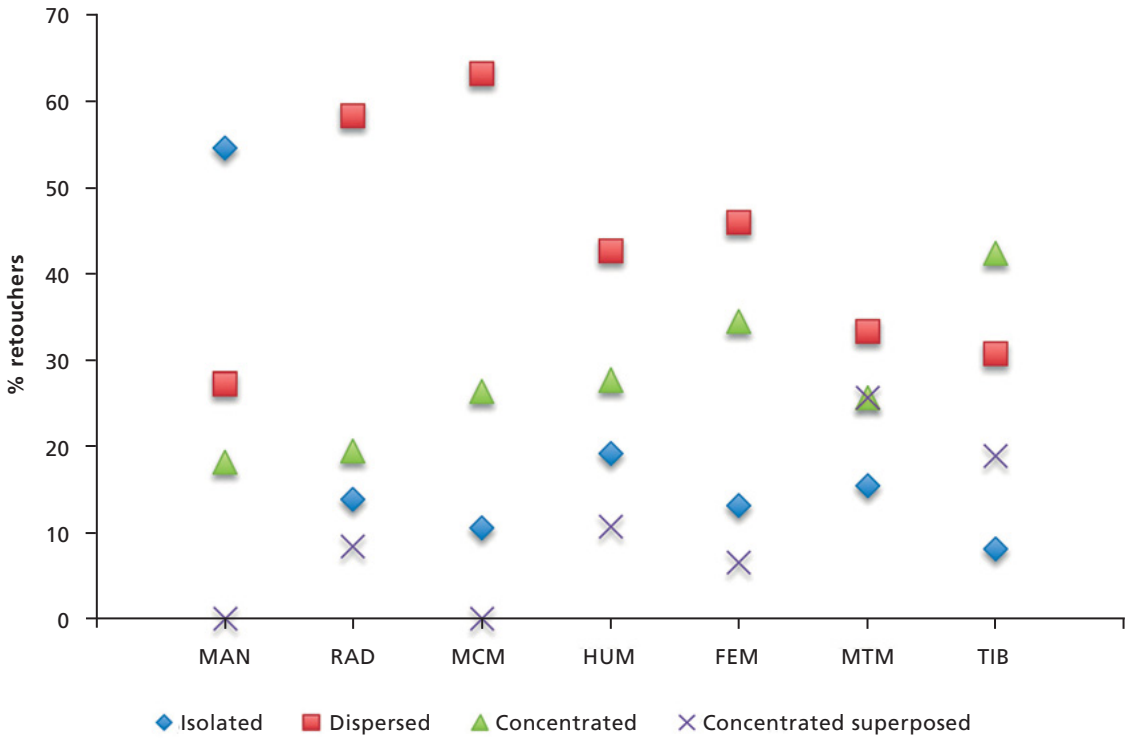

Figure 11 Trace distribution types by skeletal part. MAN = mandible; RAD = radius; MCM = metacarpal; HUM = humerus; FEM = femur; MTM = metatarsal; TIB = tibia.

that the preferred retoucher use areas on the humerus do not always have the same characteristics as the use areas on the tibia. Indeed, the anterior surface of the proximal diaphysis on the humerus has comparable characteristics to the tibia, but this is not the case for the use areas on the distal part of the humerus shaft, which has a very convex shape. The inferior edge of the mandible (**Figure 8g**) and the lateral face of the proximal radius have similar morphologies and patterns of use as retouchers. In the case of the metacarpals (**Figure 8e**), it is the anterior face that most frequently has use marks, while for the metatarsals (**Figure 8f**), it is the lateral and medial plano-convex faces that were most frequently used, reflecting similar characteristics to the tibia fragments. The lower thickness of the metatarsal cortical bone compared that of the tibia could explain the less frequent use of the metatarsals. The femur, despite the abundance of fragments, was also used relatively less frequently for retouchers, even though its surfaces are rather flat (**Figure 8b**). Here again, this could be explained by the low thickness of the femur cortical bone. For the radius, the anterior surface was the most frequently used, again implying a preference for plano-convex blanks made from relatively thick cortical bone (**Figure 8d**).

In summary, along with fragment length, the thickness of the cortical bone appears to have been

Table 11 Number of bone retouchers and NISP (number of identified specimens) by species.

	Isolated	Scattered	Concentrated	Concentrated and superimposed
Reindeer	64	186	166	70
Large mammals	3	7	14	10

a criterion influencing the selection of the blanks, which supports Vincent's (1993) previous findings. This selection is particularly important at Les Pradelles, as the majority of retouchers are on reindeer long bones, despite being potentially more fragile than large ungulate bones. While the plano-convex portions of limb bones were frequently used, slightly concave parts and other particularly convex parts were also selected.

BLANK FRESHNESS In experimental contexts, soon after an animal's death (one day for Mallye et al., 2012, two days for Vincent, 1993) its bones may be used as retouchers; bones that are too dry and have lost all their elasticity are of less use. According to Vincent (1993), one month of exposure to the open air is sufficient for a bone to lose its elastic properties; however, bones exposed to Iberian climates for over a year have still proven effective (Mozota, 2012). Likewise, intentionally defatted bones have provided adequate blanks for experimental purposes (Mallye et al., 2012). So, in glacial environments or caves, where decomposition can be particularly slow (Brain, 1981; Andrews and Cook, 1985; Mallye et al., 2009; Bertran et al., 2015), several months or even years may pass before bones become unusable, as long as they are not impacted by other taphonomic processes, such as cycles of freezing and thawing.

At Palaeolithic sites, the absence of retouchers with bone scaling does not necessarily imply that the retouchers were used soon after death of the animal. According to Tartar (2009), retouchers without scraping marks could only have been used once the periosteum was dry (i.e., a substantial time after the death, particularly in glacial context). Removing the periosteum from fresh bone to ensure the efficiency of the retoucher has been stressed by several authors (Vincent, 1993; Armand and Delagnes, 1998; Auguste, 2002; Daujeard, 2008; Mallye et al., 2012; Daujeard et al., 2014), but it is not essential according to Mozota (2012). Moreover, the periosteum can be helpful for Quina retouch, creating increased friction between the flint and the retoucher edge during the *lancé/arraché* retouching process (unpublished experiments by L. Bourguignon and A. Turq). So, while the scraping marks may stress the freshness of the blanks used as retouchers, their absence does not imply the use of dry or defatted bones. At Scladina, not all the retouchers coming from the same bear femur were scraped (Abrams et al., 2014a).

At Les Pradelles, the presence of scraping marks on 18% of the retouchers indicates that these blanks were cleaned to remove any remaining meat or periosteum and there must have been a relatively short time lapse between the butchery process and their use. This frequency is relatively low compared to that observed at some sites, including Biache-Saint-Vaast and Kůlna (Auguste, 2002), and Baume Flandin (Daujeard et al., 2014). Apart from the retouchers with bone scales (< 3%), little can be known about the timing of use for the remaining retouchers without scraping marks.

SELECTION DURING THE BUTCHERING PROCESS? Except for rare cases where the intentional and controlled production of blanks is proposed (Mozota, 2012, 2015; Abrams et al., 2014a, 2014b; Soulier, 2014), it is generally accepted that the blanks are selected from butchery waste littering the ground. At Les Pradelles, given the multitude of fragments available among the waste, the repeated use of certain long bone parts could be an argument favouring the selection of particularly suitable blanks during the butchery stage rather than after a search for appropriate fragments among the many butchered remains. This implies a good knowledge of the utility of different bones for this technical activity, whether acquired through individual experience or passed on within the group. The presence of multiple use areas (up to five on some blanks) implies the repeated use of some blanks and reinforces the suggestion of stockpiling retouchers with potentially different properties. Certain bones blanks may have been set aside by the knappers and used as needs arose during the occupation of the site. Obviously this hypothesis does not exclude the possibility that some fragments were recovered from the waste on an *ad hoc* basis.

Use of the retouchers

The issue of different morphologies equating to different properties of the selected blanks from Facies 4a raises the possibility of different functions. Potentially distinct uses are perceptible in the great variation in the use areas. Experiments have demonstrated that different stigmata are produced depending on the gesture used, the alignment of the contact surface against the cutting edge, the timing of use and the nature of the lithic raw material (Vincent, 1993; Mallye et al., 2012). At Les Pradelles, the orientation of the stigmata varies between transverse and oblique directions. Sub-longitudinal stigmata are rare. Experimentation shows that these differences may simply be due to the habitual gestures of the knappers (Vincent, 1993). According to the techno-functional studies available (Rigaud, 1977, 2007; Schwab, 2002, 2009; Tartar, 2012), this variation depends on the orientation of the retoucher in relation to the cutting edge of the tool. Transverse marks imply a perpendicular orientation of the retoucher, while longitudinal marks imply a tangential orientation. Longitudinal and sub-longitudinal marks are more characteristic of the Final Upper Palaeolithic industries (Schwab, 2009; Tartar, 2012). Although rare, such pieces have been identified in Facies 4a (< 2% of the use areas).

Although probably dependent on several variables, the length of the use areas seems, in part, related to the intensity of use; a Quina scraper generally requires more retouch than a simple scraper. At Les Pradelles, the use areas have lengths ranging from 1.2 mm to 47 mm. Almost 15% of these use area dimensions are below the minimum length (6 mm) of those obtained by Mozota (2012) during the experimental production of retouchers with simple retouch. If we take into account the minimum length (15 mm) obtained experimentally for Quina retouch, at least 53% of the use areas in Facies 4a could not have been employed to manufacture Quina scrapers. Nevertheless, the greatest lengths (> 40 mm) fall within the range recorded by Mozota (2012) for simple and Quina retouch.

Table 12 Description of the bone retoucher types from Les Pradelles.

Type	APZ location	APZ surface	APZ intensity	Mark orientation	Mark morphologie	Mark depth
A	apical	length not much longer than width	concentrated or concentrated superposed	transverse	elongated	-
B	central	length much longer than width	concentrated or concentrated superposed	transverse or oblique	elongated	-
C	central	extended in length	concentrated superposed	transverse or oblique	elongated	-
D	-	small surface	concentrated superposed	-	very elongated	-
E	-	very long	scattered	diversified	diversified	sometimes very deep
F	-	relatively extended area	-	-	-	superficial
G	angular edge	-	isolated	-	-	-
H	-	-	isolated	-	-	not very deep
I	-	-	-	very oblique	punctiform	not very deep
J	central	-	concentrated	transverse or oblique	-	-
K	-	small surface	isolated or concentrated	-	-	very deep

Based on the different criteria recorded in our database and those documented post-analysis, we have established a preliminary typology for 370 retoucher use areas. Several criteria were used: 1) location of the use area, 2) length/width of the use area, 3) intensity of use (number of blows), 4) orientation of the stigmata, 5) stigmata morphology, 6) stigmata depth, and 7) convexity of the blank. By combining these criteria, we identified 11 categories (**Table 12; Figure 12**) that we organised into four main groups for the sake of clarity.

For most of the identified categories, a systematic comparison of the lithic data (see above) with experimental results (from the literature as well as from the authors' personal works) allowed us to reject two possible uses for these bone-tools. First, their low weight and density are not compatible with knapping activities for the production of the characteristic thick flakes of the Quina Mousterian. Second, their use as soft hammers for bifacial shaping is unlikely given the near absence of such bifacial pieces in the assemblage. These comparisons suggest that they were very likely used for tool retouching/resharpening, based on the different marks left on these "bone tools" by the gestures involved in this last step of the tool manufacturing process. Depending on the type of retouched tool, the intensity of retouch, the timing of retoucher use and the retouching gesture, the resulting traces can vary widely. For instance, in the case of Quina scrapers, a long sequence of retouching and a violent gesture described as *lancé/arraché* undoubtedly left deep and concentrated traces (intensive use) on the bone retouchers. On non-Quina scrapers, a shorter sequence of retouching and a tangential percussion gesture (less violent) lead to more shallow stigmata and less intense use.

There is still a series of "retouchers" for which the nature of their use remains to be solved, and possibilities other than retouching/resharpening activities must be tested by experimental studies. We will discuss this later.

If we focus on the retouchers clearly associated with modifications of tool cutting edges, in technical and functional terms, the different defined categories reflect different objectives of lithic production. These objectives demand a particular kind of gesture, which, in turn, determine the orientation of the stigmata based on the position of the cutting edge to be retouched, the grip on the retoucher and the trajectory used during percussion. Also important is the intrinsic nature of the selected bone fragment, from its state of freshness to the morphology of the active percussion area and its mass. Numerous experiments (Henri-Martin, 1906; Siret, 1925; Semenov, 1964; Feustel, 1973; Lenoir, 1973; Dauvois, 1974; Rigaud, 1977; Leonardi, 1979; Boëda and Vincent, 1990; Vincent, 1993; Bourguignon, 1997; Armand and Delagnes, 1998; Bourguignon, 2001; Mallye et al., 2012; Tartar, 2012; Mozota, 2013, 2014; and unpublished personal experiments) regarding these different variables have allowed us to define different categories of retouchers at the site of Les Pradelles and to integrate data from lithic and bone assemblages. The four main groups are defined below (see **Table 12; Figure 12**).

The first group (Gr1) includes types A, B and C (19.7% of all retouchers), and is clearly distinguished by the morphology of its elongated stigmata. These stigmata are similar to those obtained experimentally during the manufacture and resharpening of Quina scrapers, characterized by a succession of retouch step over its delineation (Vincent, 1993; Mozota, 2013, 2014). This group features concentrated use areas oriented transversely and/or obliquely and stigmata that are often superimposed. Only the location and extent of their use areas differ, as described by Mozota (2012). Type A corresponds in every sense to the descriptions made of these retouchers during experiments to obtain Quina scrapers (Boëda and Vincent, 1990; Vincent, 1993; Bourguignon 1997, 2001; Mozota, 2012, 2013) and to descriptions of archaeological material in Quina contexts (e.g., La Quina, Hauteroche, Combe-Grenal, Axlor, Jonzac; Henri-Martin, 1910; Vincent, 1993; Malerba and Giacobini, 2002; Beauval, 2004; Mozota, 2009; Verna and d'Errico, 2011). These Type A retouchers indicate a selection of blanks that are among the largest (> 70 mm at Les Pradelles; > 50 mm in other Quina contexts, Vincent, 1993) and densest (three of six are large ungulate bone). The location of the Active

Figure 12 Main bone retoucher types defined at Les Pradelles (photographs by Beauval).

Zone of Percussion (AZP) (Cuartero, 2014) is usually apical (also in other Quina contexts; Vincent, 1993; Bourguignon, 2001; Malerba and Giacobini, 2002); the morphology of the AZP is usually plano-convex. Finally, the concentration and superimposition of the stigmata are very pronounced, reflecting the intensity of use during a long sequence of retouching. The gesture involved in obtaining this special kind of retouch is described as *lancé/arraché*. The specific purpose of this gesture is to sharpen the lithic tool by reducing the initial angle of the cutting edge (Bourguignon, 1997; Mozota, 2009). A violent gesture is required to remove these retouching flakes and undoubtedly created deep marks on the retoucher following contact with the cutting edge. This type of retoucher, the mass of which should be roughly proportional to the lithic tool mass, needs to be heavy and dense. In the case of Les Pradelles, it is most often long and made on large ungulate splinters.

Despite different stigma orientations and locations of the AZPs, Type C and Type A retouchers both indicate prolonged use, the lower concentration of stigmata in Type C being offset by the greater length of the use area. As with Type A, the selected blanks are long (usually > 80 mm) and the AZPs are plano-convex. Type C retouchers are mainly on reindeer bone (89.3%), whose intrinsic qualities are less conducive to the manufacture of Quina scrapers than the diaphyses of large ungulates. This mechanical constraint is countered by a relatively stringent selection of blanks with thick cortical bone – 60.7% of blanks are tibia fragments, 17.9% are humerus (**Table 13**) – insuring for a sufficiently dense blank to achieve Quina retouch.

Type B retouchers (10.5% of all retouchers) show the same stigma morphology as Types A and C, but the use areas are less elongated, reflecting a lower number of blows. The numbers of blows being insufficient to indicate an entire cycle of manufacture and resharpening of Quina scrapers (Bourguignon 1997, 2001), we attribute this type of retoucher to the partial resharpening of Quina cutting edges. This resharpening is also visible on some scrapers and in the characteristic waste products (Bourguignon, 1997; 2001; Bourguignon et al., 2013). It is interesting to note that for Type C retouchers that show more intensive use, the use areas are more often fractured (67.9%) than in Type B retouchers (51.3%) (see **Table 13**).

The presence of Gr1 retouchers suggests that all or part of the Quina scrapers were manufactured and/or resharpened at the site. Since the available lithic data indicate that scrapers in exogenous flint have been imported already retouched, Type B retouchers were likely most often used for resharpening these imported tools, whereas the most damaged retouchers most probably reflect the long manufacture sequence of the Quina scrapers made on local raw material.

The second group (Gr2) involves retouchers with scattered or isolated stigmata (see **Tables 12, 13**). Types G and H account for 30% of all retouchers. The number of blows is typical of a short, fleeting period of use, some with only three or four impact marks. Therefore, these retouchers were not involved in the long cycle of manufacturing Quina scrapers, nor any other type of scraper that requires the repetition of numerous identical gestures. These impact marks could be related to an "adjustment retouch", a term we use to describe a slight modification to a previously manufactured tool in order to very locally refine the line of the cutting edge or its angle, or even to adjust the edge where the tool is grasped. This brief episode of retouch took place on the spot, just before or during actual use, to adjust a tool for its intended purpose. The short use area lengths of some retouchers perfectly illustrate this interpretation. Although highly situational, the retouchers from Gr2 are the most widely used, notable for their brief use lives. The presence of Gr2 retouchers indicates the efficient use of lithic tools.

In Gr2, Type H (26.8% of all retouchers) presents the highest frequency of retouchers with a single use (90.9%), an additional argument in favour of the very fleeting nature of these Gr2 retouchers (see **Table 13**). For comparison, over half of the Gr1 blanks have been used several times. In Gr1, the blanks are always longer than 60 mm, while the length is not a criterion in the blank selection for Gr2 retouchers, especially for Type H, in which over 30% of the

Table 13 Comparison of bone retouchers by group and type. % one area = percentage of retouchers with only one use area; % TIB = percentage of retouchers on tibia; %HUM = percentage of retouchers on humerus; % broken = percentage of retouchers broken during utilization; Ncomplete = number of complete retouchers; Mean (L) = mean length of the retouchers (mm), Stdev = standard deviation of length of the retouchers, Min = minimum length of the retouchers; Max = maximum length of the retouchers; % > 60 mm (L) = percentage of retouchers greater than 60 mm in length.

Group	Type	N	% one area	% TIB	% HUM	% broken	Ncomplete	Mean (L)	Stdev	Min	Max	%>60 mm (L)
1	A	6	50 (3)	16.7 (1)	16.7 (1)	33.3 (2)	4	71.5	-	71	121	100 (4)
1	B	39	48.7 (19)	43.6 (17)	0	51.3 (20)	18	85.8	13.5	65	111	100 (18)
1	C	28	42.9 (12)	60.7 (17)	17.9 (5)	67.9 (19)	9	80.4	16.5	62	110	100 (9)
2	G	12	58.3 (7)	33.3 (4)	0	41.7 (5)	7	87.1	33.9	46	154	85.8 (6)
2	H	99	90.9 (90)	38.4 (38)	28.3 (28)	51.5 (51)	48	65.4	22.3	29	121	56.2 (27)
3	D	15	53.3 (8)	53.3 (8)	0	53.3 (8)	7	75.7	-	67	93	100 (7)
3	F	36	80.6 (29)	16.7 (7)	33.3 (12)	30.6 (11)	25	62.5	10.6	44	79	60 (15)
3	I	6	66.6 (4)	66.6 (4)	0	50 (3)	3	-	-	84	92	100 (3)
3	J	11	72.7 (8)	54.5 (6)	0	60 (6)	4	65.2	-	48	86	2 (50)
4	E	111	71.1 (79)	41.4 (46)	13.5 (15)	55.9 (62)	49	66.9	16.1	27	106	59.2 (29)
4	K	7	85.7 (6)	0	71.4 (5)	42.9 (3)	4	60.5	-	43	80	2 (50)

Table 14 Comparison of retouchers, retouched tools, scrapers and dominant animal species at several Mousterian sites.

Site	Debitage method	Retouchers	Retouched tools	Ratio retouchers / retouched tools	Scrapers	Ratio retouchers / scrapers	Dominant species	Main retoucher species	Reference
Les Pradelles 4a	Quina	496	228	2.2	94	5.3	Reindeer	Reindeer	-
Chez Pinaud c.22	Quina	202	802	0.3	565	0.4	Reindeer	Large-sized ungulate/ Reindeer	Beauval, 2004; Airvaux 2004
Roc de Marsal c.4 (K16, G18, Q17)	Quina	115	659	0.3	398	0.3	Reindeer	Reindeer	Soulier, 2007; Castel et al., 2017; Sandgathe et al. 2008
Hauteroche	Quina	37	201	0.2	146	0.3	-	-	Vincent, 1993
Axlor n.D	Quina	186	910	0.2	693	0.3	Red deer	Red deer/ Large bovid	Mozota, 2009
Abri du Maras 1	Levallois	2	43	0.05	19	0.1	Reindeer	-	Daujeard et al., 2014
Abri du Maras (upper)	Levallois	9	126	0.1	42	0.2	Reindeer	Large-sized ungulate	Daujeard et al., 2014
Abri du Maras (lower)	Levallois	2	23	0.1	7	0.3	Red deer	-	Daujeard et al., 2014
Saint-Marcel 7	Discoid	260	184	1.4	147	1.7	Red deer	Red deer	Daujeard et al., 2014
Saint-Marcel u	Discoid	17	21	0.8	18	0.9	Red deer	Red deer	Daujeard et al., 2014
Sainte-Anne 1	Levallois, Discoid, Quina	26	80	0.3	65	0.4	Reindeer	Middle-sized ungulate	Daujeard et al., 2014

blanks are less than 60 mm long. While tibia fragments have been widely used (38.4%) in Type H, the humerus appears more frequently selected than in the total sample (28.3% *versus* 16.1%), reflecting a less stringent selection process ($\chi^2 = 8.39$, $df = 1$; $p < 0.01$).

Type G (only 3.2% of all retouchers) may point to the selection of particular blanks for a specific use or may illustrate a lower degree of stringency in the selection of blanks for adjustment retouch. Use areas are developed on a very angular edge, such as the edge of the metatarsal gutter. The stigmata are usually isolated, suggesting a specific and precise gesture. In any case, the recurring presence of use areas under the horizontal ramus of the mandible near the diastema could be an argument in favour of a specific use.

The third group (Gr3) includes Types D, F, I and J (18.4% of all retouchers), and features relatively concentrated stigmata. The depth of the stigmata (shallow to superficial) suggests a lighter, much less violent gesture than for Gr1, thus excluding Quina retouch. These Gr3 retouchers are less intensely used than those from Gr1 and could have been used for manufacturing and/or resharpening tools other than Quina scrapers.

Types I and J are very rare (1.6% and 2.9%, respectively). For Type J, the stigmata are very oblique, even sometimes sub-vertical, suggesting a particular, and perhaps rare, gesture. Type I is characterised by transverse or oblique stigmata that tend to be punctiform, resulting in concentrated and centred us areas. Both types could indicate the manufacture of denticulates (Vincent, 1993).

Type F (9.7%) shows a quite developed use area with very shallow stigmata. For this type, the desired blanks are elongated, but the thickness of the cortical bone does not appear to be paramount (only 17% are on tibia). Although Type F blanks have less thick cortical bone as compared to Types B and C, they have been less frequently broken during use (see **Table 13**), indicating less violent gestures. For Type D, however, both the selection of blanks and their fragmentation is close to what is observed for Type B.

There are two further types of retouchers that we cannot clearly categorise; thus, they are artificially grouped. Type K retouchers are a very rare occurrence (N = 7) and characterized by very deep stigmata that are isolated or concentrated, but present over a very limited area. These stigmata indicate violent blows with a sharp edge, but we do not know the intended purpose of these gestures.

Type E, the most frequent of all retouchers (30%), is characterized by very elongated use areas located over a large part of the blank. The stigmata are quite scattered and display various morphologies and orientations, sometimes very deep, but rarely elongated. Stigmata on Type E retouchers are often associated with the development of fine splintering. Half of these retouchers are on tibia fragments; the preferred use areas are situated on the medial surface, between the proximal third and the distal quarter of the diaphysis. Tibias are increasingly well represented among retouchers with longer use areas. The different orientations of the stigmata within the same use area indicate a series of gestures involving changes of direction between the cutting edge of the tool and the blank; that is, if we assume that these bones were indeed used to retouch lithic tools. It could be worth exploring the use of these blanks in a passive position. Due to low mass and relatively thin compact bone, reindeer bones are not very efficient retoucher blanks compared to the bones of larger ungulates. These mechanical constraints could explain specific technical choices, the passive position perhaps allowing for higher shock resistance. Nonetheless, the presence of stigmata with very different morphologies, notably large "hacking marks" resulting from violent shocks, could also indicate the use of these blanks for purposes other than retouching lithic flakes. However, the prevalence of this type of retoucher stresses their key role in performing some yet unknown task.

What are the implications regarding the site function?

While retouched lithic tools are relatively rare at Les Pradelles, bone retouchers are highly abundant;

in fact, 2.2 times more numerous than lithic tools (**Table 14)**. High retoucher-to-tool ratios have sometimes been interpreted as evidence for the use of "retouchers" for purposes other than lithic retouch (Auguste 2002; Raynal et al., 2013; Daujeard et al., 2014). If we compare this ratio with other Quina assemblages, a technocomplex in which retouchers are very frequently observed, Les Pradelles is the only site that shows such a discrepancy between the number of retouchers, the number of lithic tools and the number of scrapers. In our view, this over-representation of retouchers in Facies 4a at Les Pradelles is due to the exportation of some of the retouched tools. This disparity is therefore likely to be related to the site function.

In Facies 4a, retouchers are five times more numerous than the retouched flakes and scrapers (**Table 15**) that were probably prepared by these retouchers (notches and some denticulates were likely prepared by stone hammer percussion). However, it should be noted that we have not been able to adequately interpret retoucher Types E and K in terms of the gestures and objectives involved. For this reason, it is important to refine our comparisons by taking into account our typology. As only one sample has been studied, the following ratios are minimum ratios. Thus, if we compare the types of retouchers with the types of tools they were likely to have prepared, we can see that the retouchers used for refining and resharpening Quina and half-Quina scrapers (A + B + C) are those that show the highest degree of disparity.

If we refer to the ratio obtained in experiments, one retoucher necessary for manufacturing one scraper (Boëda and Vincent, 1990; Vincent, 1993; Bourguignon, 1997, 2001; Mozota, 2012, 2013), we arrive at a ratio of 4.9 retouchers (Types A + C) for one Quina or half-Quina scraper in local flint (see **Table 15**). There is a ratio of 3.3 retouchers for the same kind of scraper made from non-local materials, tools that were brought to the site already manufactured and thus not initially created with the retouchers recovered at Les Pradelles.

Our data appear inconsistent with the expected patterns based on experimentation, suggesting that a significant number of Quina and half-Quina scrapers were exported from the cave, particularly those made of local materials. This is the case even though the prevalence of adjustment retouchers (Gr2 retouchers, Types G and H) indicates activities performed on site, probably in relation to the many butchery activities observed on the faunal remains (**Figure 13**; see also **Table 15**). This is corroborated by the already noted exportation of certain lithic objects, namely pieces with cortical backs and Kombewa type flakes, as well as sharpening, resharpening and recycling flakes.

Les Pradelles was undoubtedly a place of activity where lithic objects circulated. This involved not only imported tools, which were maintained on site and then abandoned, but also tools rapidly produced on site using the bone fragments that were widely available due to the butchery activities. Thus, the tools produced were used on site and frequently taken away for use at other sites (e.g., hide working, primary butchery, hunting) or during subsequent travel to a residential camp.

This flow of technical goods is consistent with that observed for food resources (see **Figure 13**). Indeed, as we mentioned earlier, reindeer were prob-

Table 15 Ratio of retoucher types/lithic tool types.

Retoucher types	Retouchers	Lithic tools	Ratio	Lithic tool type
A+C	34	7	4.9	Qunia scraper in local raw material
B	39	12	3.3	Quina and half-Quina scraper in exotic raw material
D+F+J	62	48	1.3	Other scraper in local raw material
G+H	111	198	0.6	Total retouched tools except denticulates and notches
I	11	28	0.4	Denticulates?

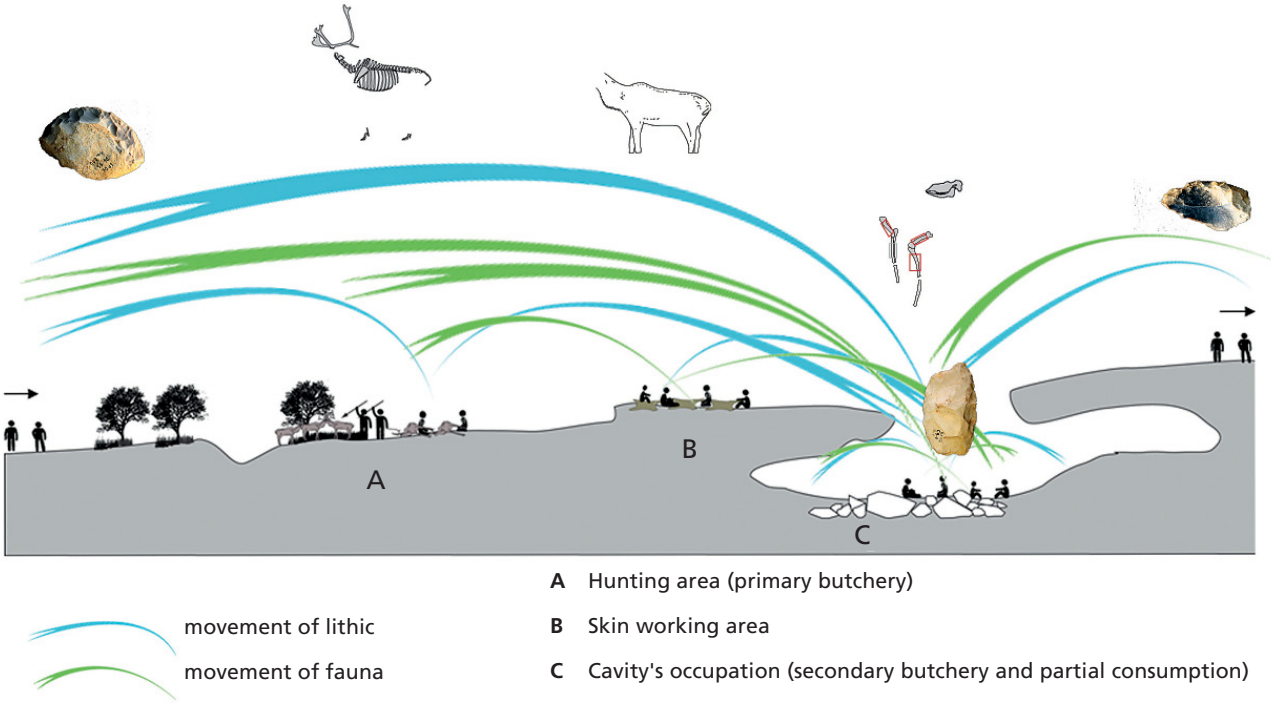

Figure 13 Synthetic techno-economic interpretation of Quina type Mousterian from Les Pradelles (image by Bourguignon).

ably slaughtered in number during their migration period, as Les Pradelles was situated in an ideal location within the migration corridor. The incomplete nature of the carcasses brought to the site indicates that initial butchery was carried out at the kill sites. The limbs, and sometimes the skulls, were then brought into the cave gallery. The primary butchery of large numbers of reindeer carcasses at the kill site implies a relatively large number of tools, some of which may have been manufactured in the cave as needs arose, explaining the exportation of part of the toolkit manufactured in the site. Within the cave, the transported carcass portions underwent intensive secondary butchery, allowing a large quantity of food resources to be obtained. A portion may have been consumed locally, while the rest would have been exported, the short occupation periods not allowing for the consumption of all the food resources on site (Meignen et al., 2007). The abundance of adjustment retouchers could therefore indicate the resharpening of tools as needs arose for butchery. The abundance of Gr1 retouchers reflects the refining and resharpening of Quina and half-Quina scrapers. However, these tools were likely used more intensively than others during skinning and hide preparation activities (Beyries, 1986, 1987; Beyries and Walter, 1996; Geneste and Plisson, 1996; Texier et al., 1996; Lemorini, 2000; Garaizar, 2007; Araujo-Igreja, 2008; Jaubert et al., 2008; Claud et al., 2012; Lazuén and González-Urquijo, 2015; Lemorini et al., 2016), which suggests that all or part of these steps took place outside the cave. Therefore, we surmise that the skins were, in part, treated on the plateau, as the cave was not suitable for laying out large numbers of skins. However, due to its layout, the cave, which opens out onto the plateau, may have been an ideal place for carrying out the intensive butchery of all these carcass elements, away from any predators or scavengers, particularly cave hyenas. Carnivore marks on the bones demonstrate the scavenging of the bone remains after Neanderthals abandoned the site. In addition to its ideal location relative to reindeer migration corridors, the strategic layout of Les Pradelles could explain why this site was regularly re-occupied by Neanderthals, as we can observe the same activities carried out at the site within over two metres of the excavation profile (Maureille et al., 2010).

Conclusion

Facies 4a of Les Pradelles has delivered a remarkable series of bone retouchers, representing one of the most important assemblages documented for the Middle Palaeolithic. The abundance of retouchers in this assemblage has allowed us to make advances in the interpretation of these objects in two areas:

1) the place of retouchers in the technical equipment of the hunter-gatherers of Les Pradelles, particularly how the blanks were selected and for what purposes they were used;
2) the significance of retouchers in the contexts of short-term occupations and secondary butchery activities at Les Pradelles, and with that, the implications for understanding the techno-economics of Palaeolithic tools, transport strategies and carcass processing.

Based on the large number of identified retouchers and experimental reference data, we have been able to establish a typology based on the inferred relationships between the marks left on the retouchers, the gestures performed and the lithic tools they were used to refine and/or resharpen. We identified three major groups of retouchers for which we believe we can establish the function in the preparation of the lithic equipment of the hunter-gatherers at Les Pradelles.

We demonstrate a link between the type of blank chosen for the retoucher and the type of tool retouched or resharpened. Except for adjustment retouchers, the relatively stringent selection of blanks, particularly aimed at the reindeer limb shaft fragments with the thickest cortical bone, is in all likelihood related to constraints caused by the use of reindeer bones whose intrinsic qualities were not necessarily optimal for use as retouchers. Thus, we postulate that for some blanks the selection took place during the butchery stage rather than a selection of appropriate splinters from among the butchery waste littering the ground. Verna and d'Errico (2011) have also proposed an immediate selection of the retouchers on human bones at La Quina. To our knowledge, this is the first time that such a suggestion has been put forward for retouchers on ungulate bones for the Middle Palaeolithic. This behaviour implies knowledge of the mechanical properties of the selected fragments as well as an anticipation of needs in relation to the activities carried out at the site.

These results have enabled us to define in greater detail the different activities carried out on- or off-site in the treatment of animal carcasses. On the one hand, the over-representation of retouchers in relation to the number of abandoned scrapers in the cave confirms the exportation of a significant proportion of the scrapers, as has already been observed in previous techno-economic studies of this level. At the same time, the available data has allowed us to propose the following scenario:

1) Importation of blanks and retouched tools (mostly scrapers, often Quina) produced from non-local raw materials;
2) Selection of some bone blanks, mainly tibia and humerus fragments;
3) On-site manufacture/maintenance of Quina and half-Quina scrapers, made from local and non-local materials, with retouchers from Gr1; some of these scrapers were subsequently taken away, probably for the treatment of skins outside the cave, or just nearby on the plateau;
4) On-site manufacture/use/maintenance of other tools (mostly non-Quina scrapers) with Gr2 retouchers for butchery activities and perhaps also for other kill/butchery sites;
5) Occasional maintenance or readjustment of tools with a variety of different retoucher types, used on site as part of the intensive butchery operations.

The "exported" tools were used either for activities carried out near the site, possibly on the plateau, or were part of the toolkit taken away during travel to more distant locations. Thus, the site of Les Pradelles appears as a specific place within the organization of a wider territory, where specific activities were undertaken at different locations. In the cave at Les Pradelles, secondary butchery and partial consumption of animal carcasses is well documented. The abundant skeletal remains at the site played a critical role in the manufacture and/or maintenance

of the tools required for these activities. The results obtained in this study offer a fine example of the interconnections between different technical subsystems during the Middle Palaeolithic, where animal exploitation for subsistence purposes and as a raw material resource was fully integrated into the technological system of lithic production.

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