The Origins of Bone Tool Technologies

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THE ORIGINS OF BONE TOOL TECHNOLOGIES: AN INTRODUCTION

Tool use is one of the hallmarks of what makes us human. This defining behaviour is fostered by our high fidelity social learning environment and unique process of cumulative cultural evolution. From the Stone Age to the Digital Revolution, the human narrative has been written in the technologies we developed to meet the challenges of everyday life. How our ancestors accomplished increasingly complex tasks reflected the skills and materials available at the time, and as technology developed in complexity, so too did their lives. For over two million years of the human lineage, stone and bone tools preserve the only record of our technological heritage and capacity for innovation. Studying the origins and development of these technologies plays a vital role in retracing our evolutionary footsteps toward becoming human.

The use of intentionally modified stone tools may extend back to more than three million years ago in East Africa (Harmand et al., 2015) and persisted in some parts of the world until historic times. These tools began as simple stone flakes and hammerstones used to butcher animal carcasses (Semaw et al., 1997, 2003; Semaw, 2000; McPherron et al., 2010), followed by the addition of stone handaxes, and later flourished into a wide array of technological and cultural traditions that serve as a record of humanity's cumulative process of behavioural evolution.

The use of bone tools followed a slightly different trajectory, first appearing during the Oldowan period as early as 2.1 million years ago in East Africa (Backwell and d'Errico, 2004) and slightly later at two million years ago in southern Africa (Backwell and d'Errico, 2001, 2008). The East African tools consisted of large mammal long bone shaft fragments intentionally shaped by knapping and a few complete bones used as hammers. In contrast, the bone implements from southern Africa were not deliberately modified to aid in butchery activities, but rather used in termite foraging, digging for tubers, processing fruits and other tasks (d'Errico and Backwell, 2009). The use of these early bone tools appears to have been infrequent and expedient before largely disappearing from the archaeological record of the ensuing Acheulean and Middle Stone Age in Africa.

Rare examples of bifaces made from elephant bones are known from several locations scattered across Europe and the Levant (see Zutovski and Barkai, 2016), but these tools date to the end of the Lower Palaeolithic (500-250 ka) and are unlikely to be technologically descendent from similar, yet much earlier, bone tools from East Africa. At roughly the same time and in the same areas of Europe and the Levant, hominins began using antlers and limb bones of large mammals in the manufacture and maintenance of lithic tools (Roberts and Parfitt, 1999; Goren-Inbar, 2011; Blasco et al., 2013; Julien et al., 2015; van Kolfschoten et al., 2015; Moigne et al., 2016). Commonly known as retouchers *(retouchoirs* in French) or percussors *(percuteurs)*, these bone tools display characteristic pits and scores

Figure 1 Participants of the "Retouching the Palaeolithic" conference at Schloss Herrenhausen in Hannover, Germany, October 2015.

indicative of use in shaping lithic tools (see Patou-Mathis, 2002); lithic fragments often embedded in the pits and scores attest to their various functions related to stone tool manufacture (Mallye et al., 2012; Tartar, 2012; Bello et al., 2013). The use of bone retouchers in various forms continued uninterrupted until stone was abandoned in favour of metal as a raw material for tools (see Taute, 1965; Schibler, 2013; Vitezović, 2013).

Bone retouchers and percussors are particularly intriguing, as they incorporate elements of both bone and stone tool technology. As stone is a more durable raw material that can withstand the effects of burial over the course of many millennia, our understanding of specific stone tool technologies and associated human behaviours is far advanced beyond that of tools made of bone and other osseous raw materials. The origin of bone tool use lagged behind that of stone tools; in a similar fashion, the initial recognition of and subsequent appreciation for Palaeolithic bone tool technology has been somewhat delayed (e.g., Dupont, 1871; Daleau, 1884; Henri-Martin, 1906, 1907). A renewed interest in bone tool technology has arisen over the past decades (e.g.,Chase, 1990; Vincent, 1993; Patou-Mathis, 2002; Mallye et al., 2012; Mozota, 2012; Blasco et al., 2013; Jéquier et al. 2013; Abrams et al., 2014; Daujeard et al., 2014; van Kolfschoten et al., 2015), and we now recognize that the production of bone tools spans much of human prehistory, and their forms are as varied as their inferred functions.

It is the relatively abrupt appearance of bone retouchers and similar osseous tools coupled with their sustained use across a wide geographic area that justifies their position at the dawning of bone tool technology. The root of this technology lies in the circumstances under which prehistoric humans ceased to consider bone as a sterile by-product of the hunting and butchery process and began to recognize bone's technological utility for the manufacture and maintenance of lithic tools. While the designation of a singular, oldest bone tool will be subject to periodic revision, the enduring significance of this origin story is one of technological innovation and adaptation – the propensity and talent for creating tools to solve new and old problems in different ways. Bone retouchers emerged at a time of broad technological upheaval, when the bifaces that record the final stages of the Lower Palaeolithic gave way to a mosaic of prepared core, flake-based technologies across Africa and Eurasia. This rapid period of innovation was driven by the interplay between various biological, social, and environmental factors (see Elias, 2012), and identifying these internal and external forces through the archaeological record provides a framework to evaluate the adaptive significance of bone retouchers. These contexts are of immeasurable value for understanding how the emergence and development of bone tool technology influenced human subsistence and other socio-economic adaptations across space and time.

To explore these behavioural and cultural facets to the use of bone retouchers and similar tools, a scientific workshop was organized around the title, "Retouching the Palaeolithic: Becoming Human and the Origins of Bone Tool Technology". The event took place in October 2015 at Schloss Herrenhausen in Hannover, Germany (**Figure 1**), with generous financial support provided by the Volkswagen Foundation's "Symposia and Summer Schools Initiative". This volume is a product of the exchange of ideas at that workshop and brings together a diverse array of perspectives on bone tools use spanning across Europe and the Levant, from the Lower Palaeolithic to the Neolithic. In part, this work aims to build on the influential volume edited by Marylène Patou-Mathis in 2002, *"Retouchoirs, compresseurs, percuteurs…Os à impressions et à éraillures"*, which has served as the reference manual for bone retouchers and other similar tools. The goal of this current volume is to reach a wider audience and move beyond the physical attributes of the bone tools themselves toward a deeper understanding of the behavioural implications behind the development of various bone tool technologies. With this synthesis, we add an important dimension to the ways in which tool use defines what it means to be human.

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KEYNOTE PAPER

IAIN DAVIDSON

TOUCHING LANGUAGE ORIGINS AGAIN: HOW WORKED BONE SHAPED OUR UNDERSTANDING

Abstract

In 1986 Bill Noble and I began to talk to each other about the origins of language. We articulated the importance of bone tools as the best marker of the imposition of form on artefacts. Some people have said that such an indication of mental representation of form can only follow from the emergence of language. I will review the arguments we produced then and show some of the evidence that strengthened our belief that they were important. I will then put them in the context of the vastly expanded knowledge of the archaeology of modern human behaviour over the last 30 years. Some of the arguments have been ignored, others have been overtaken by new finds, but the theoretical position also raised questions that have not been adequately answered. I will conclude by emphasising the importance of bone tools for understanding that theory and discussing some of the ways in which the theoretical position has moved on. Insights from studying bone tools opened up understanding of modern human cognition but we need more complex models of cognitive evolution.

Initial arguments

When Bill Noble and I began to look at areas of overlap between his interests as a psychologist of perception, particularly hearing, and my interests in the archaeology of fisher-gatherer-hunter peoples in Europe and Australia, we found that there was a fruitful intellectual area to explore in the question of language origins. Prior to our collaboration there had been much work concentrating on syntax as the important defining element of language, given the salience of Chomsky's linguistics in the 1960s (Holloway, 1969), on the anatomical conditions for speech production in humans and Neanderthals (Lieberman, 1984), on the features of the brain that might identify the language capabilities of early hominins (Falk, 1980; Holloway, 1983) and on the possible archaeological signatures (Isaac, 1976; Marshack, 1976; White, 1985). There was also an active engagement with primate communication in the laboratory (Terrace, 1979; Premack and Premack, 1983; Gardner and Gardner, 1985; Savage-Rumbaugh et al., 1986), but less-so in the wild (Marler and Mitani, 1988), and arguments by comparison with stages of human infant language acquisition (Parker and Gibson, 1979; Wynn, 1979).

Our project was to identify the impact of language on the human mind – what I would now call cognition – which was Noble's primary contribution, and how language could be identified through the products of the archaeological record, which was my job. We argued that the distinctive feature of humans, when compared with other animals, was in our reflective awareness that gave our ancestors a capacity to talk about what they perceived. Vervet monkeys, and many other animals, such as chickens (Evans et al., 1993), call attention to a predator in the air above them (Seyfarth et al., 1980), but no one has claimed that they can talk about the eagle they saw yesterday or the vulture they might see tomorrow. That reflective capacity, we argued, could have emerged through the practice of depiction (Davidson and Noble, 1989), and we acknowledged important work in the origins of depiction (Davis, 1986). The key to the identification of the evolutionary emergence of language, then, would be to find symbols in the archaeological record. Our identification of this issue happened at about the same time as others were looking at the question (Chase and Dibble, 1987), but we thought that we brought deeper knowledge of the issue in the psychological literature (Gibson, 1979).

In a later paper we were careful to define language as "the symbolic use of communicative signs; the use of signs in communicative settings to engage in acts of reference" (Noble and Davidson, 1991:224). We had already noticed that very few people concerned with language origins had defined what they meant by language – and that continues to be the case. Our use of a remarkably uncontroversial definition attracted a lot of criticism, principally because we did not include syntax, despite the fact that most definitions are very similar even when emphasizing syntax (e.g., Crystal, 1987). The meaning of the word symbol also has its problems, particularly in religious communities where an earlier meaning has been corrupted to claim that symbols are defined by religious beliefs. For most languages, the meaning of the word "symbols" as "signs that are both arbitrary and conventional" is closer to Peirce's semiotics, which spoke of signs that "represent their objects, independently alike of any resemblance or any real connection [i.e., arbitrary], because dispositions or factitious habits of their interpreters [i.e., conventions] insure their being so understood" (quoted in Nöth, 2010). Much greater sophistication in the semiotic interpretation of the archaeological record has been developed since then (Preucel, 2006; Davidson, 2013a; Culley, 2016; Kissel and Fuentes, 2017).

In the original paper we were already concerned that it was through tools that symbolic construction might be most readily identified. To that end, we criticised a then short list of archaeological items said to have symbolic meanings (see also Davidson, 1989), and field inspections revealed that some of the others fell short, too (Davidson, 1990, 1991). Several objects said to have symbolic functions did so because no one could imagine a utilitarian reason for their shaping (Edwards, 1978). What emerged from these studies were two perceptions. The first perception was that there was a fundamental question of the extent of "deliberate" shaping of stone artefacts and whether that could be determined by the repeated patterning of the forms as found (Dibble, 1989). Without the repeated patterning, it would be very difficult to establish that there was a convention. The second perception was that intentional shaping of artefacts may be better revealed by looking at bone artefacts, because, for later periods, the shaping was relatively unconstrained by the nature of the mechanics needed to shape them or the outcomes of repeated use.

The main difficulty with stone artefacts arises because there are two possible constraints on the production of stone artefact form that could lead to repeated patterning, but which do not arise from a convention that carries meaning. The first constraint is the mechanical requirements of knapping. All knappers need to maintain platform angles, areas of high mass and the appropriate force, and the combination of these three requirements leads to similarities of the forms that will be produced. This has been demonstrated in ingenious experiments that did not preference the location of removals from cores and randomised the choice of platforms and areas of mass from which flakes could be removed (Moore and Perston, 2016). The other constraint arises because habits of knappers tend to approach the mechanical problems of flaking in ways they have learned. This would produce similarities that in style studies are called “isochrestic” (Sackett, 1985; Wiessner, 1985).

One attempt to talk about this issue was the suggestion that modern humans with modern cognition made tools with “imposed form” (Mellars, 1989:347), saying: "The suggestion, in essence, is that the majority (though by no means all) Upper Palaeolithic tools appear to reflect a much more obvious attempt to modify the original shapes of the flake or blade blanks in order to achieve some specific, sharply defined form. In other words, shaping of the tools usually involves the removal of large areas of the original flake or blade blanks, so that the final form or the tool bears little if any direct relationship to the shape of the original blank chosen." This attempt at a definition was not easy to operationalise, though it did seem possible to point to forms – such as backed artefacts (see the arguments in Davidson and Noble, 1993) – where the modifications did not affect the working edge. In identifying the weaknesses of the standard story of stone artefact progression, we pointed to industries with: "distinctive artefacts, confined to relatively small regions and narrow time periods, shaped in ways that cannot be related either to the technology of their production (as handaxes can) or to the modification of the working edge as a result of the constraints imposed by the technology of use (as scrapers and denticulates can)" (Davidson and Noble, 1993:380).

In this case, there are many examples of early bone tools with modified working edges, such as the choppers from Bilzingsleben (illustrated in Noble and Davidson, 1996) and, indeed, many of the bone retouchers discussed at the Hannover conference (e.g., van Kolfschoten et al., 2015). But from the beginning of the Upper Palaeolithic there were ground and polished bone projectile tips where the makers controlled almost all aspects of the form of the artefact, including the initial idea, and these appear in Europe at the same time as bones, ivory and antlers modified for non-functional reasons, such as art (Conard, 2003). So there was the germ of an idea in the concept of “imposed form” that could be operationalised, but only with a clear vision of the role of mechanical constraints.

The concept of “imposed form” was still not problem-free, and still is not. It was used extensively in a more recent discussion of modern human behaviour (Henshilwood and Marean, 2003), but the authors did not respond to the challenge of whether the form of Acheulean handaxes was imposed (Davidson, 2003). If the form of handaxes was imposed, and the logic of the importance of imposed form is followed, modern human behaviour might be traced back to nearly 2 million years ago (Asfaw et al., 1992; Sánchez-Yustos et al., 2017). That question needs to be resolved, and I have attempted such a resolution (Davidson, 2002), admittedly without winning over all specialists on the Acheulean (but for a different approach that recognises the problem see Corbey et al., 2016).

This history demonstrates that the recognition of symbolic communication may involve understanding the symbolic mental representation of artefacts such that what is at issue is not just language origins, but cognitive evolution. In reaching that position, bone tools are revealed as of great importance for understanding when humans became capable of creating artefacts relatively free from the constraints of the mechanics of raw material.

I will turn to cognitive evolution in the final section of this paper, but the other fundamental observation is that symbolic mental representation could be found in other sorts of artefacts and the most remarkable of those are the watercraft (Davidson and Noble, 1992) necessary for people to cross from Sunda, the continental landmass that is the normal condition for what is Island Southeast Asia, to Sahul, the continental landmass that is the normal condition of the islands of Australia and New Guinea that are only separated during brief interglacial high sea-levels. One of the impacts of this observation was to force a shift of focus away from Europe and on to Sahul and the question of why Australia and the Americas seem to be so late in joining the archaeological record (Davidson, 2013b). We revisited that argument in 2010 (Davidson, 2010b), and it has been addressed by others (O'Connell et al., 2010; Kealy et al., 2015). Further important arguments about the complexity of conceptualisation of artefacts and their construction have addressed heat-treatment of toolstone (Brown et al. 2009) and the production of compound adhesives using ochre (Wadley et al., 2004).

The lesson of this history is that by concentrating on communication using symbols, we isolated characteristics of the archaeological record that, while they had been understood for many years, had not entered into discussion of the sorts of cognitive abilities of hominins. In doing so we pointed to the sorts of mental representations that were needed for these achievements (Balme et al., 2009; Davidson, 2010a). But that was not enough.

Expansions of knowledge over last 30 years

It is important to remember that one of the reasons the empirical basis for our argument seems out of date is precisely because the discoveries of the last 30 years have had the effect of fundamentally altering the picture. These discoveries only highlight the importance of developing more appropriate theoretical models of the evolution of cognition.

What made the huge empirical difference was the succession of startling discoveries from Blombos in the Western Cape, South Africa, beginning with bone artefacts (Henshilwood and Sealy, 1997), which, to some extent, confirmed what was already known from Klasies River (Singer and Wymer, 1982). Importantly, the Blombos bone tool finds, from the very beginning, included artefacts that were intentionally, fully shaped independent of their immediate use, as well as others that were expedient tools with modified working ends, but otherwise relatively unshaped. And the Blombos bone points were fully 30,000 years older than anything known from Europe. Distinctions between accidentally pointed osseous fragments, expediently modified tools and intentionally shaped tools are fundamental to sorting through the issues about the role of bone tools in human evolution.

One great difference is the changed importance given to beads in the archaeological record. It is fair to say that 30 years ago there were relatively few people studying beads (but for an honourable exception see White, 1989), and this is partly because they were widely seen as merely decorative and of no importance. But this changed with the recognition of early beads in Australia before 30,000 years ago (Morse, 1993), the discovery of early beads in Turkey and Lebanon before 40,000 years ago (Kuhn et al., 2001), the discovery of beads from Blombos in southern Africa well-dated to 75,600 thousand years ago (Henshilwood et al., 2004), the recognition that beads already known from Qafzeh Cave in Israel were 92,000 years old (Bar-Yosef Mayer, 2005), and subsequent reassessment of other previously excavated examples around the Mediterranean that may be more than 100,000 years old (Vanhaeren et al., 2006). In the explosion of interest in beads and pendants dated to the late Pleistocene, some of the studies have been methodological (White, 2007), some concerned with finds from individual sites (d’Errico et al., 2005), others with comparisons over a wide geographic area (Vanhaeren and d'Errico, 2006; Vanhaeren et al., 2006), or with theoretical arguments developed to fit scenarios relevant to these sorts of finds (Balme and Morse, 2006; Kuhn and Stiner, 2007, 2014). Interest in beads has depended on the historical contexts of the study as well as differences in approaches (Moro Abadía and Nowell, 2015). New finds continue to be added from Timor l’Este dating back to 37,000 years ago (Langley and O’Connor, 2016) and at 33,000 years ago in northern China (Wei et al., 2016). A comprehensive review of evidence for early beads and ornaments shows that they were widespread across the world with the earliest presence of modern humans (Wei et al., 2016). Some, however, resist the claim that these are beads and suggest instead that they were materials used for counting – something that could not be done without symbolic thinking (Coolidge and Overmann, 2012; Overmann, 2016). Either way, their abundance in sites around the world and their scarcity in early sites suggests that interpretations involving some sort of cognitive change are appropriate. Noble and I (Davidson and Noble, 1992) suggested that once language emerged, the use of beads as markers of members of an in-group would be selectively advan-

Figure 1 Simon Parfitt (right, front) showing the sabre-toothed cat *(Homotherium latidens)* humerus from Schöningen, which had been used as a retoucher. Also present are (from left to right) Jarod Hutson, Thomas Terberger, Marie-Anne Julien, Sandrine Costamagno and Petr Neruda. (Photo by Iain Davidson)

tageous given the potential for misunderstanding once meanings were conventionalised.

Bone tools had an important role in getting the argument to its present state. Almost all of the work referred to, including all my work with Noble, has sought explanations about cognition in a rather *ad hoc* manner. As data and argument expand, they demand the development of cognitive models that are adequate to account for cognitive evolution from an ape-like common ancestor to modern humans and that such models be testable using archaeological data. I have discussed recent attempts at theorising in several publications and the reader is referred there for further argument (Davidson 2010a, 2013a, 2014, 2016; Barnard et al. 2016). One of the points that emerges from theorising is that, rather than through the discussion of the semiotic status of finished or discarded objects, the evolutionary status of some cognitive processes are best understood through an analysis of the processes of manufacture or/and use of such artefacts. This is not the place to go into detail about such models, rather I want to end with some speculations that arose from discussions at the Hannover conference, speculations that might be related to one model of the sequence of cognitive evolution (Barnard et al., 2016).

Some final remarks

Much of the discussion at the conference was about those remarkable bone tools known as retouchers (**Figure 1**). These began to be important in Marine

Isotope Stage 9 (possibly earlier) at both ends of the Mediterranean, in Bolomor Cave in the west and in Qesem Cave in the east (Blasco et al., 2013), for instance. Others discussed the typology and context of the various finds, though they seem, generally, to share typological characteristics that are a product of use, rather than prior shaping. Nevertheless, Blasco and her colleagues point out that the Bolomor example was shaped "at the edge opposite the active area" consistent with the criterion Noble and I defined to identify imposed form (Davidson and Noble, 1993), but considerably earlier than the backed artefacts that prompted our definition.

Here, I want to elaborate on something that seemed to emerge in discussion before stalling on the minutiae of typological nomenclature. My intuitive understanding of the evidence as presented at the conference was that bone retouchers represented an important new technology for retouching stone tools. Blasco et al. (2013) suggest they may just have been an improvement on retouching materials used earlier, whether these were stone or wood. One possibility mentioned at the conference was that they appear with Quina scrapers – which we might call steep edged scrapers to avoid the parochialisms of typologists. At Qesem, several of these steep scrapers were used for hide preparation (Lemorini et al., 2016), and a linked series of arguments might run as follows: 1) use of bone retouchers permitted improved retouch of steep scrapers; 2) better production of steep scrapers permitted better preparation of hides; 3) more consistent production of well-scraped hides made the use of animal skins better for clothing; 4) better clothing allowed more certain adjustment and perhaps adaptation to cooler climates.

A sequence of this sort follows a pattern that is becoming familiar from other parts of the archaeological record: significant outcomes were a product of hominins recognising affordances that may have been there for a long time, and once that achievement was made, a new niche was constructed (Davidson, in press). We take all such niche constructions for granted; yet, they were achievements. This pattern for bone retouchers fits into a broader set of affordance discoveries and niche constructions that could be something like this:

- Previous knapping events can be a source of more tools or of new cores (Davidson and McGrew, 2005)
- The bones in the carcass can be used as tools (as suggested by Jarod Hutson and others at the Hannover conference)
- The skin on the meat can be a tool for carrying
- The skin that is used for carrying can keep you warm
- The stone to cut the wood can be resharpened with a bone
- The resharpened flake can be fashioned into a scraper that can clean the skin (as suggested by Avi Gopher)
- A flake can be combined with a bone (and perhaps a strip of skin) to make a more efficient knife (Barnard et al., 2016)

The point here is that we can associate some of these elements with particular elements of the Barnard model of cognitive evolution. We have already outlined the need to recognise the concept of a "part" before parts obtained from different sources can be combined (Barnard et al., 2016; Davidson, in press). The challenge is to fit all of these elements into a scheme of evolution of hominin cognition. But that is another story.

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MILLÁN MOZOTA

EXPERIMENTAL PROGRAMMES WITH RETOUCHERS: WHERE DO WE STAND AND WHERE DO WE GO NOW?

Abstract

This paper presents a critical review of the experimental works with bone retouchers that have been published since the beginning of research about this type of tool. The aim of this review is not the recollection of references *per se*, but a critical evaluation of different studies. This critical synthesis will show where we are today from a theoretical and methodological point of view. A number of ideas on how to improve and expand the scientific research about retouchers will be proposed together with a range of open archaeological and experimental issues, which can be addressed by the research community in the years ahead.

Keywords

Experimental archaeology; Retouchers; Bone tools; Middle Palaeolithic; Methodology

Introduction

This work focuses on the contributions of experimental archaeology to the study of bone retouchers; thus, it is necessary to begin with a brief explanation and discussion about this theoretical and methodological approach.

Experimental archaeology is a methodological framework based on actualism and empiricism, the core concepts behind a systematic, quantitative and inferential study of archaeological evidence. The works of Coles (1973, 1979), Reynolds (1994), Baena (1997) and Callahan (1999) laid the foundations for the formal development of this theoretical and methodological approach, and these works also contain the main proposals for its practical application. The aforementioned authors present experimental archaeology as a mechanism to propose and test explanatory hypotheses about archaeological evidence. This inferential framework can be used as a tool to validate or falsify hypotheses.

For experimental archaeology to have true scientific rigour, it must meet certain requirements of objectivity and control. These criteria have been specified in several studies (Baena, 1997; Callahan, 1999). It is also necessary that such experiments are integrated into a broader framework of analysis and interpretation of archaeological evidence. And, most important, the ultimate goal of this general framework cannot be the anecdotal analysis of the materiality of archaeological objects. Rather, the goal must be to propose explanatory models of past human societies.

Bone retouchers in context

Bone retouchers are a common type of tool in the Middle Palaeolithic, but are not confined solely to that period. These tools are percussion implements made of bone; most typically they are unmodified or barely modified splinters from long bones (including metapodials) of ungulates. These tools are used to retouch stone tools, both in the sense of shaping an implement (e.g., a side-scraper) and for rejuvenating a dull edge. In most cases, when archaeological retouchers have been studied in depth, it was determined that they were used in percussion tasks. Only in a few cases were they used in pressure-style retouching tasks, the use traces from which are very different from those produced by percussion.

In the early 20th century, Henri-Martin (1906) first determined the existence of this specific type of bone tool among the faunal remains of La Quina, France. These implements were diaphyseal splinters from ungulate bones, and they were possibly used to retouch Mousterian lithic tools. At this early stage, some functional uncertainty can be perceived in the texts, and researchers alternatively proposed that the bone splinters were active elements (mallets/percussion tools, *Fr. maillets/percuteurs*) or otherwise passive (anvils, *Fr. enclumes*) when writing about how they were used. At about the same time, de Mortillet and de Mortillet (1910) defined the compressor (*Fr. compresseur*) as a bone tool that was characteristic of the Solutrean period, used for pressure retouch activities. In most cases, the label of Middle Palaeolithic bone tools as anvils was soon discarded (Siret, 1925), and throughout the first half of the 20th century, these tools originally described by Henri-Martin were typically identified by the term "compressor-retoucher" (*Fr. compresseurs-retouchoirs*). But, as was typically of most works from period, there was no consideration about how individual objects, or even whole assemblages, could have been used.

In the early 1960s, Bordes (1961) includes Solutrean bone compressors in his typological lists, and stated that they were used differently than the diaphyseal splinters with impressions that came from Mousterian sites.

Confusion stemming from variability in bone retouchers nomenclature was a constant even beyond the 1960s. But, during that decade, development of the archaeological, anthropological and historical disciplines, and the new visions of archaeological science, gave a clearer idea of the nature of such tools.

In a synthesis of the European continent, Taute (1965) enumerated a large collection of retouchers in hard animal tissues (mostly bones, but also teeth and antler) with a wide chronological perspective, ranging from the Palaeolithic to the Neolithic. This work included retouchers from several Middle Palaeolithic sites in Central Europe. The bulk of Taute's sample was made of epiphyseal and diaphyseal splinters with impressions, which led to the conclusion that the tools are bone retouchers – used for retouching lithic implements with a percussion (not pressure) technique.

Since the early 1970s, researchers have found more Palaeolithic bone retouchers throughout Europe, mostly in Middle Palaeolithic (particularly Mousterian) sites. Some important examples include Kůlna Cave in the Czech Republic (Valoch, 1988), Abrigo Tagliente in Italy (Leonardi, 1979) and Peña Miel in Spain (Barandiarán, 1987), but there are dozens of sites where the presence of these tools was detected and published. Throughout the 1970s to 2000s, dozens of new and old sites with retouchers were documented and published (Mozota, 2012).

Bone retouchers were also documented in several deposits from the European Upper Palaeolithic in France, such as the Protoaurignacian and Early-to-Evolved Aurignacian layers from Gatzarria (Saenz de Buruaga, 1987; Tartar, 2012), or the Aurignacian from Grotte des Hyènes (Tartar, 2003) and Abri Castanet (Tartar, 2012) .

For the Solutrean, there are examples too, such as Le Petit Cloup Barrat in France (Castel et al., 2006). And for the Magdalenian, bone retouchers were found in La Garenne (Rigaud, 1977), Isturitz and La Vache (Schwab, 2005), all from France, and in the German sites of Gönnersdorf and Andernach (Tinnes, 2001).

Outside Europe, retouchers have been documented in other Pleistocene contexts, such as in the Middle Stone Age layers at Blombos Cave, South Africa (Henshilwood et al., 2001) and in the Middle Palaeolithic of Umm-el-Tlel (Syria) (Boëda et al., 1998) and El Harhoura (Morocco) (Michel et al., 2009). In the Americas, the presence of bone retouchers has been documented in various contexts of prehistoric hunter-gatherers. There is a type of tool defined by Jackson (1990) as an end-side retoucher (*Sp. retocador extremo lateral*). This type of tool is virtually identical to the concept of retoucher on diaphyseal splinters from European Palaeolithic sites. *Retocadores extremo laterales* have been found in Paleoindian contexts (Pleistocene) at Fell 1 in Magallanes, Chile (Massone and Prieto, 2004). There are also some examples from the recent period (Holocene) in Magallanes at the site of Orejas de Burro 1 (Lorena-L'Heureux, 2008).

As for theoretical and methodological developments, during the early 1990s Chase (1990) resumed the study of the bone tools from La Quina. He analyzed a selected sample of materials and concluded that many bone splinters were used as retouchers for percussion tasks. Chase (1990) integrated this analysis into an explanatory model of Middle Palaeolithic tools, whereby retouchers were proposed as one of the key elements reflecting Neanderthal cognitive (dis)abilities (see also Dibble, 1989). While this proposal has been disproven by many studies about Neanderthals (e.g., d'Errico, 2003; Zilhão, 2007; Hayden, 2012) its lasting importance lies in the analysis of artefacts to answer central questions about prehistoric human groups.

The Ph.D. dissertation of Vincent (1993) is also important from a methodological perspective, in that she proposed new approaches that reflect advances in archaeozoology, taphonomy and bone technology from the preceding decades.

In 2002, a synthesis of the European Palaeolithic was published (Patou-Mathis, 2002), incorporating reviews of many retoucher assemblages, mainly from the Mousterian and some examples from the Upper Palaeolithic. The work is organized in a series of standardized typological datasheets, and some use traces are studied to make functional inferences, but this is not systematic.

Experimental archaeology and bone retouchers: a historiographical perspective

A century of experimental work: from the early 20th century to the beginning of 21st century

Siret (1925) performed one of the first detailed experiments of lithic retouch with bone fragments. He conducted these activities within the framework of discussion about the role of bone splinters with impressions that had been recognized at La Quina (Henri-Martin, 1906) and other Mousterian sites. Choosing between the different hypotheses of the time, Siret concluded that the diaphyseal fragments with impressions were retouchers, not compressors or anvils, used as active elements for working flint tools. He further stated that these tools were used in pressure flaking tasks instead of percussion. He considered that the lithic tool was held in one hand and pressed against the bone tool, which was held in the other hand, until the detachment of a retouching flake.

During this period, experiments were always replicative and based on subjective and qualitative observations. In most cases, little data on the specific experimental procedures were offered.

Semenov (1956) defined some features of compressors after studying a pair of bone fragments from the Upper Palaeolithic of the Soviet Union. The blanks he studied showed two different use areas located at opposite ends of the bone fragment. After comparing the traces of use with experimental materials, he interpreted the marks as the result of pressing the compressor on the lithic edge. Semenov's most important contribution is not the study of these particular tools, but rather his inclusion of an explicit methodology linking experimentation and the analysis of tool function. In addition, he provided the means to integrate these experimental studies of artefacts into general models for the explanation of past human societies; in this case, within the orthodoxy of historical materialism.

Moving towards the 1960s and 1970s, Feustel (1973) and Dauvois (1974) performed experimental studies that again linked the impressions on diaphyseal splinters with retouching lithics. Both works provided some important insight on the matter, but, like many others, these works are of limited scope because they do not explain their methodologies or the actual data generated by the experiments.

Rigaud's (1977) work contains an experiment to analyse the stigmata present on bone retouchers from the Magdalenian layers of La Garenne, France. Typical traces were longitudinal lines (*Fr. traits longitudinaux*), which can form cupules (*Fr. cupules*) of use when they are very numerous and concentrated (**Table 1**). Also documented were scrapings (*Fr. éraflures*), or thin grooves, which are formed when the protruding points of the lithic tool edge make contact with the retoucher at the end of the movement, often lateralized to the right in the case of a right-handed artisan. Rigaud also experimented with using the blanks as compressors for pressure retouch, and characterized such traces by the presence of primary and secondary striations, which were deeply engraved on the bone blanks. This pioneering study by Rigaud details both his methodological framework and development of experimentations, including the definition and quantification of variables and statistical analysis. However, as Rigaud focused the study on lithic elements, the use traces observed on bone retouchers were not studied with the same level of detail. Nevertheless, this work was the first to provide a classification of use traces into discrete categories. These traces were reasonably well defined and explained in mechanical terms.

In Italy, Leonardi (1979) described possible bone retouchers at Abrigo Tagliente and refers to the unpublished experimental works of Guerreschi. These experiments suggest that the archaeological bones were used in percussion (not pressure) tasks for re-

Table 1 Approximate equivalences between different classifications of use traces categories proposed by the researchers and works mentioned in the text. Use traces on the same lines indicate a general equivalence.

Rigaud 1977	Vincent 1993	Ahern et al. 2004	Rosell et al. 2011	Mallye et al. 2012	Mozota 2013	Daujeard et al. 2014
Fr. Traits longitudineux	*Fr. Hachures and Entailles**	**	Shallow striations and deep striations #	Scores (rectilinear/ sinuous, convex/ concave)	Linear impressions	Hash marks or hatchings and grooves*
Fr. Éraflures	–	**	–	–	Striations	Sliding striations
–	*Fr. Cupules*	**	Grooves	Pits (triangular/ ovoid)	Trihedral impressions	Cupules or chattermarks
Fr. Cupules	–	**	–	Scaled area	Massive chipping	–

* Vincent (1993) Fr. "*Entailles*" and Daujeard et al. (2014) "Grooves" could also partially correspond to others authors' "Pits" (Mallye et al. 2012), "Trihedral impressions" (Mozota 2013) and "Grooves" (Rosell et al. 2011).

** Ahern et al. (2004) described punctiform pits and short linear channels, but their functional interpretation – see text- makes impossible to correlate these categories to other authors' classifications.

\# Rosell et al. (2011) classification of traces is based on the taphonomic studies of Blumenschine and Selvaggio (1988) and Blumenschine et al. (1996).

touching lithic tools, but no details about the specific content of the experimental works were provided.

In the 1970s and 1980s, Lenoir (1973, 1986) offered an experimental and archaeological study of Quina-type Mousterian industries, focused on lithic technology. These works marginally addressed the use of bone retouchers, and information on their use was mostly of an anecdotal or qualitative nature. Later, ETTOS (1985) published the accounts of several experimental initiatives geared towards Palaeolithic bone materials, including retouchers. This was a synthetic work, but with just a few theoretical and methodological details.

In the early 1990s, several new studies substantially improved the experimental understanding of archaeological bone retouchers. Boëda and Vincent (1990) linked the Quina-type retouch with the use of bone retouchers, and the Ph.D. dissertation of Vincent (1993) included an experimental programme to analyze bone splinter use in percussion tasks. Vincent characterized and classified three types of traces (see **Table 1**): cupules (*Fr. cupules*), which are rounded marks; hatchings (*Fr. hachures*), which are elongated and thin marks; and grooves (*Fr. entailles*), which are deeper and wider marks with an inner rim. Hatchings were the most common traces. Retouchers were classified by Vincent as soft hammers used for the manufacture and retouching of flint tools. The author noted that "semi-dry" bone was optimal for use in retouching tasks. Completely dry or green bone was considered less suitable for percussion retouch. In addition, Vincent noted that bones from adult animals were preferable because of the larger mass and density required for effective percussion. Vincent's work was a milestone in the study of bone retouchers, and her classification of stigmata into discrete categories has been used frequently by other authors. This work focused on description and classification, leaving aside inferential questions; there is a slight predominance of qualitative over quantitative criteria, yet still a major breakthrough in experimental studies of bone retouchers.

Also in the early 1990s, Chase (1990) studied a number of retouchers from La Quina (Locus 2), together with an experimental sample. Chase stated that documented traces of use in archaeological tools were identical to those from his experimental programme. He described the stigmata as short, deep, and sub-parallel marks with V-shaped sections resulting from the impact of a lithic edge against bone matter. These traces were concentrated in areas of use that eroded very quickly. According to Chase, the stigmata observed in bone retouchers corresponded to very short periods of use: between five and eight seconds. Such use served to rejuvenate a single lithic edge, and after that, the retoucher was abandoned. Chase's (1990) work is of great interest because it explicitly integrated an explanatory model of Middle Palaeolithic stone tool management (see also Dibble, 1989). In this model, bone retouchers were an impromptu tool, used for a few seconds, then abandoned. Retouched flint tools were the result of edge rejuvenation, with no previous conceptualization or planning of the tool's shape. From a practical point of view, this model severely underestimated the use life of bone retouchers. Later researchers determined that the cost in time for retouching a lithic tool is relatively short, but longer than the five to eight seconds predicted by Chase. More realistic time spans range from half to a few minutes (Mozota, 2012), depending on many variables, including the size and morphology of the lithic implement, the retouching technique, the *savoir-faire* of the maker, etc.

A study by Malerba and Giacobini (1998) presented an analysis of bone retouchers from northern Italy (Fumane, Tagliente, and San Bernardino) and several pieces from La Quina. These archaeological materials were compared to experimental implements, and the authors confirmed their use in percussion tasks. Again, experimental protocols were not explained in great detail, and it appears the entire exercise was largely replicative, which allowed the authors to confirm (or reject) an *a priori* hypothesis on how the tools were used.

Armand and Delagnes (1998) studied a sample of retouchers from layer 6C of Artenac, a La Ferrasie sub-type Charentian Mousterian site in France. The work included the results of experiments performed with 33 diaphyseal splinters of *Bos taurus* that were used to retouch flint tools. A number of parameters were considered, including angle, trajectory and direction of the percussion, force of the blow, type of hand grip and passive vs. active roles of the bone tool. With a strategy to replicate the bone retouchers from Artenac, they varied the parameters until they achieved the combination that generated the same sub-type of retouched side-scrappers present in the archaeological series. Armand and Delagnes (1998) used the same categories of stigmata listed by Vincent (1993): hatchings (*Fr. Hachures*), cupules (*Fr. Cupules*) and grooves (*Fr. Entailles*). Each stigma type was associated with a specific combination of parameters. Hatchings (*Fr. Hachures*) occurred with percussion angles around 40°, linear trajectories, an oblique direction, and a loose grasp of the retoucher. Cupules (*Fr. cupules*) resulted from strong percussions and were associated with irregularities in the edge of the lithic tool or the retouching of the butt of the flake. Finally, grooves (*Fr. entailles*) were related to percussions with re-entrant (parabolic) trajectories, with angles between 120° and 160°.

Armand and Delagnes (1998) also noted that no stigmata were recorded on the bone retoucher in two experimental situations. Specifically, no stigmata were produced while striking sharp edges with very acute percussion angles or during passive use of the retoucher (bringing the lithic piece to the bone). The authors also point out the frequent presence of scrapings on the archaeological retouchers, concentrated in the active zone. These scrapings are interpreted as a preparation of the area prior to use. The work of Armand and Delagnes (1998) is of great interest because they define and make explicit the most important elements of their experimentation. Still, the programme is replicative and deductive, with a very narrow focus on determining the type of retouch that was performed at the site of Artenac. Most introduced variables are not really quantitative, and qualitative considerations dominate the study, except for some morphometric measurements. These measurements are nevertheless of great interest because they were used to explore the dimensions of retouchers in relation to the size of the other bone splinters not employed as retouchers.

Bourguignon (2001) conducted an experimental programme to study the processes of shaping Quina-type tools by retouch. The author began by defining a number of technical parameters which determined the type of retouching. Bourguignon noted that there was a significant degree of overlap between the various types of hammers or percussion tools (soft, hard, "hard-soft") in terms of their potential use. Lower mass, density or elasticity of a bone hammer could be, to some extent, overcome with changes to the applied force or the percussion gesture. This work has a strong qualitative component of *savoir-faire* gained through personal experience, which significantly reduces its potential for scientific inference.

In the collective work dealing with retouchers and similar tools edited by Patou-Mathis, Malerba and Giacobini (2002) presented the study of retouchers from La Quina, and the Italian sites of San Bernardino and Fumane. Experimentation confirmed the use of bone splinters in percussion tasks for retouching sharp flint edges. The authors also found that right-handed artisan produced some deviation to the right side of retouchers, both in trace orientation (slightly oblique) and position of the areas of use (closer to the right side of the blank). This followed Rigaud's (1977) experimental realization that human laterality (predominant use of one hand over the other) can be detected in bone retouchers.

In the same collective work, Valensi (2002) presented the study of several phalanges of *Rangifer tarandus* and *Bos sp.*, used as retouchers. Based on experimentation, she deduced that the archaeological traces were produced on fresh bone. Moreover, each species was associated with a particular type of retouch: the *Bos* phalanges were used to perform abrupt retouch, while *Rangifer tarandus* were used for flat and invasive retouch. This work is based on a replicative-deductive strategy to infer how a particular task, detected in the archaeological material, was performed.

Ahern et al. (2004) studied the bone retouchers from layers F-G at the Vindija archaeological site in

Croatia. The authors conducted an experiment to match the traces of use from the bone retouchers with two different types of retouch present in the lithic assemblages. Two types of marks, one due to percussion and the other due to pressure flaking, were observed in the experiment (see **Table 1**). The marks made by percussion were punctiform pits with scaling on the edges, while the marks made by pressure were short, linear channels with U-shaped sections. The authors noted some differences between the experimental results and the archaeological sample: in the archaeological tools, percussion traces were more lenticular, and traces of pressure were deeper. Again, this replicative-deductive strategy limits the scope of experimentation and its potential for scientific inference. And in this case, the authors used their own specific classification of stigmata. Their results suggest that either the use traces do not correspond to the those documented by other researchers, or these marks only represent a few, very specific sub-types. Finally, it is important to note that the experiment included only one retoucher used for two different tasks.

David and Pelegrin (2009) studied two bone tools from a Mesolithic context. Both tools had two different uses: as chisels and as retouchers. Ten experiments with bone blanks were designed to study stigmata produced on bone surface by different activities, all related to flint management. According to the authors, the types of traces documented when retouching flint implements correspond to the classification of Vincent (1993). Use zones were located at the ends of bones, but not too close to the edge. The use of retouchers in pressure tasks produced lateralized areas with concentrated stigmata, located to the right side of the central axis. This lateralization was also present in the tools used for percussion retouch tasks. The researchers documented striations or secondary lines with pressure retouch, but not for percussion tasks. David and Pelegrin (2009) concluded that the traces present in the two archaeological retouchers were related to pressure retouch tasks. Their work is of great interest as an exploratory exercise of ten different tasks that could imply the use of bone retouchers, especially since some of the tasks were not usually considered in other experimentations. However, the total number of experiments, and the fact that each individual task is completely unique, makes it virtually impossible to confirm that the documented features are actually relevant, and they cannot be used for quantitative analyses.

Where do we stand? Experimentation with bone retouchers in recent years

Rosell et al. (2011) presented several tools from the Lower Palaeolithic site of Atapuerca, Spain, including a diaphyseal splinter used as a retoucher. The supplementary material of the paper details 16 experiments with dry and fresh *Bos taurus* bones used to retouch lithic blanks of quartzite and flint. The authors used a classification of traces (see **Table 1**) based on the taphonomic studies of Blumenschine and Selvaggio (1988) and Blumenschine et al. (1996). These works refer to the marks left by stone tools on bones, but with emphasis on butchering and carcass processing, and not on the use of bone as a tool. Traces are classified as shallow striations (straight or slightly curved and shallow incisions), deep striations (straight or slightly curved and deep incisions) and grooves (wide and very deep marks with a trihedral or irregular shape). This is an interesting work because the authors chose different exploratory variables (two lithic raw materials to be worked and two states of bone) and control them with a high level of detail. But, being focused on a strictly deductive-replicative strategy, the study is of little utility beyond the characterization of the tool found in Atapuerca.

Tartar's (2012) synthesis work on Aurignacian retouchers included a well-defined, specific experimental programme about the use of these tools for retouching Aurignacian blades and for knapping micro-blades. While the scope of this work would improve with the inclusion of more quantitative data, it is the author's observations about the technical mechanisms that influence the formations of stigmata and the appreciation for the choices available to the artisan using the retoucher that are relevant for current research.

My own experimental programme (Mozota, 2012, 2013, 2014) includes the largest experimental sample analyzed in detail and published to date: 38 experiments on the fragmentation of large ungulate long bones to study various aspects of blank collection for these kinds of tools and 177 experiments on retoucher use.

My work does not deal with experimental archaeology from a strict replicative perspective, nor delves into *savoir-faire*, but builds a scientific programme based on the systematic collection and organization of data, quantitative treatment of the data and a hypothetico-deductive structure. The first experimental series was designed to analyse the collection and use of retouchers made of ungulate bone splinters. Specifically, I studied the process of fracturing a sample of *Bos taurus* and *Cervus elaphus* long bones (including metapodials). The blanks obtained were then used in a second phase: retouching quartzite and flint implements. The array of possible retouching tasks and the selection of animal and lithic raw materials were based on the archaeological inventories from a series of Mousterian sites in the northern Iberian Peninsula (Mozota, 2012).

In the first series of experiments (blank collection), the goal was to study the physical mechanisms of long bone fracture, the actual stigmata caused by percussion and the products of fragmentation. The analysis incorporated a series of controlled and independent statistical variables. I also studied the most relevant morphological and metric traits of every usable blank obtained in the experiments. Two main strategies of bone fracturing were considered: one aimed at marrow extraction, and the other aimed at the production of blanks for retouchers (**Figure 1**).

Figure 1 Blank collection experiments by M. Mozota. The photographs show the fracturing of deer metapodials within a blank-producing strategy.

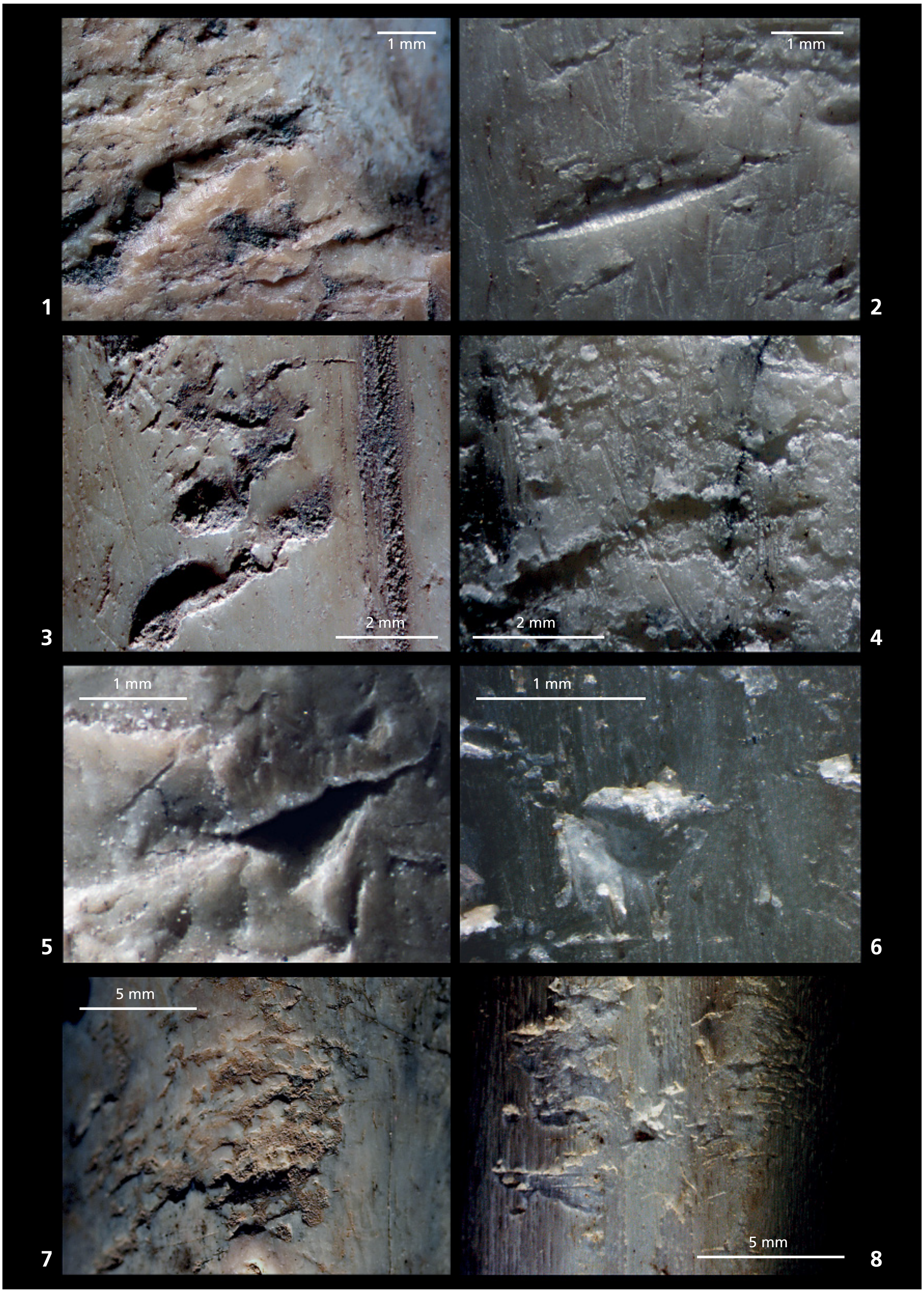

Figure 2 Traces of use in archaeological and experimental bone retouchers from Mozota (2015). (1) Linear impression detail, Peña Miel Level G. (2) Linear impression detail, experimental sample. (3) Striations and linear impressions in direct association, Peña Miel Level G. (4) Striations and linear impressions in direct association, experimental sample. (5) Trihedral impression, Peña Miel Level G. (6) Trihedral impression, experimental sample. (7) Widespread chipping, Prado Vargas Level 4. (8) Widespread chipping, experimental sample. This figure was first published in Mozota (2015) under a Creative Commons 3.0 Attribution-NonCommercial-NoDerivatives License.

In the second set of experiments (retouching), the goal was to understand the formation of different use traces and how these traces related to different retouching tasks and other variables. Using the same systematic approach, the analysis followed a series of quantifiable and independent variables. Additionally, I searched for consistent and recognizable patterns of use traces related to specific tasks that could be identified in the archaeological record. The use traces were studied mostly through quantitative variables (obtained from artefact inventories, counting and measurement of stigmata); qualitative observations were also recorded during the process.

I defined three categories of stigmata, or use traces, through three specific criteria: identifiability, repetition and univocity. In other words, the stigmata must be recognized and differentiated without any degree of ambiguity and frequently present on the used blanks. With that, the categories of stigmata were linear impressions, trihedral impressions, and striations (see **Table 1, Figure 2**).

Linear impressions are straight or slightly curved elongated marks, narrow and deep, with a V-shaped profile. These impressions are produced by a lithic edge impacting the bone surface, and are the most common retoucher use traces. Their detailed morphology can be quite variable, depending on the force applied, percussion trajectory, working angle, lithic edge configuration, blank shape, etc. When considering these numerous variables in relation to the final detailed morphology of the impressions, they showed a high degree of equifinality. Trihedral impressions are deep, with a negative trihedral shape, and are produced by the impact of an apex of the lithic edge against the bone. Striations are straight or slightly curved elongated lines, often directly associated with linear impressions (typically perpendicular or sub-perpendicular to those traces). Striations appearing in concentrations can be mistaken for scrapping marks related to butchery or blank preparation. Striations are usually produced when lithic apexes scrape against the bone surface during percussion or the application of pressure, before the lithic edge "bites" the blank producing a linear or trihedral impression.

In addition to those stigmata, another type of widespread use-wear was documented: chipping. This can be defined as alterations to the cortical bone surface due to use, located on the active areas of the blank. These alterations are produced by the concentration of impacts on a restricted area, or what Rigaud (1977) called cupules, but not the *Fr. cupules* in Vincent's (1993) classification.

For the collection phase, results indicate that when the objective was bone marrow extraction, percussion produced a higher number of non-usable splinters and a more heterogeneous morphology of potential blanks. In contrast, the blank production strategy produced a lower number of non-usable splinters and a less heterogeneous blank morphology (Mozota, 2013).

For use areas, a clear pattern of lateralization became evident when considering the position of traces on the blanks (Mozota, 2013). This interesting result is directly associated with the fact that the experimenter was right-handed. The study of use traces also yielded other conclusions related to bone freshness, retouching task, lithic raw material and intensity of use (**Figures 3 and 4**).

Dry bone shows fewer linear impressions than fresh bone when subjected to the same levels of use intensity. Also, the appearance of linear impressions on a dry bone is different from the impressions made on a fresh bone. When considering the stigma features in relation to modes of retouch, a difference arises between pressure and percussion (including both Quina and simple types of retouch). Percussion is characterized by longer linear impressions, rare massive chipping on use areas and a relatively high incidence of trihedral impressions. Pressure retouch is characterized by the opposite: shorter linear impressions, an increased presence of massive chipping and a lesser occurrence of trihedral impressions. Among percussion implements, Quina and simple retouching tasks were compared. Quina retouch is characterized by longer and more abundant linear impressions, a scarcity of striations and a high incidence of trihedral impressions and massive chipping. The opposite is true for simple retouch: fewer impressions per use area, a higher presence

Figure 3 A few of the blanks used in retouch experiments by M. Mozota. (1- 6) fresh bone splinters of *Bos taurus* long bones. (7-12) fresh bone splinters of *Cervus elaphus* metapodials. (1) Quina retouch, flint. (2) Simple retouch, quartzite. (3) Pressure retouch, flint. (4) Pressure retouch, flint. (5) Quina retouch, flint. (6) Simple retouch, quartzite. (7) Quina retouch, quartzite. (8) Quina retouch, quartzite. (9) Simple retouch, quartzite. (10) Quina retouch, flint. (11) Quina retouch, quartzite. (12) Quina retouch, quartzite.

of striations and a low incidence of trihedral impressions and massive chipping.

Combining this experimental programme with archaeological studies of archaeological retouchers, lithics, and other faunal remains from Mousterian sites in the Iberian Peninsula has contributed to general models of Neanderthal behaviour from this chronology and geographical area (Mozota, 2009, 2012, 2015).

Mallye et al. (2012) studied the Mousterian bone retouchers of Noisetier Cave (France) and detailed an experimental programme for the interpretation

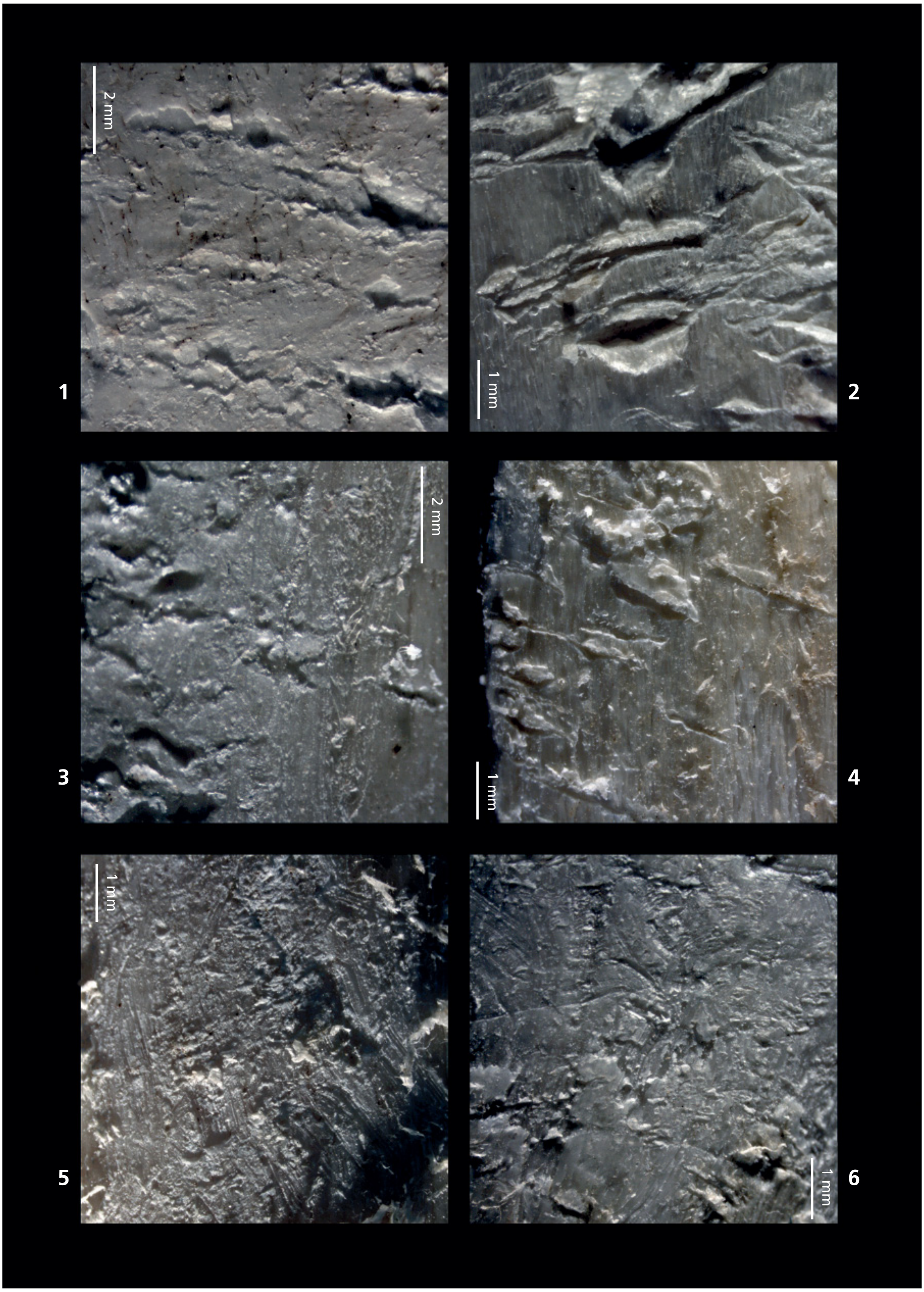

Figure 4 Low magnification images of use traces from different experimental retouchers. (1) Traces on dry bone produced by Quina retouching of flint. (2) Traces on fresh bone produced by Quina retouching of flint. (3) Traces on fresh bone produced by Quina retouching of quartzite. (4) Traces on fresh bone produced by simple (direct, non-invasive) retouching of flint. (5) Traces on fresh bone produced by pressure retouch of quartzite. (6) Traces on fresh bone produced by pressure retouch of flint.

of traces detected on the archaeological tools. They conducted 73 retouch experiments with fresh and defatted bone on tools made of quartzite and flint. These researchers studied the active areas and classified their positions on the bone blanks in some discrete categories. They also classified stigmata into two groups: pits and scores (see **Table 1**). Sub-classifications were added to each group based on a more detailed morphology: triangular and ovoid pits; and rectilinear/sinuous and smooth/rough scores. Entire use areas were also classified into discrete types: hatched (with a predominance of rectilinear scores), pitted (predominance of pits) and scaled (with massive chipping).

The experimental programme of Mallye et al. (2012) allows researchers to infer the worked material (i.e., quartzite or flint) from the stigmata and appearance of the use areas. To a lesser extent, the state of bone (fresh or defatted) could be inferred. They did not find a relationship between the use of a dominant hand and the position of the areas of use. This work brings important advancements in the planning of an experimental programme, with clear and well-organized variables, a relevant quantification of the results and a statistical treatment of the data. Additionally, this analysis is integrated into a more general study of the archaeological evidence of the subsistence patterns and ways of life of the Neanderthal groups that lived in Noisetier Cave. The main limitation of this study is the approach to the position of the use area. With its general classification of use areas into large and subjective categories the study may lack the precision required to detect relevant differences in lateralization of the active areas. While this is not an actual flaw, strict adherence to the classification scheme proposed by Mallye et al. (2012) imposes limitations on the study of handedness and brain lateralization.

Finally, Daujeard et al. (2014) studied a number of faunal assemblages with bone retoucher from southeast France, supported by an experimental programme. These researchers adapted and modified the stigma classifications of Vincent (1993), defining four categories (see **Table 1**): cupules or chattermarks, hatchings or hash marks, grooves and sliding striations. This work presents all the data very efficiently and in great detail, particularly with regard to the archaeological materials. However, it seems the experimental programme was not aimed at drawing general inferences about the tool use, but was designed to create categories to classify and describe the objects and, eventually, the archaeological assemblages.

Overall, the experimental study of bone retouchers has been a collective process involving many researchers; it began in the first decade of the 20th century and is still going on today. It originated with qualitative descriptions of stigmata, followed by the analytical classification of these traces of use. Finally, in more recent times there has been notable progress towards a fully functional understanding of the formation and development of use traces. At the same time, more systematic research programmes are being developed, with a more complete and rigorous quantitative basis.

Where do we go, now?
Current research shortcomings and prospects

General research questions

Despite the long and fruitful journey, there is still work to be done. Researchers should adjust current experimental work to the highest standards of scientific research programmes in prehistoric archaeology to ensure that we are doing the best science possible.

First of all, it should be clear that an experimental programme may include various exploratory trials or qualitative approaches, but research cannot be limited to these activities. These qualitative studies have no real capability to make scientific inferences, neither are they usually verifiable or reproducible by other researchers. Such exploratory approaches are limited in scope because they have no real explanatory power of studied phenomena. Therefore, we should conduct our experiments (or at least the main phase of our experimental programmes) within the constraints of what Callahan (1999) called level III of scientific reliability, and Baena (1997) considered rigorous models with high control of variables.

Moreover, it is not acceptable when the variables studied in our programmes are not adequate for quantitative analysis of the data (Shennan, 1997). When possible the variables must be numerically continuous. If certain features of the tools cannot be measured properly, discrete numerical variables can be used. And if this is not possible, binary, ordinal and nominal variables should be considered; however, these types of variables are less informative by definition, and fewer statistical tests can be applied to them, resulting in less overall inferential power. So, as a general strategy we should measure every stigma whenever possible rather than rely on simple counts (which is also important). And, when possible, we must count all the stigmata of a type rather than simple documentation of its presence or absence. Although these procedures have been developed in recent years, it is clear that there is still great room for improvement. Such strategies will produce data with more explanatory potential, especially when we incorporate the data with independent variables start to sort out how these variables influence the number and dimensions of stigmata.

There is another problem of a theoretical-methodological nature that is common among experimental approaches to bone retouchers: the lack of an integrated analysis of archaeological artefacts within a general framework of research on past human societies. The study of prehistoric artefacts cannot be a goal in itself. On the contrary, such studies should always be oriented towards obtaining data that can be integrated into a general explanation of human behaviour.

We cannot forget that human beings, not objects, are the ultimate subjects of our work. There is an overabundance of research that is impeccable from a technical point of view but makes almost no relevant contributions to the general state of knowledge about past human groups. To correct this situation, researchers should make explicit their research objectives, along with reporting their final results. From an experimental perspective, it is necessary to study the role of bone retouchers within the social and economic dynamics of the human groups we study. We also need to integrate the study of these tools in the general framework of how human behaviour changed over time.

So far, studies have shown that bone retouchers have a great potential to infer the economic behaviours and social organizations of past human groups (Mozota, 2009, 2015; Jéquier et al., 2012; Mallye et al., 2014). Thus, these prospects should be further exploited. Bone retouchers form a conceptual bridge between the procurement of faunal resources and the management of mineral resources. In that sense, the analysis of bone retouchers can provide vital information for understanding how faunal and lithic management are integrated into the overall subsistence strategy, and ultimately, into the economic and social organization of past human groups.

Specific research questions

CATEGORIES OF USE TRACES For the study of the use traces, most researchers have chosen to separate stigmata into a series of discrete categories (see **Table 1**), which are not only useful on a descriptive level but also allow for functional inferences based on their measurable characteristics. There are several considerations to make in this respect. The first issue to consider is that when publishing our experimental programmes, we must make explicit the criteria that we followed to distinguish between stigma types. Given the importance of stigma categories as the basis for all subsequent study, the criteria that define them must be made explicit. If possible, stigma categories also must be explained in functional terms, i.e., how each type of stigma is created, from a technical and mechanical perspective.

Another issue directly related to the classification of the stigmata is the proliferation of different classifications used by different authors. In this sense, there is nothing intrinsically right or wrong with using the classification of a previous author, modifying existing classifications, or even creating a new one. All of these options should be considered valid strategies. But most importantly, the specific classification must be evaluated on the basis of its methodological validity and its applicability. This is precisely why it is important to explain the criteria used for a new system of classification. Additionally, if a modified or new classification is offered, the authors must explain the differences between their classification and the classifications already proposed by others. Creating new classifications without providing the terminological equivalents to match them with the works of others should be discouraged. This impedes comparisons across multiple studies and generally reduces the scientific potential of the work made by the whole community of researchers.

BLANK COLLECTION One of the least explored aspects of the experimental approach to these tools is the collection of bone blanks: splinters that are selected and used, and therefore become bone retouchers. The *a priori* assumption in most studies on archaeological retouchers is that there is an impromptu selection of blanks – these bone splinters were just picked up from among the faunal remains consumed at a dwelling place. In some cases, the morphometry of archaeological blanks has been analyzed in comparison with other faunal remains (Armand and Delagnes, 1998; Mallye et al., 2012), but experimentation in this direction is almost nonexistent (but see Mozota, 2012, 2013).

There are important issues regarding the collection of blanks that can be explored and possibly answered by experimentation. In particular, it is important to evaluate (i.e., confirm or deny) the possible intentional production of blanks from long bones and metapodials, which has been proposed for some Middle Palaeolithic sites (Mozota, 2009; Jéquier et al., 2014). It is also important to explore the possible existence of such production at other locations and in other time periods. The scope of experimentation needs not to be limited to answer whether an intentional production existed, but can also be used to better understand the degree of blank selection that may have occurred in different archaeological contexts. Experimentation can also help to answer the question of which criteria human groups used for selecting retoucher blanks. All these aspects can provide relevant information about the cognitive abilities and the socio-economic organization of human groups at different times and places.

PREPARATION OF BLANKS Another potentially important area of research on bone retouchers is the preparation of blanks. It has been proposed that certain assemblages of bone retouchers were prepared before use – scraping the active surface with a lithic instrument (Vincent, 1993; Armand and Delagnes, 1998). Certain experimental qualitative observations claim that scraping is necessary for using fresh bones, since the periosteum must be removed from the active areas to enable use as a retoucher (Vincent, 1993; Armand and Delagnes, 1998). In my experience, removing the periosteum is a simple and easy task, and it improves the performance of the retoucher, but is not necessary in all cases (Mozota, 2012). Moreover, in many cases much of the periosteum is removed during the actual fracturing of the bone and is not necessary to scrape the blank afterwards (with a lithic tool or otherwise). Therefore, this issue is an ideal topic to be re-evaluated by an experimental programme using quantified variables. For this work, I believe that experimentation should include a blank collection phase with a special interest toward anatomical parts, taxonomic origin and processing of animal carcasses.

There is another issue concerning the possible preparation of the blanks that has barely been explored, either through experimentation or mere observation of archaeological materials: the possible cursory preparations of blanks to facilitate gripping. These preparations could be represented by at least two types: abrasions of the sharpest edges of the blanks (particularly with green bone), which experimentally can sometimes make the retoucher uncomfortable to hold; and preparation of the gripping area of the retoucher by cursory percussion fracture.

USING BONE RETOUCHERS WITH DIFFERENT LITHIC RAW MATERIALS Most experimental programmes about bone retouchers have studied traces left on bone surfaces when working flint implements. Only a few studies have focused on comparing the traces produced by retouching different lithic raw materials (Rosell et al., 2011; Mallye et al., 2012; Mozota, 2013). Such comparative studies have been devoted to distinguishing the traces produced when retouching quartzite blanks from those produced by flint.

There are at least two aspects of this issue of lithic raw materials in which we can significantly expand our current knowledge. The first of these aspects refers to the discrimination of flint and quartzite. I recommend the unification of criteria used by researchers who have addressed this issue, as most of these criteria likely correspond to the same mechanical phenomena and use traces, even if they received different names in each case. In addition, these works only address a single type of flint and a single type of quartzite. For the moment, no study has evaluated the influence of variable properties of the same raw material in the traces of use. For example, it has not been considered how composition or grain size of different types of quartzite or flint can influence the formation of use traces on bone retouchers. Another aspect open to new research is the retouching of quartz, obsidian, silcrete and other raw materials.

LATERALIZATION AND HANDEDNESS The human brain is highly lateralized and this motivates the predominant use of one hand over the other when performing most technical tasks, including retouch. The right hand is typically dominant, even though left-handedness has constituted a low percentage of the population along our evolutionary history (Uomini and Gowlett, 2013). The use of bone retouchers with one specific hand has been documented in different experimental programmes (Rigaud, 1977; Malerba and Giacobini, 2002; Mozota, 2009, 2012). Still, the criteria for identifying this lateralization of retouching tasks are not unified, nor has the subject been deeply explored, especially from an evolutionary and demographic perspective.

Concluding remarks

The review conducted in this work has summarized the historical development of experimental studies on retouchers, in the most general terms. This history can be described as a relatively simple process: researchers accumulated knowledge through their archaeological praxis. This process came together with a progressive development of techniques and methodologies and accelerated with moments of theoretical and methodological innovation. All of these advances allowed for the transition from a qualitative archaeology to alternative approaches that offered more quantitative and verifiable results. Yet, it would be a mistake to think that the most recent works, which provide more information and have a greater explanatory capability, represent more meritorious efforts by recent researchers. As in all fields of science, the most recent works build upon the cascading efforts of previous researchers. Without the first identifications of retouchers in the early years of the 20th century, it would have been impossible to make the first qualitative experiments on retouching lithics with bone; without those studies, it would not have been possible to identify the dozens of assemblages of retouchers that were published since the 1960s; and without that critical mass, researchers of the early 21st century would not have been able to develop their studies to include statistical calculations, which provide greater scientific rigour.

This work has also made it clear that the research potential of retouchers, specifically experimental analysis of retouchers, is promising. There are significant contributions to be made in this area, particularly in support of, or opposition to, recent explanatory models about Palaeolithic human groups. Thus, I want to personally encourage all researchers to address these and other issues in the years to come.

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WHEN DISCARDED BONES BECAME IMPORTANT: NEW BONE RETOUCHERS FROM THE LOWER SEQUENCE OF QESEM CAVE, ISRAEL (*CA.* 300-420 KA)

Abstract

Pleistocene archaeological sites contain a high diversity of bone fragments resulting from activities related to anthropogenic processing of animal carcasses and other biostratinomic and fossil diagenetic phenomena. Specifically, intentional bone breakage to access marrow generates a high number of small- and large-sized bone fragments, which are eventually discarded. Yet, some of these bones are morphologically suitable for human use and are introduced into the lithic tool manufacturing processes. Here, we present some new early cases of bone retouchers from the Middle Pleistocene site of Qesem Cave, Israel. This site shows a long stratigraphic sequence of over 11 m of sediments, dated between 420 and 200 ka by U-series, TL and ESR, all assigned to the late Lower Palaeolithic Acheulo-Yabrudian Cultural Complex (AYCC). Among the many technological and socio-economic innovations of this post-Acheulian/pre-Mousterian entity is the use of bone retouchers. In previous studies we reported nine bone retouchers from the hearth area at the top part of the lower sequence of Qesem Cave (dated to ca. ~300 ka). Here, we present 15 new items from a deeper sedimentary deposit located under the rock shelf (> 300 ka, closer to 400 ka). These objects are fragments of long bone shafts with a slight pattern of selection towards specific ungulate size categories. Nine retouchers belong to small ungulates, four to medium-sized animals, and two to large ungulates. We suggest that some of these implements may have played a role in the shaping and/or re-sharpening of Quina and demi-Quina scrapers, as well as in the shaping of other tools. Bone retouchers became a significant part of knapping toolkits in the subsequent cultural complexes and served a specific role within lithic reduction sequences.

Keywords

Middle Pleistocene; Levant; Bone retouchers; Acheulo-Yabrudian Cultural Complex (AYCC); Qesem Cave

Introduction

Bones used for shaping stone tools are prevalent in late Lower Palaeolithic Europe and in the Levant as early as MIS 13 (Roberts and Parfitt, 1999; Smith, 2013; Stout et al., 2014). These bone tools vary in typology (retouchers, compressors, hammers) and function, and it has become clear that using discarded bone for shaping stone tools is rooted deep in humanity's prehistory as a tool maker and hunter.

The need to incorporate this group of bone tools within studies of Palaeolithic lithic technology and subsistence economy has advanced rapidly among Palaeolithic archaeologists, while the need to provide a cultural context and consider the significance of this phenomenon clearly demands more thought and discussion. This paper details an assemblage of bone retouchers from the Middle Pleistocene Qesem Cave, Israel, and attempts to view these tools used for shaping stone tools in their wider cultural context. We will first present the Qesem Cave archaeological context, and then present the bone retouchers, and finally make suggestions on the context and role of bone retouchers at Qesem Cave that may be relevant to other sites in the region with bone retouchers, including future discoveries, and hopefully to an even wider scale.

As an introduction to the topic, we stress that we are not exploring the old Palaeolithic tradition of using bone as raw material for making tools, mainly handaxe-like tools shaped on bones of large animals. Such tools appear in Acheulian sites both in Europe (e.g., Castel di Guido; Boschian and Saccà, 2014) and in the Levant (e.g., Revadim Quarry; Rabinovich et al., 2012). This tradition of modifying and shaping tools on bone predates the use of discarded bone fragments as retouchers; both are part of a long history of non-dietary uses of bones by hominins, representing primordial undercurrents of the complex bone-stone relationship (see Zutovski and Barkai, 2016).

Qesem Cave in context

Qesem Cave is a large karstic chamber cave located 12 km east of Tel Aviv (**Figure 1**) in a presently Mediterranean climatic zone, with 500-600 mm of annual rain, very similar to the environment reconstructed for the area during the late Lower Palaeolithic based on microfauna, fauna, sediments and stable isotopes (e.g., Gopher et al., 2010; Stiner et al., 2011; Smith et al., 2013; Maul et al., 2016). The sedimentary sequence is dated by Uranium-series, TL and ESR, with over one hundred dates spanning MIS 11 to MIS 7, between 420 and 200 ka (Barkai et al., 2003; Gopher et al., 2010; Mercier et al., 2013; Falguères et al., 2016), and with good accordance between the different methods.

Qesem Cave is a Middle Pleistocene site assigned to the Acheulo-Yabrudian Cultural Complex (AYCC) of the late Lower Paleolithic, postdating the Acheulian but predating the Mousterian in the Levant. Qesem is a well-preserved cave rich in lithics (e.g., Assaf et al., 2015; Parush et al., 2015) and faunal remains (e.g., Stiner et al., 2009, 2011; Blasco et al., 2014), and it also yielded human dental remains (Hershkovitz et al., 2011, 2016). The ongoing field and laboratory work at the cave has provided a major source of information on the AYCC. The AYCC has matured in recent years into a surprisingly dynamic, innovative local entity, quite distinctly divorced from the preceding Lower Palaeolithic Acheulian. We have suggested that the AYCC, as a whole, and Qesem Cave in particular, displays a unique cultural transformation from the Acheulian, possibly related to local hominin evolutionary processes and the appearance of a new hominin lineage in the Levant (Ben-Dor et al. 2011; Barkai and Gopher 2013; Gopher and Barkai, 2016; and see discussion below).

The introduction of bone retouchers is a well established phenomenon from the very beginning of the Middle Pleistocene AYCC at Qesem Cave (somewhat before 400 ka); yet, it is but one of the many innovations of this post-Acheulian era. It is reasonable to examine the background and nature of these changes in the Levant that brought about, amongst other things, the emergence of bone retouchers as a distinctive cultural element. We believe that our intensive studies of these changes in hominin behaviour and adaptation at Qesem Cave in recent years provide a reasonable arena in which the new bone retouchers can be contextualized (Barkai and Gopher, 2013; Blasco et al., 2013; Rosell et al., 2015). Below, we briefly mention selected aspects from long list of innovations offered by the Qesem Cave data that may be relevant to the overall site context.

Most conspicuous is the habitual use of fire (Karkanas et al., 2007). A constructed central hearth

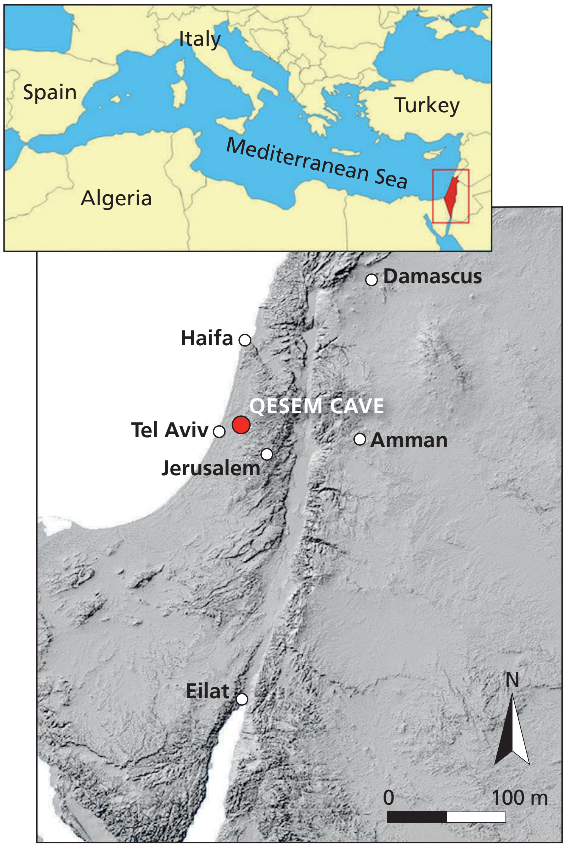
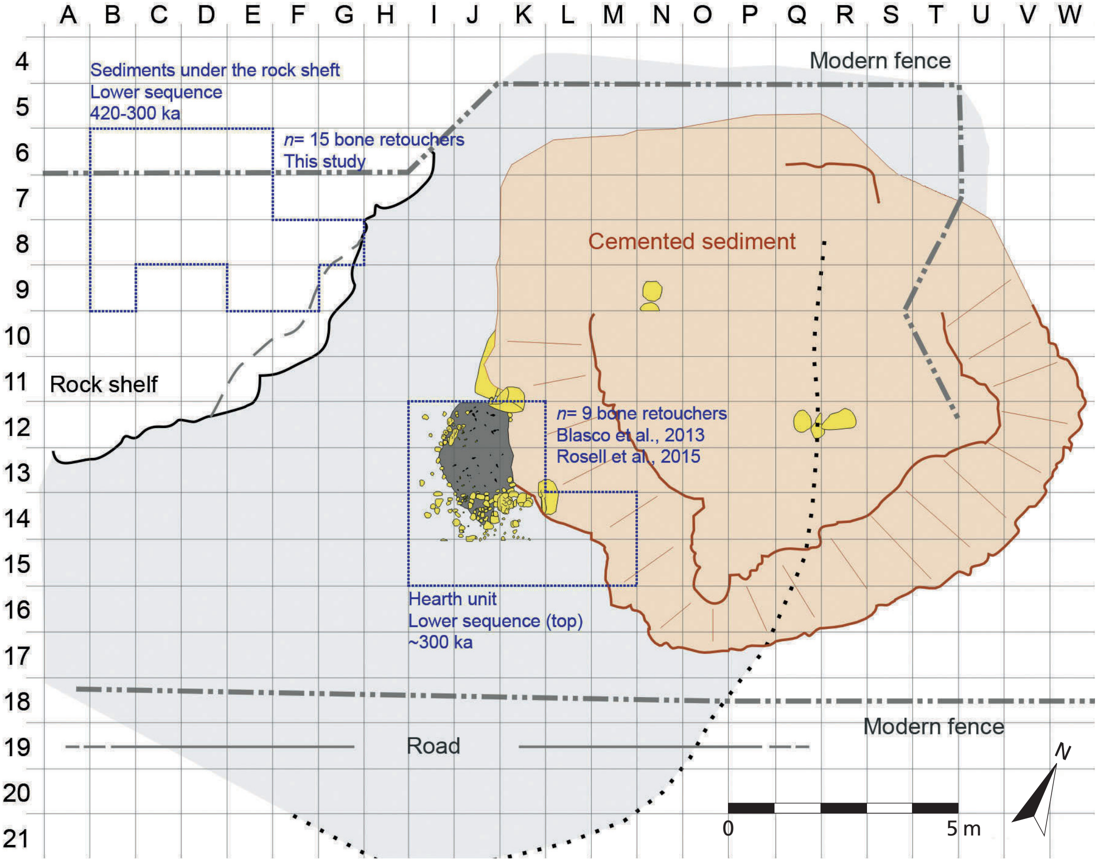


Figure 1 Location of Qesem Cave in the Levant and position of the studied faunal samples in relation to the grid system of the excavation.



dated to ca. 300 ka was exposed (Shahack-Gross et al., 2014) and hearth-centred activities were identified, showing functionally differentiated and distinct activity areas around it – one dominated by blade-cutting tools and one by Quina scrapers. A spatial distribution analysis of the faunal remains around this hearth indicates further spatial patterning, including a possible tossing zone (Blasco et al., 2016a).

Another aspect is the economy. The taxonomic profile at Qesem consists of Palearctic species only, with fallow deer (*Dama* cf. *mesopotamica*) as main species. This differs from earlier and later faunal assemblages of the southern Levant, which show more African influences. It is worth mentioning there are no elephants at Qesem Cave or any other AYCC site (see Ben Dor et al., 2011; Barkai and Gopher, 2013). We have indications of cooperative / social hunting targeted mainly at prime-aged fallow deer (Stiner et al., 2009; Blasco et al., 2014). On-site butchering involved a designated tool kit comprising blades and small, sharp flakes produced by means of lithic recycling (Lemorini et al. 2015, Parush et al. 2015), and Quina and demi-Quina scrapers. Unique patterns of cut marks on bones were interpreted as an indication of meat sharing habits, an important point concerning hunters-gatherer behaviour (Stiner et al., 2009, 2011).

Innovative lithic aspects include: 1) raw material acquisition from near-by and farther afield sources, including flint quarrying from deep underground sources as well as a high correlation between raw materials and tool types; 2) intensive and systematic blade production employing an efficient and straightforward technology, with naturally backed knives and a clear component of Upper Paleolithic-like tools, including end scrapers, burins and some Chatelperron-like points; 3) intensive flint recycling activities indicative of a few well established trajectories (Barkai et al., 2009; Barkai and Gopher, 2013; Assaf et al., 2015; Parush et al., 2015); 4) a noticeable, fully fledged presence of "ahead-of-their-time" Quina scrapers (ca. 420 ka), in addition to Quina debitage, Quina retouch and re-sharpening. We should mention the fact that Quina is not very well known in the Levant before or after the AYCC (Lemorini et al., 2016; Zupancich et al., 2016a).

As for human remains, 13 teeth have been found throughout the sequence to date, none of which show affinities to *Homo erectus* (Hershkovitz et al. 2011, 2016). Although they resemble to some extent the anatomically modern human Skhul-Qafzeh samples of the Middle Palaeolithic Levant, they bear Neanderthal traits, too. So, they may belong to an as yet unknown and new, local hominin lineage.

Material and methods

The faunal remains at Qesem Cave are studied according to the conventional standards published for zooarchaeology and taphonomy (Binford, 1978; Lyman, 1994; Stiner, 1994; Blasco et al., 2013; and references there in). Given the high degree of fragmentation, most of the remains have not been identified at the anatomical and taxonomic level. These specimens have been classified as long bones (appendicular skeleton), flat bones (cranial, axial skeleton) and articular bones (patellae, carpal, tarsal, sesamoid bones). To include these specimens with those identified to the genus/species level, we established five size categories related to the estimated body weight of taxa identified in the assemblage following Africanist methodologies (Bunn et al., 1988; Sahnouni et al., 2013; see details for Qesem in Blasco et al., 2014), as follows: size class 1, very small size including 1a and 1b (< 20 kg); size class 2, small size (20-120 kg); size class 3, medium size including 3a and 3b (120-300 kg); size class 4, large size (300-1000 kg); and, size classes 5 and 6, very large size (> 1000 kg). Quantification of skeletal parts is based on number of specimens (NSP) and number of identified specimens (NISP).

The damage observed on the bone surface has been treated both macroscopically and microscopically using a stereo light microscope (up to 120x magnification, oblique cold light source) and a KH-8700 3D Digital Microscope. The analysis was completed with an analytical FEI QUANTA 600 Environmental Scanning Electron Microscope (ESEM)

Figure 2 Examples of recycled blades and flakes (A-B) and scrapers (C) from the hearth unit and the lower sediments under the rock shelf from Qesem Cave.

operated in low vacuum mode (LV). In the case of bone retouchers, the identified damage has been described following the criteria and the terminology related to the orientation, type, distribution and morphology, established in previous works (Armand and Delagnes, 1998; Malerba and Giacobini, 1998; Patou-Mathis, 2002; Mozota, 2009; Mallye et al., 2012). This damage consists of pits, defined as depressions with triangular or ovoid forms on the bone surface, and striations, which refer to deep incisions with rectilinear, sinuous, concave or convex delineation. In the same way, the striation texture surface has been classified as smooth or rough. The distribution of the striations is noted in terms of isolated, dispersed, concentrated or superposed. In cases of concentrated and superposed distributions, we ascribe the term "use areas", the locations of which are described according to width axis (apical, central, covering and lateral).

Data presentation

The bone retouchers presented here come from two stratigraphically and spatially distinct assemblages. The first assemblage originates from an area characterized by a superimposed central hearth, dated to about 300 ka, and the zone around it (Shahack-Gross et al., 2014). The second assemblage originates from sediments under the rock shelf at the northern part of the cave (**Figure 1**). The bone retouchers from the hearth unit were already presented in previous works (Blasco et al., 2013; Rosell et al., 2015); however, the objectives of this paper, based on a comparison between the two assemblages, require the description of all items and their archaeological context.

Hearth Unit

The hearth unit is dated around 300 ka (Falguères et al., 2016) and it mainly occupies parts of the central and southern areas of the site, including the areas associated with the hearth (squares I-J-K-L/12-13-14-15, ~15m^2; Blasco et al., 2016a) (**Figure 1**). This combustion feature displays specific characteristics that point to a certain diachrony in its formation, as at least two major cycles of intensive fire use can be recognised (Shahack-Gross et al., 2014). This succession of cycles at the same location in the cave suggests that the hearth, as a central beacon in the interior landscape of the cave, has repeatedly played a role as a focus of hominin activities (Blasco et al., 2016a). The lithic assemblage of the hearth area consists of 18,837 items and shows the highest density of all the assemblages of the cave (6144 per m^3 for the hearth itself; see Gopher et al., 2016), indeed indicating intensive lithic production, use and discard in this area. The lithic industry of the hearth is attributed to the Amudian industry and shows a conspicuous presence of cutting implements, including blades, naturally backed knives and small

	Hearth unit		Lower sequence	
	NSP	NISP	NSP	NISP
Carnivora	1	1	1	1
Stephanorhinus hemitoechus	12	12	8	8
Equus ferus	103	103	21	21
Equus hydruntinus	18	18	-	-
Sus scrofa	38	38	18	18
Cervidae	28	28	2	2
Dama cf. *mesopotamica*	2370	2370	1655	1655
Cervus cf. *elaphus*	213	213	163	163
Bos primigenius	123	123	97	97
Capra aegagrus	1	1	7	7
cf. *Capreolus capreolus*	25	25	11	11
Hystrix	-	-	1	1
Testudo sp.	57	57	104	104
Cygnus sp.	-	-	1	1
Columba sp.	1	1	-	-
Corvus ruficollis	3	3	-	-
Large bird	2	2	-	-
Aves, indeterminate	-	-	2	2
Very large size	4	-	-	-
Large size	1988	-	1324	-
Medium size	6510	-	2776	-
Small size	24,484	-	14,436	-
Unidentified	1323	-	1646	-
Total	37,304	2995	22,273	2091

Table 1 Number of specimens (NSP) and number of identified specimens (NISP) from the hearth unit and the lower sequence under the rock shelf.

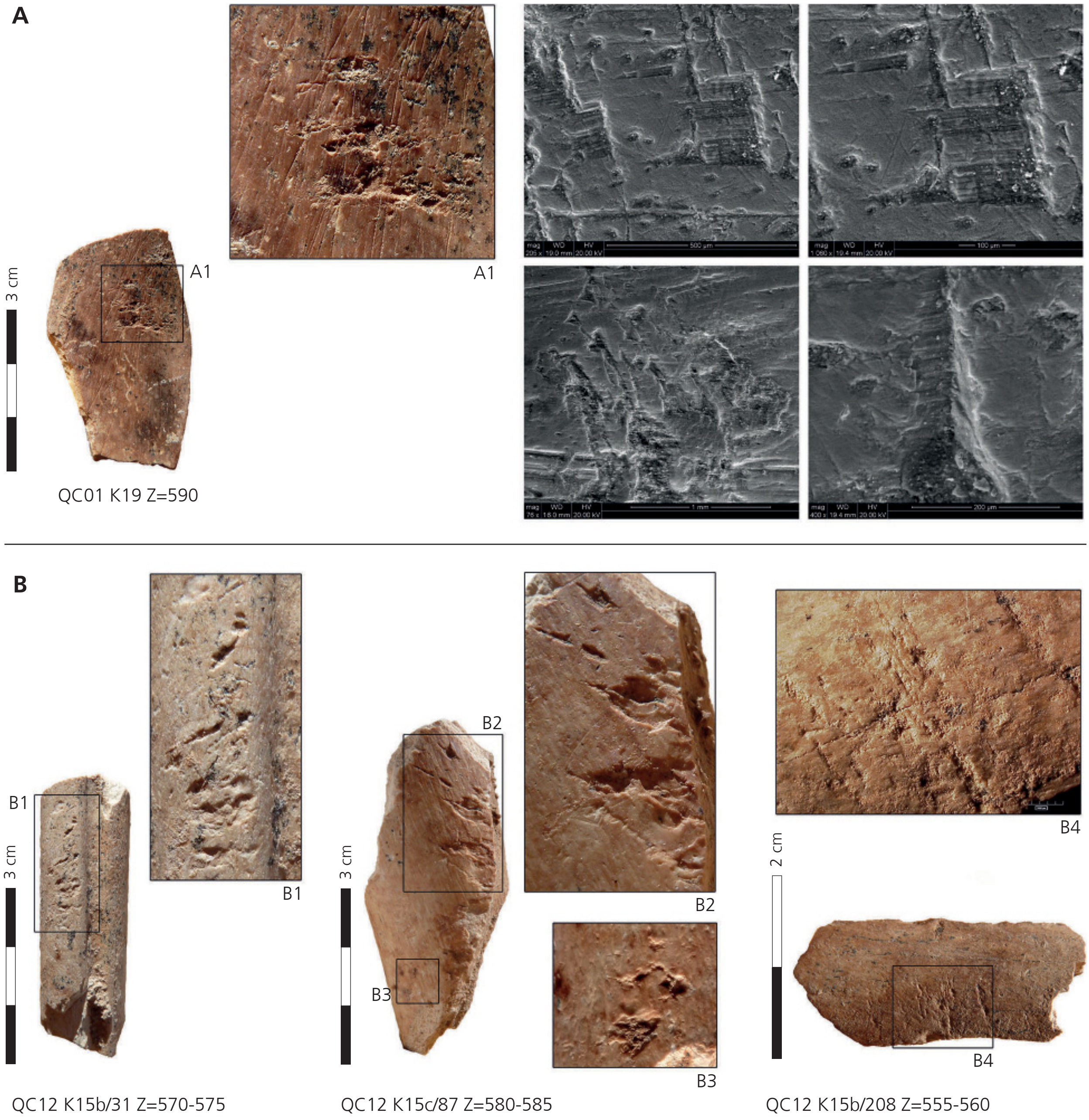


Figure 3 Examples of bone retouchers from the hearth unit (including the associated southern area) of Qesem Cave: (A) long bone shaft of a medium-sized ungulate and details of the percussion striations under ESEM (modified from Blasco et al., 2013); (B) (from left to right) fallow deer metatarsal, red deer humerus and long bone shaft of a medium-sized ungulate (B1-B3 modified from Rosell et al., 2015).

sharp items produced by means of lithic recycling (**Figure 2**), indicating a set of cutlery densely concentrated in the likely meat roasting area.

The number of faunal remains studied in this sector is 37,304 teeth and bone fragments (**Table 1**). The fauna shows a high degree of fragmentation, most apparent in the area directly associated with the overlapping combustion features. In this specific point, the bone fragments rarely exceed 2 cm in length, increasing slightly in the adjacent areas (Blasco et al., 2014). Generally speaking, the assemblage consists long bone diaphysis fragments of small-sized ungulates, mostly belonging to *Dama* cf. *mesopotamica*. Remains of other medium-sized un-

Table 2 Inventory and interpretative results for the bone retouchers at Qesem Cave.

ID Item	Skeletal element	Taxa	Length	Thickness	Use area			Damage					Reference
			(mm)	(mm)	No.	Location	Distribution	Pits	Striations / Scores	Areas	Freshness	Use intensity	
QC01 K19 Z=590	Long bone shaft	Medium size	43	6	1	Cent	Conc	Ov	Rect, Sin/Sm	Scal, Hat	Interm	M-Int	Blasco et al. 2013
QC06 I13d Z=590-595/376	Long bone shaft	Medium size	31	6	1	Cent+Apic	Disp	Ov	Rect, Sin/Sm, Ro	-	F- Interm	L	Rosell et al., 2015
QC08 J12a Z=560-565/1	Long bone shaft	Large size	58	8	1	Cent	Conc	-	Rect/Sm	-	F- Interm	Sl	Rosell et al., 2015
QC08 J12a Z=555-560/5	Long bone shaft	Large size	26	8	1	Cent+Apic	Disp	Ov	Rect /Sm, Ro	-	F- Interm	Sl	Rosell et al., 2015
QC12 K15c Z=580-585/87	Humerus	*Cervus* cf. *elaphus*	52	7	2	Lat/Cent	Conc/Conc	Tr	Rect, Sin/Sm	Scal	Interm	M-Int	Rosell et al., 2015
QC12 J15b Z=585-590/113	Tibia	Medium size	32	6	1	Cent	Disp	Ov	Rect/Sm	-	F-Interm	Sl-L	Rosell et al., 2015
QC12 K15a Z=555-560/196	Long bone shaft	Small size	26	4	1	Lat	Disp	Tr	Rect/Sm, Ro	-	Interm	Sl	Rosell et al., 2015
QC12 K15b Z=555-560/208	Long bone shaft	Medium size	33	6	1	Lat	Conc	Tr	Rect/Sm	Hat	F	L-M	Rosell et al., 2015
QC12 K15b Z=570-575/31	Metatarsus	*Dama* cf. *mesopotamica*	48	5	1	Cent	Disp	Ov	Rect/Sm	Pit	Interm	L	Rosell et al., 2015
QC13 F9c Z=725-730/25	Metacarpus	*Dama* cf. *mesopotamica*	54	6	1	Api	Conc	Ov	-	Scal	Interm	M	This study
QC13 F9b+d Z=660-665/16	Long bone	Medium size	37	7	1	Lat+Cent	Disp	-	Rect/Sm	-	F	L	This study
QC13 F09b+d Z=665-670/33	Long bone	Medium size	35	6	1	Api+Cent	Conc	Ov	Rect/Ro	Hat	Dry	M	This study
QC13 E8b Z=890-985/2	Long bone	Large size	43	9	1	Lat	Conc	Ov	Rect/Sm	Pit	Interm	Int	This study
QC13 E8b Z=875-880/10	Metacarpus	*Cervus cf. elaphus*	62	8	2	Api/Api	Conc/Isol	-	Rect/Sm	Pit/-	Dry	M-L	This study
QC13 E8b Z=835-840/10	Metacarpus	*Dama* cf. *mesopotamica*	39	7	1	Cov	Disp	Ov/Tr	Rect,Cvx/Sm	-	F-Interm	M	This study
QC13 E8b Z=945-950/4	Long bone	Small size	33	4	1	Lat+Cent	Dist	-	Rect/Sm	-	F	L	This study
QC13 E8b Z=915-920/5	Tibia	*Dama* cf. *mesopotamica*	52	5	1	Cent	Isol	-	Rect/Sm	-	F	L	This study
QC13 E8d Z=845-850/1	Humerus	*Dama* cf. *mesopotamica*	48	6	2	Api/Lat	Isol	-	Rect/Ro	-/Scal	Interm	L	This study
QC13 E8d Z=835-840/3	Long bone	Large size	43	8	1	Apic	Conc	-	Sin/Sm	-	F	L-Int	This study
QC13 D6b+d Z=900-940/481	Femur	*Cervus* cf. *elaphus*	73	6	1	Cent	Conc	Ov	Rect/Ro	Scal	F	L-Sl	This study
QC13 D6b+d Z=900-940/492	Long bone	Small size	38	4	1	Apic	Conc	-	Sin/Sm	Scal	F-Interm	M	This study
QC13 B8b Z=940-945/1	Long bone	Small size	21	4	1	Apic+Lat	Isol	Ov	Rect+Sin/Ro	-	Dry	L	This study
QC13 D7c Z=1040-1045/2	Long bone	Small size	40	5	2	Lat/Lat+Api	Conc/Disp	Ov/-	-/Rect/Ro	Pit/Scal	Interm	M-Int	This study
QC13 D7b+d Z=990-995/17	Long bone	Small size	30	5	1	Lat	Disp	-	Rect/Sm	-	Fr	L	This study

Cent= Central; Apical=Apic; Lat= Lat; Cov= Covering; Conc=Concentrated; Disp=Dispersed; Iso=Isolated; Tr=Triangular; Ov=Ovoid; Rect=Rectilinear; Sin=Sinuous; Ccv=Concave; Cvx=Convexa; Sm=Smooth; Ro=Rough; Hat=Hatched area; Scal=Scaled area; Pit=Pitted area; F=Fresh; Interm=Intermediate freshness; L=Low-used; M=Medium-used; Sl=Slightly used; Int= Intensively used.

gulates have also been recognised, such as red deer (*Cervus* cf. *elaphus*) and other large-sized ungulates, including horses (*Equus ferus*), rhinos (*Stephanorhinus hemitoechus*) and aurochs (*Bos primigenius*). The presence of flat bones and/or bone fragments belonging to the axial and cranial skeleton of these ungulates is proportionally very low. Bones belonging to other very small-sized animals have also been documented, such as tortoises (*Testudo* sp.) and some birds (Blasco et al., 2014, 2016b; Sánchez Marco et al., 2016).

Cut marks, as well as intentional anthropogenic fractures and burning alterations, are abundant throughout the assemblage. This indicates a clear association of ungulates and very small-sized animals (e.g., tortoises) with subsistence activities of the human groups (Stiner et al., 2009, 2011; Blasco et al., 2014, 2016a, 2016b). On the other hand, carnivore-induced damage is virtually nonexistent, indicating few visits of these animals to the cave, if at all.

The studied assemblage from the hearth unit yielded nine bone retouchers, constituting 0.02% of the assemblage (**Figure 3; Table 2**): two limb bone shafts of large-sized animals, four limb bone shafts of medium sizes, one red deer humerus, one fallow deer tibia and one limb bone shaft of a small-sized animal. All these items are broken; up to now no complete bones were used as bone retouchers at Qesem. Their lengths range from 58 mm, for a diaphysis fragment of a large-sized animal, to 31 mm, for a diaphysis fragment of a small-sized animal. The modifications observed are mainly pits, mostly ovoid morphology and in two cases triangular, striations and grooves. The striations and the grooves are rectilinear in nearly all cases. Slightly sinuous striations are present in two diaphyses of medium-sized animals and one deer humerus. Rough incisions are observed only in the case of one large-sized diaphysis and one medium-sized diaphysis. In all cases, it is possible to define a single use area, characterised by hatched areas in two medium-sized diaphyses and scaled areas in two medium-sized diaphyses. Almost all use areas are located in the centre of the fragments. Only in one medium and one small-sized diaphysis do we see use areas in a lateral position; one large and one medium-sized diaphysis have use areas located in the apical position. Only in the case of the deer humerus can we mention two use areas, one located in the centre of the diaphyseal fragment and another more to the side. In any case, they are discrete use areas, formed by a relatively low number of percussion marks, indicating a slight to moderate use of these blanks.

The absence of chips and significant loss of cortical tissue suggests that the bone blanks were mostly used fresh or in an intermediate stage of freshness. This could be related to the scraping-marks observed in the use areas of three items, likely associated with removing the periosteum.

Sediments from the Lower Sequence under the Rock Shelf

The second assemblage comes from a new chamber discovered under the rock shelf in the northern part of the cave (**Figure 1**). According to Gopher et al. (2010), Mercier et al. (2013) and Falguères et al. (2016), all the sediments of the stratigraphic sequence under the rock shelf are older than 300 ka. The sedimentary sequence under the shelf is composed of at least six metres of sediments, as bedrock has not been reached yet. The uppermost levels of the sequence under the shelf contain a Yabrudian lithic assemblage; the sediments directly underneath that are characterized by an Amudian lithic assemblage (see Parush et al. 2016; **Figure 2**). Most of the new bone retouchers presented here originate from a deep sounding under the rock shelf, some three to four metres below the abovementioned Amudian layer. Three retouchers originate from the middle part of the sedimentary sequence under the rock shelf and one was found two metres below the upper Amudian level. All in all, the bone retouchers presented here originate from the deepest and medial sectors of the sedimentary column below the shelf and are older than 300 ka, most probably closer to 400 ka for the deepest sample. The lithic assemblages from these contexts are currently under study and seem to belong to an Amudian industry.

Figure 4 Examples of bone retouchers from the lower sequence of Qesem Cave located under the rock shelf: (A) red deer femur; (B) long bone shaft of small-sized ungulate; (C) fallow deer metacarpal; (D) long bone shaft of small-sized ungulate; (E) fallow deer metacarpal; (F) long bone shaft of large-sized ungulate.

So far, a total of 22,273 faunal remains have been studied from this sector (**Table 1**). The faunal composition does not differ to any significant extent from the fauna in the central hearth unit. The fragments of small-sized ungulates, including *Dama* cf. *mesopotamic*a, remain the most abundant, followed by medium and large-sized ungulates, particularly deer (*Cervus elaphus*), aurochs (*Bos primigenius*) and horses (*Equus ferus*). Very large-sized ungulates, such as rhino (*Stephanorhinus hemitoechus*), have also been recovered, although they are present in significantly lower numbers than other ungulates. As in the hearth unit, tortoise (*Testudo* sp.) and bird remains have also been recovered. Following the general dynamics of the stratigraphic sequence of Qesem, the unit under the rock shelf is dominated by limb bone fragments, mostly under 30 mm in length.

From a taphonomic point of view, the assemblage does not differ greatly from the hearth unit. Cut marks remain relatively abundant (NSP = 368), as do the signs of intentional fracturing (NSP = 280). Although no combustion structures have been recognised, the number of bones with signs of thermal alteration is still abundant (NSP = 6,644), indicating that the use of fire is already included in the behavioural pattern of the hominids that inhabited Qesem Cave from its oldest formation phase. Carnivore modifications are again very scarce.

The total number of bone retouchers identified so far is 15 (**Figure 4; Table 2**), amounting to 0.07% of the assemblage, which is only slightly higher than in the hearth unit. Regarding the bone blanks selected, we observe greater diversity than in the hearth area. In this particular case, there seems to be no preference for animals according to body size. Percussion marks have been observed on two limb bone shafts of large-sized animals, two limb bone shafts of medium-sized animals, one shaft of red deer femur, one mid-shaft of red deer metacarpal, five limb bone shafts of small-sized animals, two mid-shaft fragments of fallow deer metacarpal, one shaft fragment of fallow deer humerus and one shaft fragment of fallow deer tibia. The longest blank measures 73 mm, represented by a fragment of a deer femur, and the shortest is 21 mm, a long bone diaphysis fragment of a small-sized animal. However, most are within a range of 35-45 mm. As in the hearth unit, the smooth-textured percussion striations are the most abundant modification, although some pits of ovoid morphology are also seen, as well as one case of triangular pit morphology. Rough incisions also appear in five cases. In general, most striations are rectilinear, although one large and one small-sized diaphysis show smooth sinuous striations, and one fallow deer metacarpal fragment exhibits smooth, convex striations. In seven of the retouchers, the striations are concentrated in well-defined use areas. However, there are five bone blanks where the striations are scattered over the entire surface and three with single, isolated striations. There is no clear trend in the position of these striations, or in the use areas, on the bone surface. In seven cases the striations or use areas trend towards the lateral position, while six show damage in the apical position. Two cases have modifications located in the centre of the fragment. Only one of the bone blanks, a red deer metacarpal, bears two well-defined use areas, which are situated toward both apical ends of the fragment.

The low intensity with which these objects appear to have been used means that there are very few overlapping marks. Only one long bone diaphysis shows a hatched area. One large-sized diaphysis, one red deer metacarpal bone and one small-sized diaphysis each show pitted areas. Scaled areas are shown on one red deer femur, one fallow deer humerus and one small-sized diaphysis.

As in the hearth unit assemblage, most blanks appear to have been used in a fresh or semi-fresh state. However, one red deer metacarpal bone, one medium-sized diaphysis and one small-sized diaphysis include some striations associated with chipped, or exfoliated, surfaces as a result of rapid drying of the bone from subaerial exposure or fire. As a result, these blanks appear to have been used in a dry state, indicating a lack of preference in selection regarding the freshness of the bone blanks.

Discussion

We open the discussion with a general statement about a bio-energetic model Ben Dor et al. (2011) proposed for the demise of *Homo erectus* and the appearance of a new hominin lineage some 400,000 years ago in the Levant. Explaining this model is especially useful here since the proposed biological replacement took place in tandem with significant innovative cultural changes, among which we find the bone retouchers. This bio-energetic model suggests that the disappearance of elephants from the human diet in the Levant around this time triggered a selection process in favour of those who were better adapted to the hunting of larger numbers of

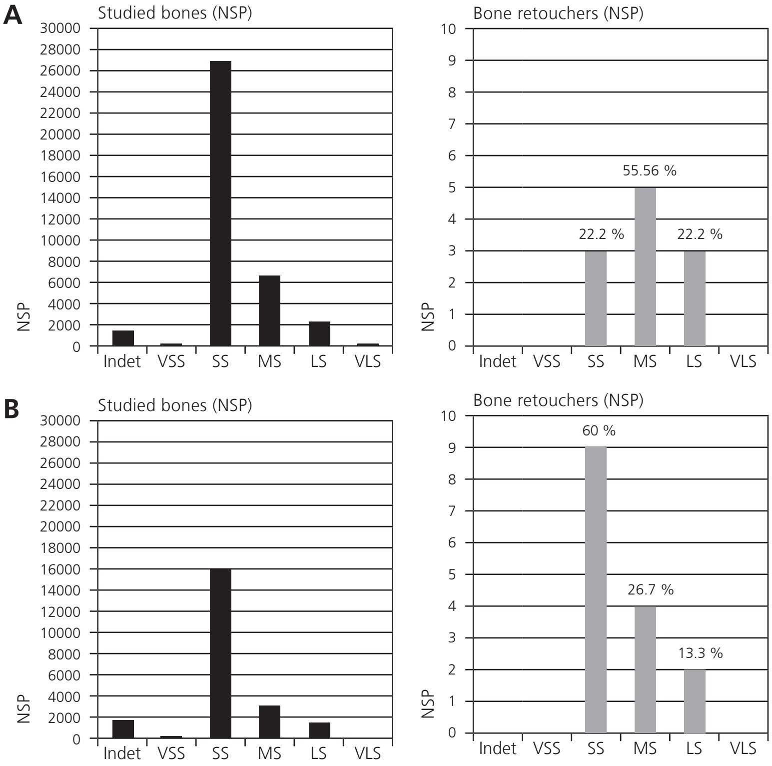


Figure 5 Number of specimens (NSP) and bone retouchers from Qesem Cave grouped into body-size classes: (A) specimens from the hearth area (and associated southern area); (B) specimens from the lower sequence located under the rock shelf.
VSS: very small size or size class 1, including 1a and 1b (< 20 kg); SS: small size or size class 2 (~20-120 kg); MS: medium size or size class 3, including 3a and 3b (~120-300 kg); LS: large size or size class 4 (~300-1000 kg); VLS: very large size or size classes 5 and 6 (> 1000 kg); Indet: indeterminate (following Bunn et al., 1988).

smaller, faster animals. The absence of elephants at Qesem Cave and the dominance of fallow deer, conjoined with the plethora of recorded cultural change at Qesem Cave, are the basic ingredients of the model. We emphasize the cultural and behavioural aspects since many of them shows a clear departure from the preceding Acheulian (e.g., Barkai and Gopher 2013; Gopher and Barkai, 2016) – a complete change in lifeways compared to the Acheulian Cultural Complex. So, something specific and special has happened in the Levant some 400 ka, post-Acheulian and pre-Mousterian. The finds of Qesem Cave show, on the one hand, a suite of "ahead-of-their-time" transformative innovations in human behaviour and culture, and, on the other hand, the possible appearance of a new lineage of hominins (Barkai and Gopher, 2013). It is in this innovative cultural landscape that bone retouchers are contextualized.

From a technological point of view, the AYCC consists of innovative industries. Among the most significant is the systematic production and retouching of over a thousand Quina and demi-Quina scrapers. The elements related to retouching in AYCC assemblages seem to be relevant; therefore, bone retouchers should be studied in detail. From this point of view, the presence of bone retouchers in the hearth unit and under the rock shelf suggests that these items represented a common technological solution for the human groups who occupied Qesem Cave. It should be stressed, however, that only faunal remains related to Amudian assemblages are presented here. These assemblages include Quina and demi-Quina scrapers, though in lesser proportions compared to Yabrudian assemblages (e.g., Parush et al., 2016). We have just started to study faunal assemblages originating from Yabrudian layers, and it would be interesting to quantify the ratio of scrapers to bone retouchers in these assemblages and compare the results to the data presented here. Our first impression is that there are quite a number of bone retouchers in the Yabrudian too.

Broadly speaking, the two Amudian units studied do not show significant differences. Both assemblages maintain similar technology and the composition of the faunal record is similar. Perhaps the most important difference is the presence of a preserved fireplace in the hearth unit as the central element of the activities (Blasco et al., 2016a), but this does not mean that in the lower unit (unit under the rock shelf) hearth related activities were less significant. The large number of bones with signs of thermal alteration precisely indicates the existence of similar behaviour regarding fire as in the upper sedimentary units.

Although some bone retouchers from Qesem show use areas that could be linked to intensive use, most of these items show isolated and scattered marks, forming discrete areas that could be related to low use intensity. These characteristics may be connected to immediate activities, in which bone blanks are selected for very specific tasks, re-sharpening an edge, for example, and then discarded again among the rest of the waste. The bone blanks seem to be selected following a preference for medium-sized animals, taking into account the ratio between body size categories and bone retouchers recovered in both units (**Figure 5**). Selection is also observed regarding length of the blanks. In both areas, the dominant bone fragments do not exceed 3 cm in length, but the bone blanks used are all between 3 cm and 7 cm (**Figure 6**). Therefore, there appears to be a preference for larger/longer bone elements, perhaps depending on the physical characteristics of the knapped items or other specific needs. A selection of blanks by bone characteristics, such as length and/or thickness, has also been suggested in some European sites of later periods, including Payre (MIS 9-5) (Daujeard et al., 2014) and Noisetier (MIS 3) (Mallye et al., 2012) in France. Other localities, however, do not show the same preferences, such as the case of Biache-Saint-Vaast (MIS 7) (Auguste, 2002), Artenac (MIS 6) (Armand and Delagnes, 1998), and Chez-Pinaud/Jonzac (MIS 3) (Beauval, 2004, Jaubert et al., 2008), all in France.

Bone retouchers being used as soft hammers (of sorts) have practical purposes, and possibly structural advantages. Suffice is to say that for the AYCC in the Levant, we may relate the possible use of soft retouchers to a quite restricted range of flint tools. We find the bone retouchers at Qesem to be insufficiently large and heavy for shaping handaxes, which we note are rare at Qesem Cave (Barkai and Gopher, 2009). Thus, we suggest that these bone tools may be related mainly to shaping tools, such as blades and flakes, as well as Quina and demi-Quina scrapers. Quina scrapers exhibit a very special and unique shaping technology, characterized by a scalar retouch on their working edges. These scrapers are at present the topic of large-scale, detailed use wear and residue analyses, accompanied by an intensive experimental programme. Preliminary results indicate three major functions: hide working, bone working and butchering (Lemorini et al., 2016;

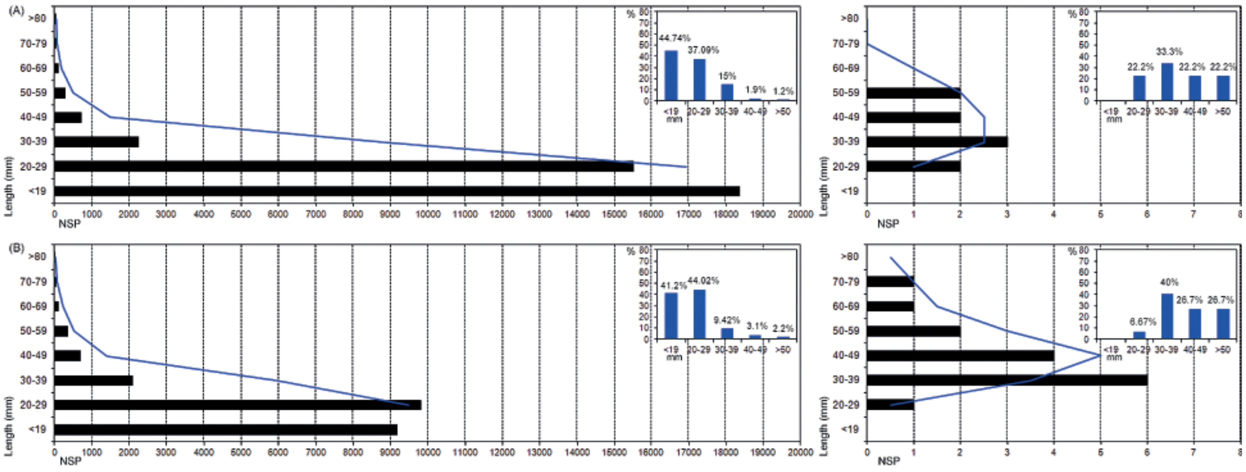
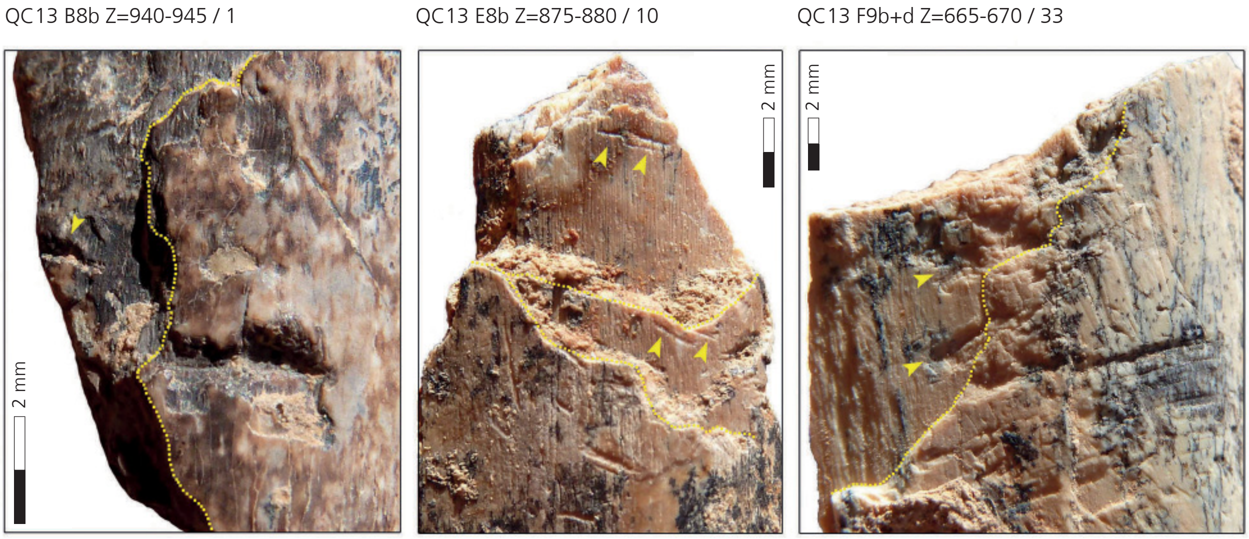


Figure 6 Lengths of all bone specimens (left) and bone retouchers (right), grouped in 10 mm intervals (excepting for the first and last range): (A) specimens from the hearth area (and surrounding area); (B) specimens from the lower sequence of Qesem Cave located under the rock shelf.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QC13 F9b+d Z=665-670 / 33

Figure 7 Bone retouchers probably used in a dry or semi-dry state from the area under the rock shelf. Note that percussion striations and chips are located on previous detachment of bone plaques, likely as a result of the bone's lack of natural elasticity when used.

Zupancich et al., 2016a, 2016b). These results encourage us to see the innovative Quina scrapers at Qesem Cave and other sites as part of a new behaviour in the AYCC where bone retouchers appear for the first time and in large quantities. Quina scrapers, together with blades and small cutting tools made of recycled items, may have been part of a local strategy aimed at processing the carcasses of medium-sized game (see Claud et al. 2012 for a case in France) – a particular combination of technologies that reflects a specific adaptation with no known counterparts in Africa or Europe at present.

It should be borne in mind that both Quina scrapers and bone retouchers, to the best of our knowledge, appear in the Levant no later than the AYCC and cease to appear within the Middle Palaeolithic Mousterian. However, the quantity of bone retouchers is exceptionally low to account for the number of shaped tools and Quina or demi-Quina type scrapers found at the site. The hearth unit contained a total of 462 tools, while 1412 tools have been documented in the portion of the lower sequence under the rock shelf analysed thus far (B-C-D-E/6-7-8 and B/9, Z=700-1050). There is still a great deal of material to be analysed and it will be critical to study the faunal remains from scraper-rich Yabrudian contexts. This is currently under way and additional bone retouchers have been found. More significantly, the number of marks on the use areas is too low for what is required to transform a flake into a Quina or demi-Quina scraper with the characteristic multi-staged, overlapping retouches, assuming that each mark corresponds to one contact between retoucher and the flint item being retouched. In this sense, most bone retouchers from Qesem are substantially different from those recovered in later sites and perhaps more associated with the entire process of scraper shaping. At La Quina, in France, the bone retouchers show a large number of overlapping percussion marks that are mostly pitted areas configured into large use areas, which sometimes preserve use areas at both apical ends of limb bone blanks (Verna and d'Errico, 2011). From this perspective, it is conceivable that most of the Qesem retouchers are more likely to be linked to short use episodes within the configuration of the retouched tools, like occasional re-sharpening or curving.

On the other hand, according to several experiments (Mozota, 2009; Rosell et al., 2011; Verna and d'Errico, 2011; Daujeard et al., 2014), bone retouchers are usually used fresh or in an intermediary state of freshness. In these cases, the most common features are deep to shallow marks, usually clustered in well-defined use areas. Most of the bone retouchers from Qesem show these characteristics, indicating a relatively short period of time between bone discard and re-selection for use as a retoucher. However, two bone blanks from the unit under the rock shelf and one from the hearth unit show different characteristics. These bone fragments show chips associated with a loss of cortical tissue, and percussion striations on previous detachment of bone plaques as a result of the bone's loss of natural elasticity (**Figure 7**). So, these bone blanks could have been used in dry state, suggesting an occasional indifference for the state of the bones.

All these elements allow us to place the Qesem bone retouchers within a framework of recycling. That is, they are previously discarded objects, which, after fulfilling their initial nutritional function are taken from the waste and given a different function from the original. This second life cycle plays an important part in the lithic industry *chaîne opératoire*. However, these objects require no more preparation than possible scraping of the periosteum to improve percussion. In this case, they differ from some of the objects recovered at level XVIIa of the Spanish site of Bolomor Cave (MIS 9), where one of the bone fragments used as a retoucher was shaped before use, presumably to make it more ergonomic (Blasco et al., 2013; Rosell et al., 2015).

From this perspective, Qesem Cave, and by extension the AYCC, represents a new stage in which the recycling of previously discarded objects appears to play an important role. Considering the age of this new approach (*ca*. 400 ka), Qesem could be considered one of the places where the previous Acheulian techno-complexes were supplanted for the first time during the second half of the Middle Pleistocene. Therefore, the use of bones to retouch lithic artefacts should be viewed in the same light as other sophisticated and diversified technologies, including laminar items, Quina and demi-Quina scrapers and backed knives, and the habitual use of fire as a central element of hominin occupations and recycling. This additional technological innovation appears to have different expressions in other world regions, but they all indicate the inclusion of bone in the lithic *chaîne opératoire*.

To date, the AYCC does not have any other large faunal assemblages similar to Qesem Cave; thus, no comparative studies validating the importance of these objects in the AYCC in the Levant can be made. However, other evidence is available in the European Middle Pleistocene that reinforces the idea of a diversified use of bone for purposes beyond nutrition. At the French site of Caune de l'Arago (MIS 12) teeth and jaws of large animals have been recovered with very long marks that have been interpreted as *billots*, or large bone fragments on the surface of which meat or other soft materials were cut (Moigne et al., 2016). There is also clear evidence for introducing bone and antler into the lithic *chaîne opératoire* during MIS 13 at the site of Boxgrove (UK). At this site, a collection of deer antlers with deep striations has been interpreted as a result of their use as hammers to make large tools, e.g., bifaces (Roberts, 1997; Roberts and Parfitt, 1999; Bello et al., 2013). Along with these hammers were found some bone retouchers for more delicate activities, some of which preserve small fragments of embedded flint (Smith, 2010, 2013). A single bone retoucher on a deer femur has been mentioned at the site of Terra Amata, France (MIS 11) (Moigne et al., 2016).

Although sporadic evidence of bone retouchers can be detected in the preceding Acheulian period (e.g., Boxgrove), this technological behaviour seems to have become widespread during the post-Acheulian contexts and especially after MIS 9 in Europe. Some relevant cases are Schöningen in Germany (Julien et al., 2015; van Kolfschoten et al., 2015), Orgnac 3 (Moncel et al., 2012), La Micoque (Langlois, 2004) and Cagny-l'Epinette (Lamotte and Tuffreau, 2001) in France, and Bolomor Cave and Gran Dolina in Spain (Rosell et al., 2011, 2015; Blasco et al., 2013; Rodríguez-Hidalgo et al., 2013). From this point of view, bone retouchers may be considered an element that was deeply assimilated during post-Acheulian times and widely adopted in subsequent periods and cultural complexes. This does not mean that soft retouchers were not used in previous periods, but rather that the spectrum of uses for recycled bone expanded significantly during

MIS 9 in western Europe, and previous to that in the AYCC of the Levant, to include bone retouchers aimed at rather delicate flint working.

Conclusions

Qesem Cave, and by extension the AYCC, shows a series of innovative technological behaviours, amongst which retouching acquired a growing importance. This may be part of an increasing diversity of human needs and newly introduced activities. At Qesem Cave we observe a broadening in the spectrum of activities, ranging from the most highly planned and complex, like the emergence of food sharing and social hunting (Stiner et al., 2009; 2011; Blasco et al., 2014), to what may be considered immediate and improvised, but equally successful. This duality of more immediate activities that do not require prior planning, like lithic recycling, and highly planned activities emphasizes the highly flexible and creative nature of these hominin groups in developing innovative solutions to novel tasks.

In this sense, some of the Qesem retouchers, and the immediacy with which they appear to have been used, fit with the improvised part of the activity spectrum. They are simple objects with little or no prior preparation and recycled from waste previously discarded by the same or previous hominin groups. Their use appears to have been short and limited to a few retouch motions, perhaps related to the curving and/or re-sharpening of lithic tools, including Quina scrapers. This sense of improvisation increases by the detection of the use of fresh, intermediate, and even dry bone blanks for these purposes.

Finally, this paper also delves into the role of these tools within the changing cultural landscape and the changing discourse between humanity and the world – culture and nature. Deciphering the relationships between hominins, animals, bone and stone may be significant to understanding Palaeolithic hunter-gatherers. In this context, bone retouchers are, in our view, a qualitative change, and their appearance is clearly not random or coincidental. These bones were used in what may basically be viewed as a recycling context: they were used to shape stone tools for use in meat processing or in hunting of animals whose bones were then used as bone retouchers to shape stone tools. This falls way beyond a partnership in shaping tools; it is rather an amalgamation of the two materials, of two basic existential dispositions. These tools then should not be looked at in isolation but rather as a component of a wide-ranging cultural transformation (e.g., Barkai and Gopher 2013; Gopher and Barkai, 2016).

We see this technology-related innovation as a two-faceted story. On the one hand, we are dealing with a new concept originating from interactions with the natural world, between hominins and animals. This involves a distancing of immediate and direct consumption, introducing another use for hunted animals – in a way, a deep concept of recycling. The second facet of bone retouchers is the union of bone, gained through hunting and food consumption, and stone technology, represented by tools for hunting. In our view, this in important integration of two primordial elements of Palaeolithic existence – a polarity yet to be studied in depth.

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ON THE USE OF METAPODIALS AS TOOLS AT SCHÖNINGEN 13II-4

Abstract

The Schöningen 13II-4 "Spear Horizon" provides an unparalleled view of Middle Pleistocene hominin technological and subsistence behaviours. The site preserves the remains of more than fifty butchered horses in addition to other large mammals, but the associated lithic assemblage is relatively small. As a complement to the lithic tools, Middle Pleistocene hominins at Schöningen used a variety of bone implements related to stone tool manufacture and maintenance. Here we describe a collection of metapodials from the Schöningen 13II-4 Spear Horizon interpreted as soft hammers. These bones bear consistent patterns of damage to the proximal and distal ends, indicating their repeated use in heavy percussive activities. We present the results of preliminary experimental studies aimed to better understand how and for what purposes these implements were used, and we conclude that the damage to the Schöningen metapodials is consistent with use in both stone working and bone breaking tasks. Based on the apparent lack of large stone cobbles in the lithic assemblage, the metapodial tools likely replaced hammerstones in the lithic *chaîne opératoire* and in processing bones for marrow. While it is clear that metacarpals and metatarsals were preferred over other bones for use as soft hammers, there is a relative lack of metapodials among the roughly 15,000 faunal remains in the entire assemblage. This pattern of skeletal part representation indicates that metapodials may have been transported away from the Schöningen 13II-4 site to be used at other locations across the landscape. Together with the well-known spears, these bone implements underscore the importance of non-lithic technologies for Middle Pleistocene hominins.

Keywords

Schöningen 13II-4; Middle Pleistocene; Non-lithic technology; Soft hammer; Metapodial

Introduction

The Schöningen 13II-4 "Spear Horizon" site rose to fame upon the discovery of multiple wooden spears preserved within a Middle Pleistocene-aged lakeshore deposit (Thieme, 1997). These 300,000-year-old weapons were recovered alongside a large accumulation of butchered animal remains, providing an unparalleled view of the hunting lifeways and butchery practices of Middle Pleistocene hominins.

Among the faunal remains, dozens of large mammal limb bone shaft fragments show traces of damage produced by retouching and re-sharpening lithic tools (Voormolen, 2008; van Kolfschoten et al., 2015b). Such "retouchers" are ubiquitous components of European Upper and Middle Palaeolithic tool-kits and have been recognised at a number of Lower Palaeolithic sites. Bone and antler retouchers from the 500,000-year-old site of Boxgrove, UK (Roberts and Parfitt, 1999) demonstrate the ancient origin of this technology, and further examples are known from several Lower Palaeolithic archaeological deposits in France, Spain, and the Levant (e.g., Blasco et al., 2013; Rosell et al., 2015; Moigne et al., 2016). Most of these early sites yielded only a few limb bone fragments with pits and scores typical of retouchers, whereas the Schöningen assemblage includes dozens of bone implements made on a variety of skeletal parts from several species (Voormolen, 2008; van Kolfschoten et al., 2015b). This flexibility in the selection of different bones as raw material displayed at Schöningen signifies an extraordinarily sophisticated approach to bone tool technology that is generally not granted to hominins of such antiquity.

A further distinctive component of the bone technology at Schöningen is a collection of horse metacarpals and metatarsals with a peculiar pattern of battering damage to the proximal and distal ends (**Figure 1**), a small sample of which have been previously described by Voormolen (2008) and van Kolfschoten et al. (2015b) who interpreted the damage as resulting from heavy-duty hammering activities. Curiously, these implements are unique to the Schöningen Pleistocene deposits; to our knowledge, similar bone tools made from horse metapodials have not been reported from the Lower Palaeolithic, or other Middle and Upper Palaeolithic sites, for that matter. Damage to the metapodials is markedly different from the pits and scores observed on "classic" bone retouchers (i.e., limb bone shaft fragments), suggesting their use in a different set of tasks. Classic bone retouchers have been the subjects of numerous experimental and functional analyses (e.g., Vincent, 1993; Mallye et al., 2012; Tartar, 2012; Mozota, 2013; Daujeard et al., 2014), but experimental inquiry into the use of metapodials as tools is merely anecdotal. Moreover, the hypothesis relating the observed damage on the Schöningen metapodials to heavy-duty hammering activities (van Kolfschoten et al., 2015b) has never been tested experimentally.

Here we describe the complete collection of metapodials with battering damage from the Schöningen 13II-4 "Spear Horizon" and detail a series of preliminary experiments aimed to test if these bones are suitable for heavy-duty hammering activities and to better understand what function(s) they may have served for Middle Pleistocene hominins. Taking into account the complete archaeological context of these tools, we explore the overall suite of technological behaviours associated with the widespread use of bone tools at Schöningen.

Site background

The Schöningen 13II-4 "Spear Horizon" site represents one in a series of Middle Pleistocene localities excavated in an expansive open-cast lignite mine near the town of Schöningen in Lower Saxony, Germany, roughly 100 km east of Hannover (**Figure 2**). Research over the past several decades have generated volumes of geological, environmental, palaeontological, and archaeological data to contextualise these remarkable finds (e.g., Thieme, 2007; Behre, 2012; Conard et al., 2015).

Geologically, the Schöningen 13II site complex is situated within a tunnel valley formed during the Elsterian glaciation and features a series of laterally and vertically stacked lacustrine/deltaic sediment deposits (Lang et al., 2012; Lang et al., 2015). The local stratigraphic profile includes five sedimentary cycles corresponding to lake level shallowing events; the fourth cycle includes the main find-bearing layers (4a, 4b, 4b/4c, 4c) known as the "Spear Horizon". Recent efforts to date the site provided a maximum age of 337-300 ka (Marine Isotope Stage 9) based on the thermoluminescence signal of heated flints from the nearby archaeological site of 13I-1,

Figure 1 Representative battering damage to distal articular surface of metacarpal (10037). Scale bar = 5 cm.

which lies stratigraphically below the 13II-4 "Spear Horizon" (Richter and Krbetschek 2015).

Pollen indicators reflect both terrestrial and aquatic interglacial vegetation, dominated by open grassland interspersed with stands of pine *(Pinus* sp.) and birch *(Betula* sp.) (Urban and Bigga, 2015). The faunal is typical of the prevailing interglacial conditions, dominated by horse *(Equus mosbachensis)* and fewer bones of several bovid and cervid species, as well as a diversity of other large and small mammals, fish, birds, and amphibians (Voormolen, 2008; van Kolfschoten, 2012, 2014; van Kolfschoten et

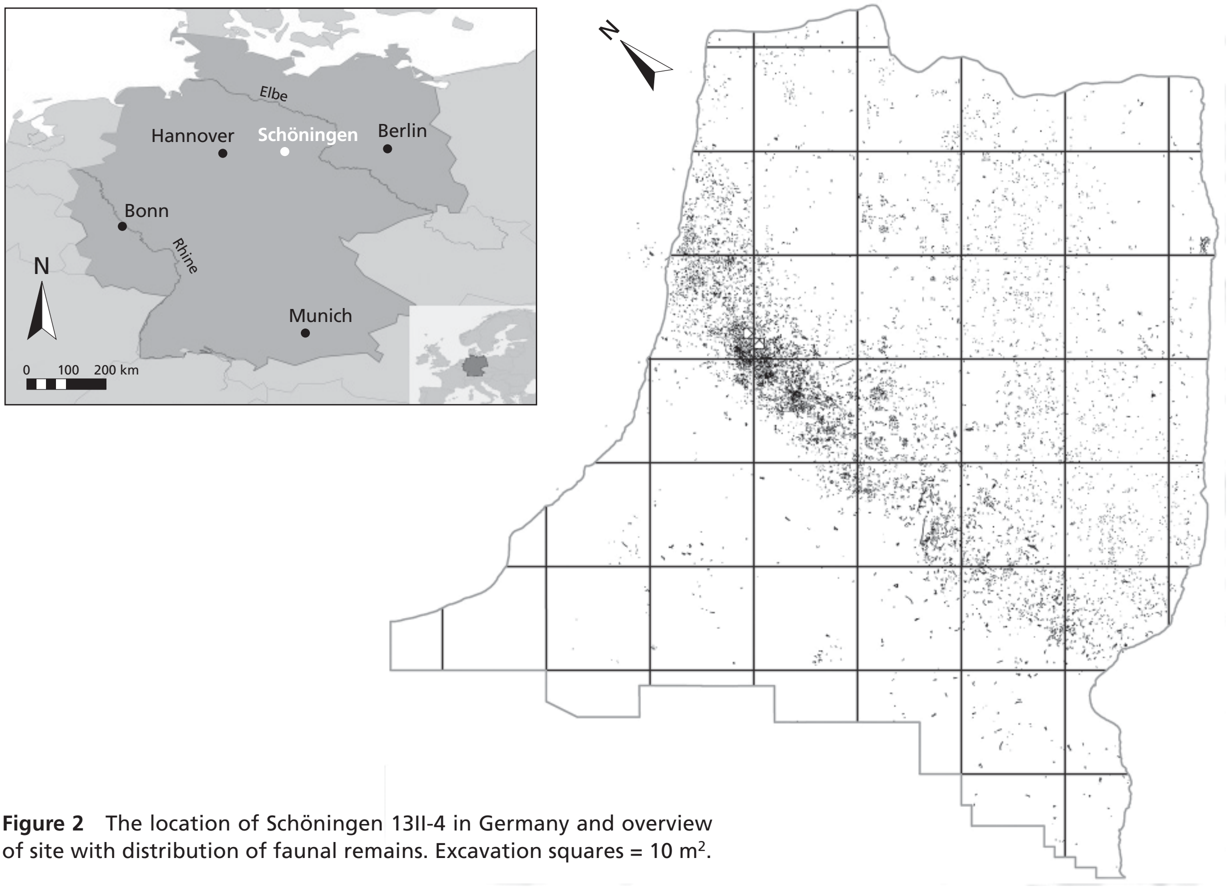

Figure 2 The location of Schöningen 13II-4 in Germany and overview of site with distribution of faunal remains. Excavation squares = 10 m^2.

al., 2015a). Most of the archaeological remains are concentrated in a ten-metre-wide band oriented north-to-south across the central portion of the excavation area (see **Figure 2**). This linear concentration likely corresponds to a former shoreline of the lake, with dry land to the west and the deeper part of the lake basin to the east (Böhner et al., 2015; Turner et al., in press). The more than 50 horse individuals represented in the complete assemblage are thought to represent the remains of multiple hunting and butchery episodes at or near the former lakeshore (Voormolen, 2008; van Kolfschoten et al., 2015a; Hutson et al., in press). The modest lithic assemblage, amounting to roughly 1500 artefacts, is made from local, high-quality flint and features intensely retouched and re-sharpened tools attributed to the late Lower Palaeolithic (Serangeli and Conard, 2015). Most of the lithic material is representative of a very expedient tool-kit, dominated by scrapers, small flakes, and retouch debris; large cores and hammerstones are almost entirely absent.

Framework for studying the Schöningen metapodial hammers

Due to the rarity of metapodial hammers in Palaeolithic assemblages of any age, their function has only been recently hinted at, and the previous interpretation of Schöningen metapodials used as hammers was not backed by any experimental trials (van Kolfschoten et al., 2015b). Without question, the degree of damage observed on most of these metapodials was generated by a considerable force against a hard object. The most likely target materials at Schöningen were stone and other bones, although wood is also a possibility.

Because no pieces of flint were found embedded in the proximal or distal ends of any previously studied metapodial hammer from Schöningen, van Kolfschoten et al. (2015b) considered it unlikely that stone working was the activity that produced the damage. The Schöningen 13II-4 deposit contains dozens of smaller limb bone shaft fragments that preserve the distinctive markings of use as retouchers, many of which include embedded flint. For the purpose of stone working, the proximal and distal ends of horse metapodials are not particularly suited for the delicate task of retouching the cutting edge of a lithic tool. If the metapodials were indeed used in lithic manufacture, a more likely scenario is that the observed damage relates to knapping activities that require a greater force, such as shaping, trimming, or the creation of flakes. These tasks may not leave traces of flint embedded in the bone, as with each successive blow the cortical surface of the bone erodes, taking with it any embedded flint. With regard to the Schöningen 13II-4 lithic assemblage, the presence of several thin flakes and chips with diffuse bulbs and lips demonstrates the use of soft hammer percussion (Serangeli and Conard, 2015), whereas other features indicate the use of hard (stone) hammers. Several metapodials reported by van Kolfschoten et al. (2015b) include both battering damage and retoucher use traces on the diaphyses; therefore, the metapodials could have served as multipurpose tools for various light and heavy-duty tasks within the lithic reduction sequence.

Citing the absence of large stones to serve as hammers or anvils in the Schöningen 13II-4 deposit, van Kolfschoten et al. (2015b) proposed that the metapodials were used to break open limb bones for marrow. This suggestion is bolstered by the lack of various impact features on the bones indicative of fracture using a hammerstone, namely percussion pits and microstriations associated with impact notches. Ethnographic observations of butchery activities and other experimental studies can also inform on the possibility of using metapodials for breaking other bones when hammerstones are not available.

Concerning the lack of large stones for breaking bones at Schöningen, Serangeli and Conard (2015) report nothing recognizable as a hammer or anvil, but Mania (1995:95) notes the presence of “some hammerstones of small quartz and quartzite pebbles” and “a large core” used as a chopping tool at Schöningen; however, it is unclear whether this is in reference to one of the archaeological layers at Schöningen 12 or 13. Nevertheless, it is safe to reckon that large hammerstones are exceedingly rare, or even absent, at Schöningen 13II-4. It is possible that hominins transported any large stones away from the site upon their departure. Many of the lithic cutting tools were likely brought to the site in finished form (Serangeli and Conard, 2015), so it is feasible that useable lithic materials, including hammerstones, would also be transported away from the site for use elsewhere on the landscape.

Based on observations of Nunamiut butchers breaking caribou *(Rangifer tarandus)* limb bones with other bones (report by Dan Witter in Binford, 1978:153-155), van Kolfschoten et al. (2015b) reasoned that the damage to the Schöningen metapodials is possibly the result of hammering activities to access marrow. Along a similar vein, Sadek-Kooros (1972) conducted a set of experiments that preliminarily tested the use of fresh bone to fracture lamb *(Ovis aries)* metatarsals. There was presumably some success with breaking lamb metatarsals with other fresh bones, but the details are not provided. In order to build a case for the use of bone tools at Makapansgat, South Africa, Dart (1959, 1961) enlisted Trevor Jones to replicate “cannon-bone scoops and daggers” by smashing through fresh metapodials with the articular ends of other metapodials. Making these tools required “an amount of planning, patience and persistence that is best appreciated by those who attempt to carry it out” (Dart, 1959:81), suggesting this was not an easy endeavour.

From these studies, it appears possible to break the limb bones of small and medium-sized ungulate limb bones with other bones of the same species, but there are several issues with analogizing these ethnographic and experimental accounts with the archaeological record at Schöningen. First, of 23 limb bones broken during the Nunamiut observations, only four were broken with other bones (Binford, 1978); the remainder were broken with the back of a metal hunting knife or a slender stone baton. It is clear that using bones to break other bones, albeit possible, was not the preferred method among Nunamiut butchers. Second, the limb bone portions used as hammers were the distal condyles of a femur and a head of a humerus. None of these bone portions from Schöningen show battering damage. Lastly, the caribou bones in the Nunamiut observations were substantially smaller and less robust than the horse *(Equus mosbachensis)* and bovid *(Bison* and *Bos)* limb bones from Schöningen. A healthy prime adult bull caribou mentioned in Binford's (1978:17) experiments weighed only 110 kg, and the lambs obtained from a commercial butcher by Sadek-Kooros (1972) likely weighed considerably less than 100 kg. Maximal estimated weight of *Equus mosbachensis* varies between 630 and 750 kg (Eisenmann, 2003:37), and mean body mass for Pleistocene *Bos primigenius* and *Bison priscus* is estimated at over 1000 kg (Saarinen et al., 2016:9). While bone density values are similar across different species of cervids, equids, and bovids (Lyman, 1984; Lam et al., 1999), the bones of larger species are thicker and presumably more difficult to break. In fact, Hadza butchers wielding axes, knifes, hammerstones, and anvils required increasingly more blows to break limb bones of progressively larger ungulate species (Oliver, 1993:213): the mean number of blows to break dik-dik *(Madoqua kirkii)* limb bones was 1.7, 7.1 blows for impala *(Aepyceros melampus)*, 9.9 for zebra *(Equus quagga)*, and 14.6 for buffalo *(Syncerus caffer)*.

Frison (1978) determined that bone implements were an important part of the butchery tool kit assemblages at prehistoric North American bison *(Bison bison)* kill sites. Detailed experiments revealed that femora and tibiae broken at an angle across their diaphyses to produce a "chopper" with a sharp point and a good handhold performed well, and even better than stone, at certain butchery activities, but were "worthless as a tool for breaking heavy long bone" (Frison, 1978:306). The manner in which these femora and tibiae were used in the context of bison kill sites is quite different than the proposed use of the Schöningen metapodials, but the difficulties encountered introduces an element of doubt regarding the possibility of breaking the robust limb bones of a bison with another bone. Dart (1959, 1961) was more successful in fracturing metapodials by means of using other bones, but breakage of sheep, goat, and ox metapodials occurred with some effort, after 30 to 140 blows from the articular ends of metapodials and the pointed distal ends of tibiae. However, Dart's (1959) stated intention was to reproduce a specific shape of break observed in several antelope metacarpals from the Makapansgat grey breccia, which calls into question the fidelity of the experiments.

With these concerns, we were sceptical from the onset that it would be possible to break a limb bone of a large ungulate with a metapodial from the same species. Nonetheless, a series of preliminary experiments were designed to test the performance of metapodials for breaking limb bones of large ungulates.

We began with the hypothesis that metapodials cannot be used to break limb bones of the same species. If the metapodial fractured or otherwise experienced failure, rendering it no longer functional as a hammer, prior to the fracture or failure of the target bone of the same species, then the hypothesis can be accepted. In consequence, the metapodials at Schöningen were not likely to have been used as hammers to break the limb bones identified in the faunal assemblage. Among the many alternative hypotheses are that the metapodials were used in the course of stone tool manufacture and maintenance, or the metapodials were struck against a hard object (stone or bone) with the intention of breaking the metapodial for access to the marrow inside.

Coming back to the original hypothesis, if the target bone fractured before the metapodial hammer, then the hypothesis can be rejected. Therefore, it is possible that the Schöningen metapodials were used as hammers to break limb bones. From this observation we can look to other features of the faunal assemblage to build a stronger case for the use of metapodials as hammers for breaking limb bones.

In concert with the bone breaking experiments, we also employed metapodials in various stone working tasks to determine their performance in creating lithic flakes from larger cobbles. These demonstrations were not designed to test a specific hypothesis, but aimed at seeking an alternative explanation for the damage on the metapodials if their use in breaking bones was rejected.

Materials and methods

Archaeological remains

The entire Schöningen 13II-4 "Spear Horizon" faunal assemblage, consisting of roughly 15,000 specimens, has been a subject of study by the MONREPOS Archaeological Research Centre and Museum for Human Behavioural Evolution since 2013. Portions of the assemblage have been previously described by Voormolen (2008) and van Kolfschoten et al. (2015a). For this study, each bone was individually examined and various taxonomic, anatomical, and taphonomic features were recorded in detail. Bone surface modifications were identified using a 10-20x hand lens and up to 40x digital microscopy when necessary. Metapodials were analysed with particular scrutiny, noting the previous observations of Voormolen (2008), van Kolfschoten et al. (2015b), and Julien et al. (2015) that highlighted the distinctive battering damage to the articular surfaces. All specimens displaying such damage were identified by species, skeletal element, and bone portion (proximal, distal, complete). Incomplete bones were classified into binned categories of 25% based on the percentage of remaining diaphysis. The location of the damage was documented as occurring at the proximal articulation or distal epiphysis, and the aspect was noted as medial or lateral. Two types of damage were documented: crushing and flaking. Crushing is defined as the attritional deformation of the articular surface through compression. Flaking takes the form of shallow to deep, arcuate to angular flake scars emanating from the articular margin. All ancient fractures were categorized as proximal, diaphyseal, or distal breaks, and fracture outlines were further identified as curved, longitudinal, or transverse relative to the long axis of the bone, following Villa and Mahieu (1991). These observations were intended to capture the variation in damage and bone breakage that may relate to the timing, intensity, and/or duration of use of the metapodials in percussive activities. Other traces of hominin butchery, modifications linked to flint-knapping, and carnivore damage were documented following accepted standards of identification (see Lyman, 1994; Fisher, 1995; Fernández-Jalvo and Andrews, 2016).

Experimental protocol

Experiments were designed to test the performance of metapodials in stone tool manufacture and breaking limb bones. It must be noted that these experimental trials should be considered as preliminary empirical tests for the use of metapodials in hammering activities, the results of which can serve as a foundation for further testing in a more rigorously controlled experimental programme. Here, our intentions were to determine the suitability of metapodials for stone working and bone breaking and to evaluate the types of damage produced. The damaged Schöningen metapodials have been previously discussed by van Kolfschoten et al. (2015b) as resulting from breaking bones for marrow, but this hypothesis has never been empirically tested, until now. Moreover, these experiments represent the first attempt to evaluate the performance of metapodials in stone working tasks and the resulting damage.

The first set of experiments involved a series of fresh, never-frozen, adult horse *(Equus caballus)* metapodials acquired from a commercial butcher; all were obtained already disarticulated from the upper limb. A period of one to two days elapsed between the slaughter of the animals and the experiments. The distal epiphyses were entirely fused on all horse metapodials, which established an age at death for the horse(s) to older than 15-20 months (Silver, 1963:252-253). The skin was removed, taking care to preserve the periosteum, the metapodials were disarticulated from the phalanges, and the various sinews were removed to expose the distal articular surfaces for use as hammers. If present, the adhering carpals, tarsals, and accessory metapodials were left in place.

The distal ends of two horse metapodials from the series were used in a fresh state to produce flakes from a Baltic flint core. During use, the metapodials were regularly checked for damage. Upon exhausting the core in one of the trials, the metapodial was swung against a large stone anvil until breakage occurred, a modified version of the percussion by "batting" technique described by Blasco et al. (2014). After use, any adhering tissues were removed from the metapodials, two holes were drilled into the shafts, and then the bones were dried in a low temperature oven to rid the bones of grease.

An additional two metapodials from the series were buried in loose sediment for a period of approximately six months, after which the proximal and distal ends were used in a semi-dry state to generate flint flakes. Both metapodials were swung against a large stone anvil after completion of the stone working tasks until breakage occurred.

For comparison, a sub-fossil metatarsal from a small *Equus* species (cf. *Equus hydruntinus)* was used to create flint flakes in order to assess damage created on bone with a significantly reduced organic fraction. The sub-fossil metatarsal was donated to the MONREPOS Archaeological Research Centre and Museum for Human Behavioural Evolution, along with a number of other unprovenienced specimens, by an amateur fossil collector.

For the second set of experiments, fresh *Bos taurus* metatarsals were obtained from a commercial butcher and used as hammers in an attempt to break open other fresh *Bos taurus* limb bones. Again, one to two days passed between slaughter and the experiments. The metatarsals were acquired already disarticulated from the rest of the limb. Further processing prior to the experiments included skinning, disarticulation from the phalanges, and removal of sinews to expose the distal articular surfaces. On the metapodials, the periosteum was preserved. The target limb bones were also disarticulated and stripped of all meat, but the periosteum was left intact. Some metapodial distal epiphyses were fused, while others were unfused, but held tightly to the metaphysis by a plate of epiphyseal cartilage. Fusion of distal metapodials typically occurs between two and three years of age (Silver, 1963:252-253), which is consistent with the age at which most beef cattle are killed, usually between 2.5 and 3.5 years. The target *Bos taurus* limb bones came from animals of a similar age.

Unfortunately, horse bones were not available for this phase of the experiments. We acknowledge that the morphology of bovid and equid metapodials is different, especially at the distal end, but we are confident that the performance of cattle metapodials in these experiments is equitable to that of horse metapodials based on their overall architectural similarities and comparable densities (see Lam et al., 1999; Ioannidou, 2003).

For each trial, each target limb bone was impacted with the distal end of a metapodial while resting on the ground or with a second limb bone serving as an anvil. With successive blows, the metapodial and target bone were inspected periodically to assess their integrity. The trial continued until complete failure of either the metapodial or target bone across the entire circumference of the shaft or through the distal epiphysis of the metapodial. The bones were gently simmered in water for approximately one hour with an enzyme-based detergent to remove any remaining meat and other tissues.

With the stone working and bone breaking experiments, damage to the proximal and distal ends of the metapodial and breakage characteristics of the shafts were recorded in the same manner as with the archaeological sample from Schöningen. Likewise, breakage features of the target bones were documented using standard zooarchaeological protocols.

The bone tool assemblage from Schöningen 13II-4

In our analysis of the complete faunal assemblage from the Schöningen 13II-4 "Spear Horizon," we identified 46 limb bones with crushing and flaking damage (**Table 1**). This total includes 14 horse *(Equus*

Figure 3 Horse metacarpal (1474) showing curved breaks across the disphysis and distal epiphysis. Scale bar = 5 cm.

mosbachensis) metapodials and one bison *(Bison priscus)* metacarpal previously reported by Voormolen (2008) and van Kolfschoten et al. (2015b). Much of the damage takes the form of crushing and flaking to the distal epiphyseal condyles of horse metapodials. On close inspection, these features are also prevalent on many proximal ends of metapodials. Several distal humeri also show similar battering damage. We documented three cervid *(Cervus elaphus)* distal metapodials with soft hammer damage and two further examples identified as bovid: one aurochs *(Bos primigenius)* metacarpal and one bison *(Bison priscus)* metatarsal. Because crushing and flaking damage is most prevalent on horse metapodials at Schöningen, further discussions will focus on evaluating the damage to those elements of the assemblage.

Horse metapodials

A total of 37 horse metapodials include crushing and flaking damage to the proximal and distal ends: 11 metacarpals, 24 metatarsals, and two indeterminate metapodial. From the entire sample of metapodial hammers, all are adult bones with fused distal epiphyses, except for one metacarpal (2881+4221) represented by a conjoining metaphysis and diaphysis pair that is not completely fused.

Crushing damage is present on the distal ends of all metacarpal hammers in the assemblage; thus, such damage can be considered a defining characteristic of metapodial soft hammers, in general. Flaking damage on the distal epiphyses is common, but not universal. Moreover, flaking damage always occurs in tandem with crushing. Only one

Table 1 Inventory of metapodials and other limb bones with damage interpreted as resulting from use as soft hammers. ID numbers shown in bold have been reported previously (van Kolfschoten et al. 2015b). Portion: D+S= distal+shaft; P+S = proximal+shaft. Damage: C = crushing, F = flaking.

						Damage			Breakage		
ID number	Square	Level	Side	Portion	Retouch	Proximal	Distal		Proximal	Diaphysis	Distal
							Lateral	Medial			
EQUID											
Metacarpal											
1474	684 / 27	4b / 4c	L	D+S (26-50%)	no			C		curved	curved
1648	684 / 29	4b	L	D+S (0-25%)	no			C		transverse	
2451	686 / 22	4b / 4c	L	P+S (26-50%)	yes	C				curved	
2881+4221	687 / 18+689 / 19	4b	L	D+S (26-50%)	no		C	C		curved	
4314	689 / 20	4b / 4c	L	Complete	yes		C	C			
6840	695 / 11	4a / 4b	L	Medial	yes		C, F	C	longitudinal	longitudinal	
7785	699 / 4	4b	R	Complete	yes		C	C			
9900	709 / 40	4b / 4c	R	D+S (0-25%)	no		C, F	C, F		curved	
10159+10162	711 / 6	4a	R	D+S (0-25%)	no		C			curved	longitudinal
10765	715 / 41	4c	R	Complete	yes			C, F			
15015	728 / -997	4b / 4c	R	D+S (0-25%)	no		C, F	C, F		transverse	
Metatarsal											
1495	684 / 27	4b / 4c	R	D+S (0-25%)	no		C, F	C, F		curved	
1541	684 / 28	4b	L	Proximal	no	C			curved		
3064	687 / 24	4b	R	P+S (26-50%)	yes	C, F			longitudinal	curved	
4292	689 / 19	4b	L	D+S (26-50%)	yes		C, F	C, F		transverse	
4552	689 / 26	4c	L	D+S (0-25%)	no		C, F	C, F		curved	
4564	689 / 26	4b	L	D+S (0-25%)	no		C, F	C, F		curved	
4743	690 / 18	4b	L	D+S (26-50%)	yes		C	C, F		curved	
5558.1	691 / 29	4b	R	P+S (51-75%)	no	C			longitudinal	curved	
5560+5561	691 / 29	4b / 4c	L	D+S (26-50%)	no		C, F	C, F		curved	curved
5636	691 / 40	4b	L	P+S (26-50%)	no	C, F			longitudinal	curved	
5719	692 / 15	4b / 4c	L	D+S (0-25%)	no		C, F	C, F		transverse	
6180	693 / 17	4b	R	D+S (0-25%)	no			C		curved	
6239	693 / 19	4b	R	P+S (0-25%)	no	C			transverse		

6734	694 / 20	4b	L	P+S (26-50%)	no	C, F			transverse	curved	
6866	695 / 12	4b	R	P+S (0-25%)	no	C			longitudinal		
7429	697 / 17	4b	R	D+S (0-25%)	no		C	C		curved	
8060	700 / 7	4b	L	P+S (26-50%)	yes	C, F			longitudinal	curved	
9068	705 / 1	4b	R	D+S (0-25%)	yes		C, F	C, F		transverse	
9157	706 / 1	4b	R	P+S (0-25%)	no	C			transverse	curved	
9193	706 / 16	4b / 4c	R	P+S (0-25%)	no	C				curved	
9529	707 / 34	4b	R	P+S (0-25%)	no	C, F				curved	
10037	710 / 9	4b	R	D+S (26-50%)	no		C	C, F		curved	
15577	721 / -978	4b	R	D+S (26-50%)	no		C	C, F		curved	
20760	706 / 9		L	P+S (0-25%)	no	C			longitudinal	curved	
Metapodial											
8879	703 / 5	4b	L	Distal	no					curved	
19782	713 / 18	4b / 4c	I	D+S (0-25%)	no		C, F		curved	transverse	
Humerus											
1842	684 / 32	4c	L	D+S (26-50%)	no		C	C, F		curved	longitudinal
3357 + 3358	687 / 45	4b	R	D+S (26-50%)	yes			C		curved	
7118	696 / 13	4b	L	D+S (26-50%)	yes		C	C		transverse	
CERVID											
Metacarpal											
8872	703 / 44	4b / 4c	L	D+S (26-50%)	no			C, F		curved	
18642.7	700 / 70 (arbitrary)	Abraumberg	R	D+S (0-25%)	no		C			curved	
Metapodial											
12860	717 / -996	4b	I	Distal	no		C, F				
BOS											
Metacarpal											
1229	683 / 30	4b / 4c	R	Complete	no		C	C			
BISON											
Metacarpal											
1259	683 / 30	4a / 4b	L	Complete	yes	C	C	C			
Metatarsal											
7720	699 / 16		L	Complete	yes		C	C			

Figure 4 Horse metacarpal (6840) with longitudinal break along the diaphysis and extending through the proximal epiphysis. The anterior shaft preserves traces of retouching activities and the distal articular condyles show crushing and flaking damage. Scale bar = 5 cm.

Figure 5 Horse metatarsal (9157) with crushing damage to proximal epiphysis. Scale bar = 5 cm.

specimen (2451) displays crushing damage to the proximal end. Elements from the right and left sides are equally represented, and there is no preference shown for either the medial or lateral condyle on the distal end. Seven of ten metacarpals that include the complete distal end show damage to both condyles.

In terms of breakage, all metacarpal hammers with only the proximal or distal end preserved include less than half of the original length of the diaphysis. Many preserve only a quarter of the original length. Transverse breaks across the diaphysis occur only on specimens preserving 0-25% of the original shaft length, although there are some examples of curved breaks on these shorter specimens. The longer specimens, with 26-50% of original metacarpal length, preserve only curved breaks on the diaphysis. Specimen 1474 displays a second curved break across the distal end (**Figure 3**), where nearly the entire distal epiphysis has been detached from the remaining portion of the diaphysis. There are three complete metacarpals with soft hammer damage, and one specimen (6840) that includes an unusual longitudinal break extending from the distal metaphysis to the proximal end, so that the distal epiphysis is complete, but only the lateral portions of the diaphysis and proximal articulation are preserved (**Figure 4**).

It is interesting to note that all complete metacarpals with soft hammer damage and the specimen with the longitudinal break also include long striations on the anterior face underlying extensive damage related to stone working (see **Figure 4**). The numerous pits and scores on these specimens appear similar to marks created through retouch-

Figure 6 Horse metatarsal (5558.1) preserving more than 50% of the original shaft length and showing crushing damage to proximal end. Scale bar = 5 cm.

ing activities (e.g., Patou-Mathis, 2002; Mallye et al., 2012). The proximal metacarpal specimen also shows similar striations and stone working damage to the anterior shaft. In this case, as with the specimen with the longitudinal break, the striations, pits, and scores are abruptly truncated by the fracture. We suspect the crushing damage to the proximal ends led to breakage of the shaft; moreover, the crushing damage likely followed or was penecontemporaneous with the damage to the diaphysis related to stone working. Clearly, these metacarpals had longer and more complex taphonomic histories than their individual functions as soft hammers or stone working tools.

The metatarsals used as soft hammers show similar types of damage as the metacarpal sample. Of the 24 metatarsals, 12 proximal ends and 12 distal ends show crushing and flaking damage. As with the metacarpals, crushing damage is present on all metatarsal hammers (except 8879, discussed below). Flaking damage is considerably more prevalent on the distal metatarsals than on the metacarpals, with ten of 12 distal ends showing flake scars on the condyles. Crushing damage to the proximal ends is more common on the metatarsals than metacarpals (**Figure 5**). Some proximal ends also show some flaking damage, albeit considerably less invasive than on the distal ends. As with the metacarpals, bones from the left or right side of the body were used as hammers in relatively equal proportions; similarly, there is no preference shown for either distal articular condyle. In fact, of the specimens preserving both condyles, all but one (6180) shows damage to both medial and lateral condyles.

The dimensions of the metatarsal hammers are equally divided between 0-25% and 25-50% of their original length. Only one specimen (5558.1; **Figure 6**) with a shaft length beyond 50% was documented among the metatarsals, and no complete horse metatarsals with hammer damage were

Figure 7 Horse metatarsal (5560 + 5561) with dual break across diaphysis and distal epiphysis. Scale bar = 5 cm.

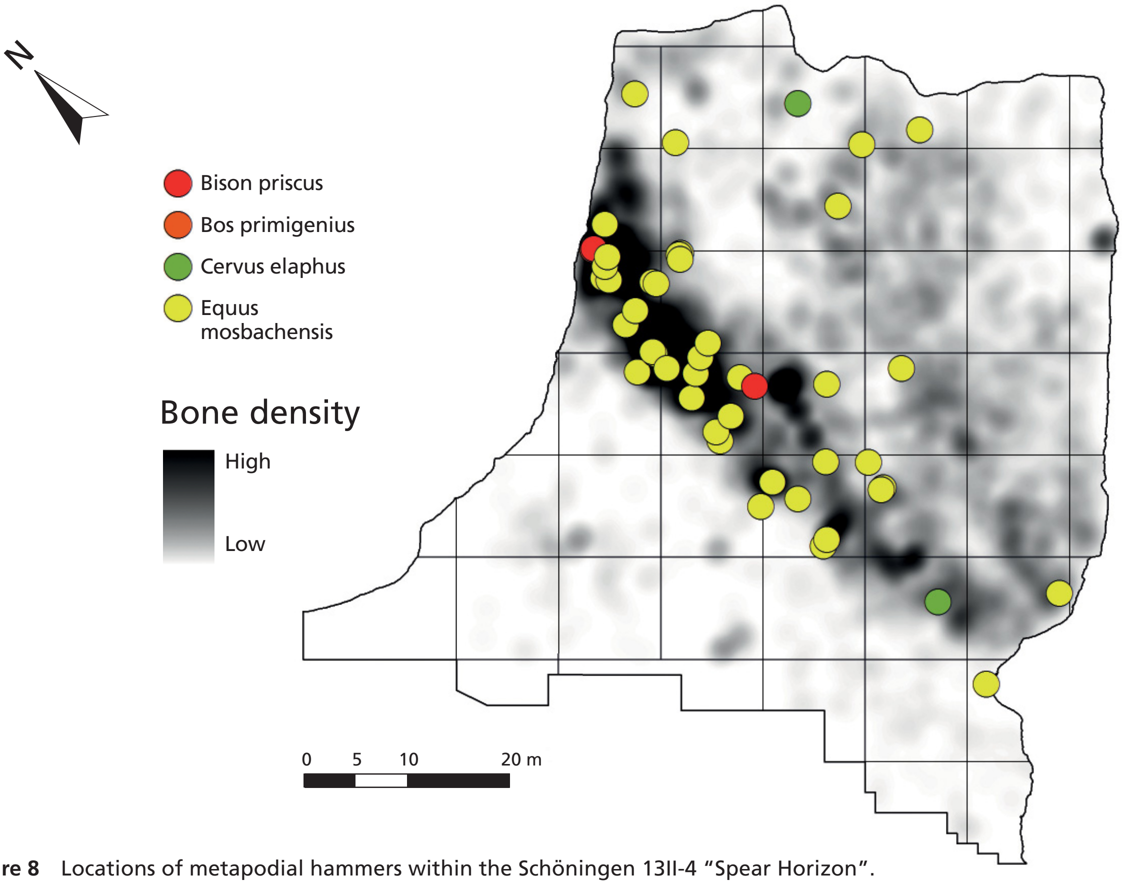

Figure 8 Locations of metapodial hammers within the Schöningen 13II-4 "Spear Horizon".

recorded. Proximal breakage outlines are mostly longitudinal through the articular surface, followed by transverse outlines across the metaphysis, and a solitary example was recorded with a curved breakage outline. Breaks across the diaphysis are dominated by curved outlines; three show transverse outlines. One notable specimen comprises a conjoining pair of bones (5560+5561; **Figure 7**), with a dual diaphyseal and distal break, reminiscent of the breakage pattern in specimen 1474 discussed above. The curved break across the diaphysis is coupled with a second curved break through the distal epiphysis where the two bones refit.

Five of the metatarsal specimens also preserve pits and scores on the diaphysis consistent with marks from retouching activities, some of which measure among the longest of specimens in the sample. Though broken, these specimens show affinities to the complete metacarpals, with extensive longitudinal striations paired with pits and scores indicative of stone working activities.

Two bones could only be identified as metapodials (see **Table 1**). Specimen 8879 includes only a small, broken piece of the distal epiphysis with the same breakage morphology as specimen 5561 (see **Figure 7**). However, the conjoining portion of the diaphysis has not been identified and there is no crushing or flaking damage to the remaining portion of the distal epiphysis. The other metapodial specimen (19782) shows crushing and flaking to the remaining portion of epiphysis and similar breakage features to the other metapodials in the assemblage. The irregular, transverse break through the distal epiphysis is likely postdepositional.

The spatial arrangement of metapodial soft hammers identified as horse mirrors the overall distribution of bones in the "Spear Horizon" (**Figure 8**). Most are located along the nearly 10 m x 40 m main artefact concentration at the site. This arrangement likely reflects some aspect of the relict shoreline during the Middle Pleistocene occupation of the site, where much of the butchery activities took place. This is made clear by the distribution of hominin-modified bones and lithic debris along the same concentration. A few metapodial tools lie further to the east in the part of the site judged to have been toward the deeper part of the lake basin. These stray finds in the lower density areas may represent different hunting and butchery episodes during times when the lake level was lower.

Horse humeri

In addition to the metapodials with soft hammer damage, three horse humeri show crushing of the distal articular condyles along the margin of the trochlea (see **Table 1**). Although the damage is similar to that shown on metapodials (**Figure 9**), crushing damage on distal humeri is comparatively rare; thus, it is unclear whether this can be attributed to the use of distal humeri as tools or some other pre- or postdepositional processes.

Two of the three humeri show traces of use in retouching activities, which does confirm their use as tools in some capacity. One of these specimens is a refit pair (3357+3358; **Figure 10**), comprising a distal humerus-plus-shaft with a conjoining portion of the medial shaft. Together, these specimens display a complex modification sequence. Striations oriented parallel to the long axis of the bone extend across both bone specimens. Lightly-incised marks consistent with retouching activities occur together with striations near the proximal break on the large distal-plus-shaft specimen (3358); these marks do not extend onto the medial shaft specimen (3357). There are multiple negative flake scars from impact on the interior bone wall of the shaft fragment, but no visible impact point on the exterior surface. The

Figure 9 Horse humerus (1842) with crushing damage to the distal epiphysis. Scale bar = 5 cm.

Figure 10 Horse humerus (3358) with crushing damage to the distal epiphysis. Scale bar = 5 cm. Note: conjoining shaft fragment (3357) with pits and scores from retouching not shown.

sequence of damage appears to have proceeded from the striations and retouch damage to breakage from impact. The possible use of the distal end as a soft hammer could have occurred at any time during the sequence.

Specimen 7118 has damage from retouching activities in the same location on the medial shaft, but with no associated striations. At the proximal break there are two negative flake scars on the interior bone wall positioned on the medial and lateral sides, representing impact and rebound points resulting from the use of an anvil. It may be the case that these two humerus specimens with possible soft hammer damage and marks from retouching activities were complete during most of their use lives, much like the complete metatarsal specimens with similar features.

The humerus of a European saber-toothed cat *(Homotherium latidens)* from the Schöningen 13II-4 "Spear Horizon" also shows striations, marks from retouching activities, and damage to the distal epiphyses (Serangeli et al. 2015; van Kolfschoten et al., 2015b). This specimen was not available for detailed study here, but the damage to the distal epiphysis has been interpreted as manipulation by carnivores. Based on the available images of the specimen and limited first-hand observation, we argue the damage is not related to carnivore gnawing, but rather the crushed or eroded area on the distal epiphysis may be the result of use as a soft hammer. Scraping marks overlie weathering cracks and exfolilated surfaces, suggesting that the *Homotherium* humerus was used in a lightly weathered state (Serangeli et al. 2015; van Kolfschoten et al., 2015b), which may have resulted in the atypical pattern of damage to the distal epiphysis.

Cervid metapodials

Only three cervid metapodials include crushing and flaking damage to the distal epiphyses (see **Table 1**). The crushing and flaking damage to the dis-

Figure 11 Red deer metapodials (8872, left; 12680, right) with light crushing damage to the epiphyses. Scale bar = 5 cm.

tal epiphysis of specimen 8872 (**Figure 11**) is less invasive than on the horse specimens, but significant enough to be considered as resulting from the same activities. Also included among the cervid metapodial hammers is an unfused distal condyle (12680) from an indeterminate metapodial with light damage to the articular margin (see **Figure 11**). We included specimen 18642.7 despite its insecure attribution to the "Spear Horizon". The specimen comes from unprovenienced overburden (Abraumberg) sediment, but the damage compares well with other specimens from the "Spear Horizon" levels.

As for the distribution of cervid metapodial hammers, they are located away from the main concentration and are not associated with the large assemblage of butchered horse bones (see **Figure 8**). However, they are situated in the vicinity of dense concentrations of other cervid remains and were likely used during the butchery process of an individual animal killed on site.

Bovid metapodials

Like cervids, bovid bones are less abundant than horse remains at the site, and soft hammer damage has been recorded on only three metapodial specimens (see **Table 1**), all of which are complete bones. Two metacarpals show heavily worn distal articular condyles: specimen 1229 (**Figure 12**) is an aurochs *(Bos primigenius)* and specimen 1259 (**Figure 13**) is from a bison *(Bison priscus)*. Additionally, the bison metacarpal also displays crushing damage to the proximal end and extensive striations, pits, and scores on the anterior face of the diaphysis. A bison metatarsal (7720; **Figure 14**) shows crushing of the distal articular surfaces and striations associated with dense fields of pits and scores from stone working. Several areas on this metatarsal are scaled, where bony plates have become detached from the surface, suggesting this bone was used, at least for some time, in a degreased or dry state. Overall, these complete bovid

Figure 12 Aurochs metacarpal (1229) with crushing damage to the distal epiphysis. Scale bar = 5 cm.

bones show very similar patterns of damage as the complete horse metacarpals, and were likely used for the same purpose(s).

In terms of distribution, the bovid metapodial hammers are located within the main concentration and among other bovid bones with butchery marks (see **Figure 8**). Specimens 1229 *(Bos primigenius)* and 1259 *(Bison priscus)* were recovered from the same one-metre excavation square toward the north end of the main concentration. This peculiar arrangement may suggest that these bones were gathered from existing carcass remains at the site or were carried to the site from the surrounding landscape by hominins.

Experimental results

As mentioned previously, features of the Schöningen 13II-4 "Spear Horizon" lithic assemblage indicate some elements of both soft and hard hammer percussion (Serangeli and Conard, 2015). This argument is supported by the identification of dozens of limb shaft fragments bearing the tell-tale pits and scores of stone working activities (Voormolen, 2008; van Kolfschoten et al., 2015b). On the other hand, the lack of several distinctive hammerstone percussion features (percussion pits and microstriations) on the intentionally fractured limb bones and absence of large hammerstones in the Schöningen 13-4 "Spear Horizon" deposit is taken as evidence that the crushing and flaking of the distal ends of the metapodials was the result of breaking bones for marrow extraction (van Kolfschoten et al., 2015b). To evaluate these claims, we designed a series of experiments to evaluate the performance of metapodials in stone working and bone breaking tasks.

Stone working experiments

In all trials, the horse metapodials performed well as soft hammers for striking simple flakes from a flint core. With fresh bone, crushing damage to the distal epiphyses was quickly produced after a few

Figure 13 Bison metacarpal (1259) with heavy crushing damage to the distal epiphysis, crushing damage to the proximal epiphysis, and pits and scores on the diaphysis from retouching activities. Scale bar = 5 cm.

Figure 14 Bison metatarsal (7720) with heavy crushing damage to the distal epiphysis and pits and scores on the diaphysis from retouching activities. Scale bar = 5 cm.

blows against the flint (**Figure 15**). Flaking of the distal epiphysis did not occur with such ease during flint knapping activities. We are under the impression that flaking is produced with substantially higher force than required for crushing damage to occur; however, we stress that the angle at which the bone is struck against the flint and the duration of use likely play important roles in the resulting damage. Flaking damage (**Figure 16**) was only produced when swinging the metapodial against a large flint anvil with great force. Likewise, breakage of the metapodial did not occur during the course of producing flakes. It does not appear that the low-impact forces or fatigue from multiple low-impact blows are sufficient to cause bone breakage. Only when the intent was to break the metapodial were we able to produce a fracture (see **Figure 16**) consistent with that seen in the Schöningen assemblage. We contend that the amount of force required to break a metapodial through the shaft or across the epiphysis far exceeds that produced during retouching activities and likely beyond that of most flake-producing tasks. However, under the right conditions, perhaps using a substantially defatted or dry metapodial and with sustained use, breakage of the metapodial could occur during the production of lithic flakes. Accordingly, we argue that the Schöningen metapodial hammers were wielded with such force that the breakage was either intentional or, at least, there was an awareness that these implements could break during use.

For the dry bone trials, crushing damage was produced with little effort on the distal ends (**Figures 17 & 18**), appearing no different than on fresh bone. Again, flaking damage only occurred with great force, beyond that normally generated during most knapping activities. When present, flaking damage on dry bone appeared more angular than on fresh bone (see **Figures 17 & 18**), although this is based on very small sample. Crushing and flaking was

Figure 15 Crushing damage to fresh horse distal metapodial resulting from experimental stone working. Scale bar = 5 cm.

Figure 16 Flaking damage to fresh horse distal metapodial and breakage through the distal epiphysis resulting from experimental stone working. Scale bar = 5 cm.

also produced on proximal ends (see **Figure 18**). It should be noted that the damage on the proximal ends of the Schöningen metapodials encroaches on the articular surfaces of some bones (see **Figures 5 & 13**), which would have required the removal of the carpal/tarsal mass and sinews that hold the joints together. With a fresh carcass, all of this is possible with a sharp cutting edge, but the process was simplified for our experiments through burial of the metapodials and natural decay of any adhering tissues. With the removal of the carpal mass, the broad, proximal ends of the metacarpals provided a large working area that created a lot of shatter when struck against the flint, some of which became embedded in the surface of the bone (see **Figure 17**). None of the Schöningen specimens have embedded flint related to soft hammer damage on the proximal or distal ends. In terms of breakage, again it was the case that fracture occurred only when the metacarpals were intentionally struck against a large

Figure 17 Crushing and flaking damage to dry horse distal metapodial resulting from experimental stone working. Arrow marks small piece of flint embedded in the bone. Scale bar = 5 cm.

flint anvil. One metacarpal struck with its distal end displays a transverse fracture just above the epiphysis (see **Figure 18**), while the other metacarpal was struck against the flint cobble with its proximal end and shows a curved break across the diaphysis (see **Figure 17**). Despite its dry appearance, this bone retained enough bone grease or marrow to break in a manner more consistent with fresh bone.

During the last trial involving a subfossil metatarsal (cf. *Equus hydruntinus)*, flaking on the distal epiphysis was easily produced with minimal force (**Figure 19**), and a transverse break was generated across the shaft after only a few blows. The flaking is somewhat angular and does not penetrate deeply into the bone. Furthermore, flaking occurred without the appearance of crushing damage to the epiphysis, likely because the bone was relatively brittle and inelastic.

Bone breaking experiments

Results of the seven trials of breaking limb bones with the distal ends of metapodials are outlined in **Table 2**. Three of the seven trials resulted in the breakage of the target limb bone; the metapodials failed prior to the target bone in the four remaining trials. These experiments were conducted under the hypothesis that metapodials cannot be used to break limb bones. Based on the results, this hypothesis is preliminarily rejected. Thus, it is possible that the Schöningen metapodials were used to break limb bones. Additional experimental trials across a

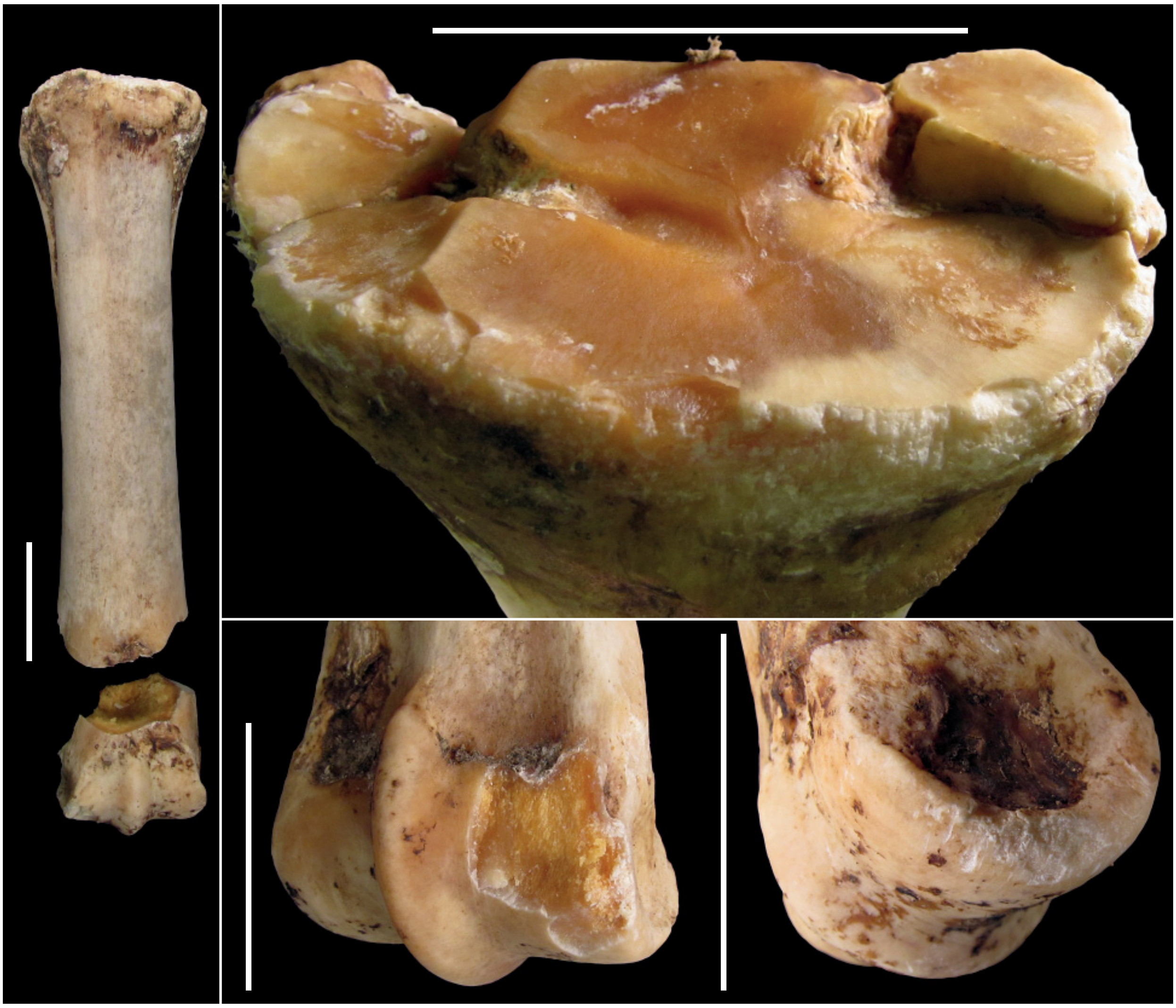

Figure 18 Crushing and flaking damage to dry horse proximal and distal metapodial resulting from experimental stone working. Scale bar = 5 cm.

Figure 19 Flaking damage to distal epiphysis of small equid species metapodial resulting from experimental stone working. Scale bar = 5 cm.

Table 2 Results of bone breaking experiments. (-) indicates condyle not used to impact target bone; (none) indicates condyle was used to impact target bone but no damage was observed. Damage: C = crushing, F = flaking.

				Damage to Metatarsals			
				Distal		Breakage	
Trial #	Target bone	# Blows	Broken bone	Lateral	Medial	Diaphysis	Epiphysis
1	Tibia	53	Target	none	-		
2	Femur	5	Target	-	none		
3	Radio-ulna	14	Metatarsal	none	-	curved	
4	Humerus	22	Metatarsal	F	-	curved	
5	Radio-ulna	33	Metatarsal	none	-	curved	
6 [a]	Humerus	8	Target	-	C		
7 [b,c]	Radio-ulna	44 + 32	Metatarsal	C, F	C, F	curved	oblique

[a] metatarsal reused from trial 1, [b] metatarsal reused from trial 2, [c] radio-ulna reused from trial 3

range of large ungulate species, including horse, are necessary to confirm that breaking limb bones in this manner is possible in cases beyond the relatively young cattle bones used here.

In the trials resulting in breakage of the target bone, the tibia (trial 1; **Figure 20**) fractured after 53 heavy blows from the metatarsal hammer. In contrast, the femur (trial 2; **Figure 21**) and a humerus (trial 6; **Figure 22**) broke with relative ease, requiring only five and eight blows, respectively. It should be noted that the same metatarsal was used in trials 1 and 6. This lends support for the durability of the metapodial hammers and their potential use in breaking numerous limb bones during a single or multiple butchery episodes.

Concerning damage to the target limb bones, there were no visible percussion pits or striations indicting the bones were struck with a hammer, but a single negative flake scar was noted on the interior wall of the femur shaft from trial 2 (see **Figure 21**). During trial 6, a tibia was used as an anvil to elevate the proximal end of the humerus off the ground, and one of the resulting humerus shaft fragments includes two negative flake scars (see **Figure 22**), one resulting from direct impact by the metatarsal and the other likely representing a counterblow from the tibia anvil. There were no indications of percussion on the tibia in trial 1 other than the hackle marks on the fracture surface caused by dynamic loading (see **Figure 20**).

As an aside, none of the target limb bone surfaces were prepared by removing the periosteum, which could have inhibited the production of marks on the bone surfaces. However, it was noticed that within the first few blows with the metatarsal, the periosteum began to tear away from the bone (**Figure 23**), exposing the surface to subsequent blows. Therefore, we conclude that the periosteum did not play a role in the absence of the surface damage to the target limb bones. This revelation has implications for the long-held notion that "the secret to controlled breakage of marrow bones is the removal of the periosteum in the area to be impacted" (Binford, 1981:134). Our experiments show removal of the periosteum can be achieved with blows from a metapodial hammer, and does not necessarily require the use of a sharp stone tool. Both methods produce similar results, but blows from a metapodial leave no traces of bone preparation, whereas stone tools will invariably leave elongated striations oriented parallel to the long axis of the bone. These striations do occur on many of the Schöningen 13II-4 limb bone fragments, but their presence may be related to preparation of the surfaces for stone working activities rather than for bone breakage for marrow.

The damage produced to the distal condyles of the metatarsals during these trials was minimal. Despite the high number of blows delivered by the metatarsal in trial 1, no damage was observed on

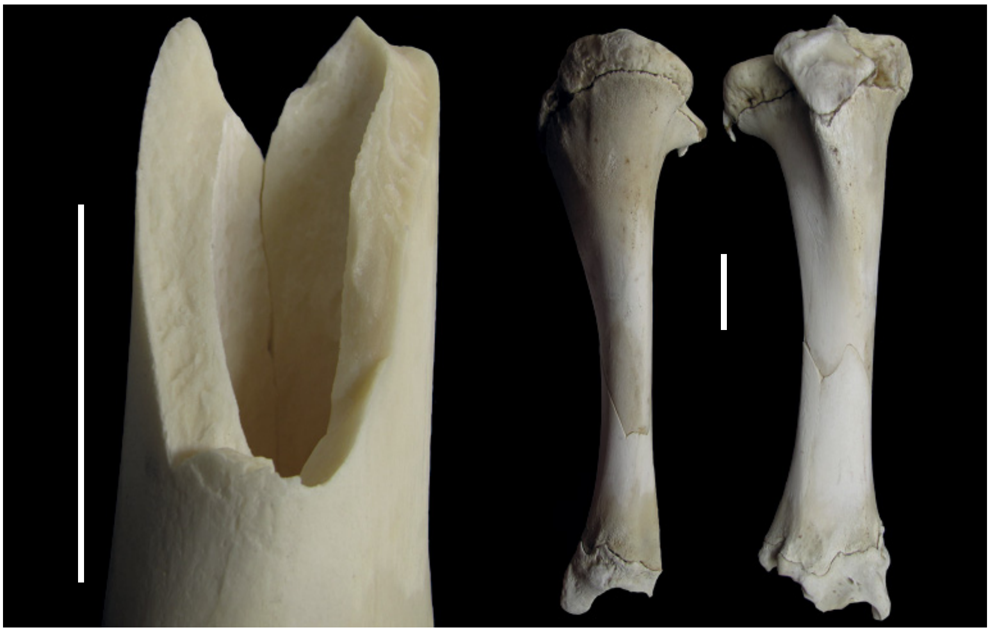

Figure 20 *Bos taurus* tibia experimentally broken with *Bos taurus* metapodial; breakage surfaces shows hackle marks indicating dynamic fracture. Scale bar = 5 cm.

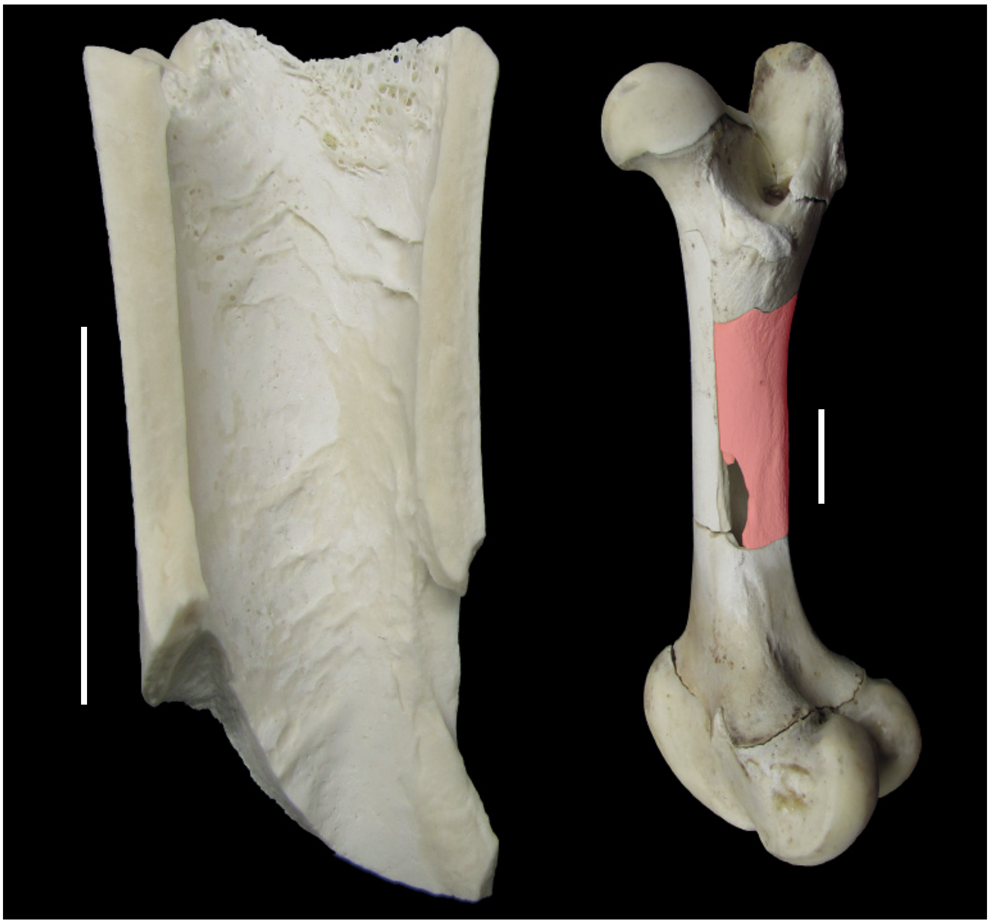

Figure 21 *Bos taurus* femur experimentally broken with *Bos taurus* metapodial; interior surface of shaded shaft fragment includes irregular impact notch. Scale bar = 5 cm.

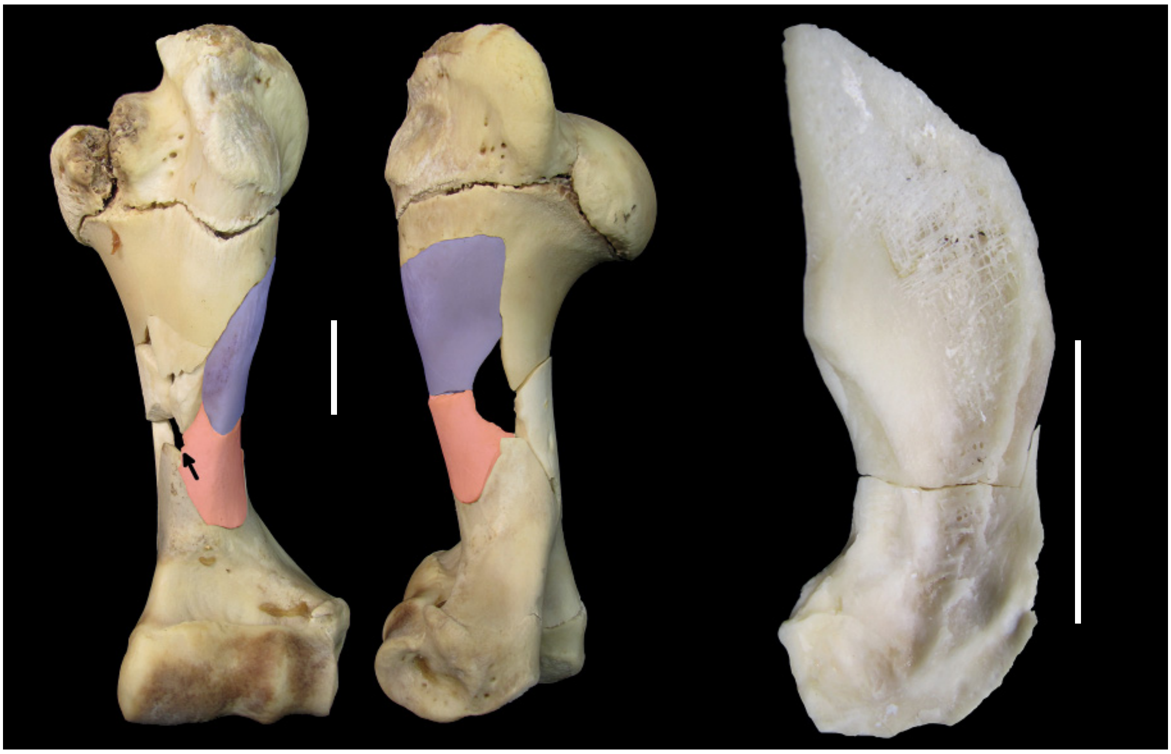

Figure 22 *Bos taurus* humerus experimentally broken with *Bos taurus* metapodial. Arrow denotes location of impact; interior surface of shaded limb fragments preserve impact notch and second counterblow notch. Scale bar = 5 cm.

the lateral condyle. Likewise, five blows produced no damage on the medial condyle of the metatarsal used in trial 2. Three blows into trial 6, light crushing damage appeared on the medial condyle of the metatarsal (**Figure 24**). We do not expect a random development of damage to the distal condyles, but rather crushing, followed by flaking, is likely the result of impact beyond a certain force threshold delivered at a particular angle, the exact parameters of which cannot be so precisely determined with the limited number of experimental trials conducted for this study. Nevertheless, it is noteworthy that 53 hammer blows broke the intended target bone in trial 1, yet no observable damage was produced. This has obvious consequences for the ability to recognize such tools and associated behaviours in the archaeological record at Schöningen and other Palaeolithic localities.

In four of the trials, the metatarsal broke prior to the target bone. This does not detract from the results where the target bone was broken first, but does highlight the varying degrees of success with this method of breaking bones. However, failure to break the target bone in these trials likely had as much to do with inexperience using this particular technique rather than the inability of metapodials to successfully perform the task at hand. For example, trial 4 resulted in the failure of the metatarsal after 22 blows against a humerus mid-shaft, just below the teres major tubercle. In trial 6, the blows were targeted more toward the proximal end, adjacent to the teres major tubercle on the medial side (see **Figure 22**), and the humerus fractured after only eight blows. Just as with a hammerstone, the location of the blows is critical to the successful fracture of the target bone, a process that must be learned through trial and error by a novice experimenter, but a convention likely well known to Middle Pleistocene hominins seeking access to marrow.

Trials 3, 5, and 7 enlisted a radio-ulna as the target bone, and in all trials the metatarsal broke first. The radio-ulnae were struck on the anterior face toward the proximal end along the medial margin, locations with numerous impact marks in the Schöningen

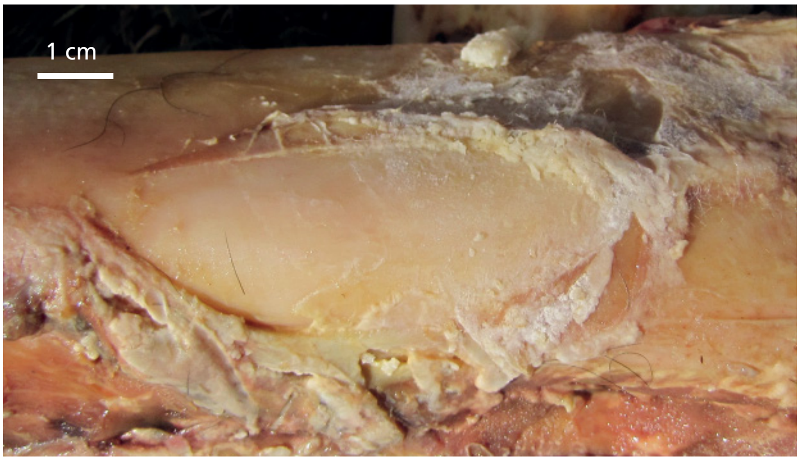

Figure 23 Periosteum pulling away from *Bos taurus* limb shaft during bone breaking experiments.

13II-4 assemblage. In trials 3 and 5, the metatarsal broke after 14 and 22 blows, respectively. The medial condyle of the metatarsal used in trial 7 failed after 32 blows and the trial was terminated after a further 44 blows to the lateral condyle. In trial 7, a complete tibia was used as an anvil to elevate the proximal portion of the radio-ulna off the ground, but this technique proved ineffective. In the end none of the radio-ulnae were broken; obviously the location in which the radio-ulnae was struck needs to be reconsidered in any future experiments.

Damage produced in these trials is clearly mirrored in the Schöningen 13II-4 "Spear Horizon" metapodial assemblage, both on the distal condyles and in the patterns of breakage across the shaft or distal epiphysis. **Figure 25** shows crushing and flak-

Figure 24 Light crushing damage to *Bos taurus* distal metapodial resulting from bone breaking experimental trial 6. Scale bar = 5 cm.

Figure 25 Crushing and flaking damage to *Bos taurus* distal metapodial resulting from bone breaking experimental trials 2 and 7. Fractures across shaft and condyle are similar to those shown in the Schöningen assemblage (1474, 5560+5561, and 8879) and in the stone working experiments. Scale bar = 5 cm.

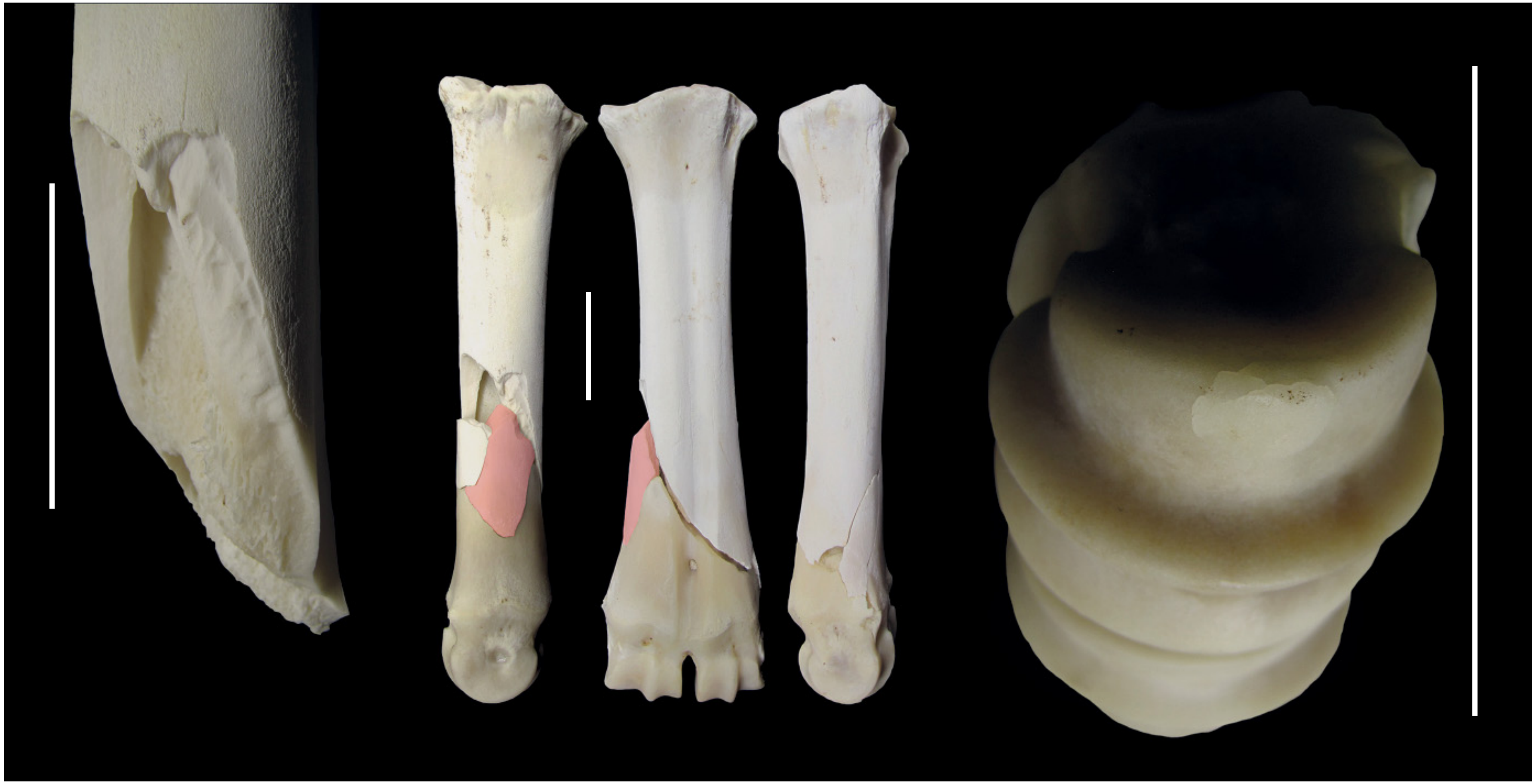

Figure 26 Incipient bone flake on *Bos taurus* distal metapodial from bone breaking experimental trial 4. Hackle marks are visible on the breakage surface. Wedge flake produced by dynamic fracture is shaded in red. Scale bar = 5 cm.

ing damage to the distal condyles produced in trials 2 and 7. No crushing damage was observed on the metatarsal used in trial 4, but a small bone flake not entirely detached from the epiphysis was evident after cleaning of the specimen (**Figure 26**). Both crushing and flaking on the condyles is evident after the extended use of the metapodial in trial 7 (see **Figure 25**); this metatarsal was reused after only five blows (no damage) in trial 2. No damage was observed on the metapodials from trials 3 and 5. In terms of breakage, the same fracture patterns were present in the experimental sample as in the archaeological assemblage, with all metatarsals showing curved breaks across the diaphysis (see **Figures 25 & 26**). The metatarsal from trial 7 also experienced an oblique break across the medial condyle (see **Figure 25**), which is similar to the breaks observed in Schöningen specimens 1474, 5560+5561, and 8879, and one of the fresh metapodials used in the stone working trials (see **Figures 3, 7, 16**).

Discussion

To summarize the results of our experiments, the metapodials were effective in both stone working and bone breaking tasks. Crushing and flaking damage to the distal epiphyses was produced irrespective of the target material, and the observed damage was similar on fresh, dry, and subfossil bone. The difference between flaking and crushing damage appears to be dependent upon the specific trajectory and intensity of the blow against a hard and somewhat stationary target. Duration of use may also play a role in the appearance of different types of damage; crushing damage is more common, but the chance of flaking damage occurring increases with extended use. Based on our experimental trials, there is little to differentiate between the damage produced when striking a metapodial hammer against stone or bone. It is expected that crushing and flaking damage would frequently occur when bone is struck against a material of equal or greater hardness. In this case, the mineral portion of bone, apatite (hydroxyapatite), scores 5 on the Mohs scale of mineral hardness, while flint, and other cryptocrystalline silicates (quartz), measures 7 on the hardness scale. Finally, fracture of the metapodials came about only through multiple heavy blows, beyond that required for retouching dulled cutting edges and most flake-producing tasks. However, we were able to break a subfossil metapodial from a smaller equid species with relative ease; therefore, defatted or dry metapodials may be more susceptible to such breaks, especially under sustained use. In contrast, the bone breaking experiments involved the intentional delivery of a high-impact force with a metapodial to successfully break the target bone for access to the marrow. In such cases, fracture of the metapodial is inevitable with continued use.

Based on these observations, we resolve to define archaeological examples of metapodial soft hammers based solely on the crushing and flaking damage to the proximal and distal ends, damage that is readily distinguished from other taphonomic modifications. Crushing and flaking damage produced in our experimental trials bears noteworthy resemblance to that observed on many of the metapodials in the Schöningen 13II-4 "Spear Horizon" assemblage, attesting to their use as soft hammers. Absent the distinctive crushing and flaking damage, we do not consider the breakage patterns of the metapodials across the shaft to be a good indicator of soft hammer use without further experimentation (see below). On the other hand, we do consider curved breaks across the epiphysis to indicate use as a soft hammer. With that, we have allowed for one exception here: specimen 8879, which includes only a small portion of a distal epiphysis fractured diagonally across the articular surface. This specimen preserves no crushing or flaking damage, but the breakage morphology clearly indicates the bone was struck on the edge of the distal condyle with great force against a hard object. Based on two experimental examples (see **Figures 16 & 25**) and the refitted specimen from Schöningen (5560+5561; see **Figure 7**), this unique type of break is best explained by use as a soft hammer.

Attempting to differentiate the target material (stone or bone) against which the Schöningen

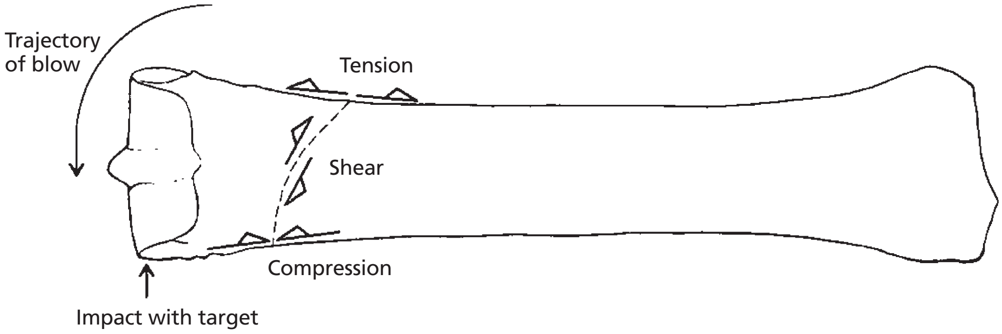

Figure 27 Simplified schematic diagram of forces involved in the use of a bone hammer.

metapodials were struck remains a challenge since the stone working and bone breaking trials yielded nearly identical results. The presence of embedded flint within the bone matrix would provide a clear indication that stone working tasks account for the crushing and flaking damage at some point in the use life of the tool. Flint became embedded in the proximal end of a metapodial during one of the dry bone trials (see **Figure 17**), but this was not replicated in any of the trials with fresh bone. Our analysis of the Schöningen metapodials found no flint inclusions on or near the proximal and distal ends (see also van Kolfschoten et al., 2015b). Ultimately, the presence of embedded flint positively implicates stone working activities, but its absence does not negate the possibility of stone as the target material, nor does it confirm use on bone.

The metatarsals in our experimental trials show remarkably consistent breakage patters, which can provide some insight into the dynamics of their fracture in comparison to other modes of breakage. **Figure 27** depicts the elementary mechanics of the experiments, including trajectory of the blow, impact with the target, and the resulting forces leading to breakage (see Johnson, 1985, and references therein). The shaft on the side delivering the blow to the target bone experiences compression forces upon impact. In turn, the shaft on the side opposite the impact is subjected to tension forces. Shear is introduced as the bone flexes from impact. The spongy nature of the distal epiphysis absorbs the stress waves created by dynamic loading, which, in general, leads to deformation of the epiphysis in the form of crushing and flaking rather than a fracture that cross-cuts the epiphysis. However, off axis loading of trabecular bone can lead to shear failure (Ford and Keaveny, 1996), which accounts for occasional breaks across the distal epiphyses. As cortical bone is stronger in compression than tension, breakage is initiated in the area of greatest tensile strain. The fracture front propagates across the diaphysis in order to relieve the initial strain from impact and eventually merges with other local fracture fronts resulting from bending forces. A wedge flake often detaches from the tension side due to bending failure when the bone flexes, and the fracture surfaces frequently exhibit hackle marks and other stress relief features (see **Figure 26**).

Curved (spiral or helical) breaks across the diaphysis, wedge flakes, and hackle marks all indicate fracture of fresh bone, usually by dynamic loading (Johnson, 1985; but see Haynes, 1983). Bones impacted by a hammerstone can also exhibit these features, but will often include notches with microstriations on the cortical surface, percussion pits, and negative flake scars within the medullary cavity (Blumenschine and Selvaggio, 1988; Capaldo and Blumenschine, 1994; Pickering and Egeland, 2006). Based on our experiments with fresh cattle bones, limbs struck by a metapodial hammer show no surface damage, but do include notches and negative flake scars, in addition to wedge flakes and hackle marks. The presence or absence of these features can be used to identify the manner of breakage for metapodials, albeit with some important caveats, as all bones fractured under dynamic loading will display similar features.

Although it appears that metapodial hammers break in a consistent pattern, there are many processes that can produce the same features on individual bones. The most distinctive characteristic of metapodials broken through use as soft hammers, rather than by impact from a hard or soft hammer, is the lack of impact notches and negative flake scars within the interior wall of the bone. However, metapodials employed as soft hammers could experience multiple cycles of use, including as multi-purpose tools for stone working tasks, and could later be intentionally broken for marrow, both of which could introduce additional impact features not related to use as soft hammers. Furthermore, broken metapodials usually consist of separate proximal and distal ends, with additional fragments of diaphysis. Not all distinguishing fracture features would be present on every bone fragment, thus making it difficult to discriminate between the different modes of breakage without an extensive and successful bone refitting programme. In fact, not all bones broken by hammerstones preserve these fracture characteristics. Capaldo and Blumenschine (1994:731) recorded notches on only 23.3% of bone fragments ≥ 2 cm in controlled breakage experiments. Similar investigations by Pickering and Egeland (2006:466-467) found only 7.9% of bone fragments ≥ 1 cm included notches or were identified as impact flakes; roughly 23% of bones broken (based on complete elements) showed no percussion marks of any kind.

Much of the limb bone assemblage from the Schöningen 13II-4 "Spear Horizon" consists of broken fragments of limb shafts, many of which preserve notches and negative flake scars. There are also numerous examples of impact flakes with striking platforms and bulbs of percussion indicative of impact. However, none include percussion pits or striations that can be confidently attributed to direct impact by a hammerstone or absorption of impact by a stone anvil as opposed to scraping marks, pits, and scores associated with stone working activities (i.e., retouch). Thus, we agree with the assessment of van Kolfschoten et al. (2015b) that breakage of the limb bones at Schöningen was not likely to have been caused by impact from a hammerstone in most cases, but rather from impact by a metapodial hammer. We have demonstrated that it is possible to break open limb bones with blows from a metapodial hammer, and the surface modifications, or lack thereof, on the broken limb bone assemblage provide additional support for this conclusion. Intentionally fractured limb bones are ubiquitous at Palaeolithic sites, but the lack of hammerstones is somewhat peculiar, and the presence of metapodial hammers is unique to the Schöningen archaeological deposits. In this context, bone marrow appears to have been an important component of the hominin diet at Schöningen, well worth the additional costs of recovery that required the procurement of metapodials to break open the bones.

Owing to the dozens of bones in the Schöningen 13II-4 "Spear Horizon" assemblage that preserve pits and scores from stone-working activities, including on several of the metapodials mentioned here, we suspect some of the crushing and flaking damage to the metapodials can also be attributed to heavy-duty stone working tasks. We have demonstrated that the proximal and distal ends of the metapodials are well suited to flake producing tasks.

With these dual stone working and bone breaking capabilities, it appears that the metapodial hammers completely supplanted hammerstones in the Schöningen hominin toolkit. Any task usually attributed to a hammerstone could have been taken up by a metapodial hammer. While there does not appear to have been selection for specific bones used as retouchers (van Kolfschoten et al., 2015b), other than a broad preference for limb bone shafts, metapodials were deliberately selected over all other bones for use as heavy-duty hammering tools.

Another Schöningen locality, site 12II-4, which is located roughly 1 km to the north and thought to be contemporaneous with the "Spear Horizon", also includes a variety of bone tools and few lithic artefacts relative to faunal remains (Julien et al., 2015). This commonality indicates a shared bone tool technology and behavioural link across multiple sites along the Schöningen lakeshore and vicinity. Because metapodials were useful for multiple tasks, it is possible that some of these tools even moved around the landscape, as did the Schöningen spears and other lithic tools. Based on the rarity of spruce *(Picea)* in the pollen assemblage (e.g., Urban, 2007), the spears were brought to the site as fully functioning hunting weapons, with some possible processing or reworking at the "Spear Horizon" site (Schoch, 2015). As for the stone tools, Serangeli and Conard (2015) suggest a relatively high proportion of the lithic artefacts were imported to the site in finished form and re-sharpened on site. With such an abundance of prey carcasses at the site, it would be likely that more metapodials were taken away from the "Spear Horizon" site than were imported. The movement of bones across the landscape could account for the remains of rare species used as tools at various Schöningen localities, including the *Homotherium* humerus from the "Spear Horizon" (see Serangeli et al., 2015; van Kolfschoten et al., 2015b) and the lone specimen from a large cervid (cf. *Megaloceros giganteus)* from Schöningen 12II-2 (Julien et al., 2015).

This presumption may be difficult to reconcile with the fact that nine wooden spears and a lance were abandoned at the site, but there does appear to be a distinct underrepresentation of metapodials in the overall faunal assemblage. Skeletal part abundances reported by van Kolfschoten et al. (2015a:144) show a deficit of metapodials relative to other limb bones. Humerus and radius are represented by 167 and 166 specimens, respectively, whereas only 60 metacarpal specimens were identified. The same pattern holds for the hind limb, with 227 specimens for both femur and tibia, and only 72 metatarsal specimens. An additional 31 unidentified metapodial fragments are listed in the inventory. These abundances are described as "number of elements"; however, the figures are almost certainly based on number of identified specimens and not a representation of complete skeletal elements. Based on our preliminary observations, the abundance of metapodials is much lower than other limb bones when using other derived measures, such as minimum number of elements. Regardless of how the bones are counted, the lesser abundance of metapodials cannot be easily explained as a matter of preservation or other taphonomic processes, such as carnivore gnawing. Overall, the bone assemblage is extraordinarily well preserved and all portions of the skeleton are preserved in various frequencies. Bone density studies show that individual portions of metapodials (i.e., proximal, distal, and mid-shafts) are as dense or denser than comparable portions of nearly all other limb bones (Lam et al., 1999:351-353). Carnivore damage to the assemblage, and specifically to metapodials, is rare. Thus, removal of metapodials from the site by hominins is a legitimate explanation for their relative absence. It is possible that metapodials left the site as "riders" with more valuable portions of the carcasses, such as the skins, which would also account for the low number of phalanges. As a sizeable proportion of the metapodial fragments present at the site were used as tools, these bones were valued in their own right as raw material, despite their almost negligible food value (Outram and Rowley-Conwy, 1998).

There is no mistaking the parallels here with the club-wielding *Australopithecus prometheus* and the osteodontokeratic culture professed by Dart (1957), but this is a far cry from the bloodthirsty apes of Dart's conjuring. These were intelligent hominins, skilled hunters, and expert craftsmen who utilized a wide range of non-lithic raw materials for weapons and tools. Faced with an apparent lack of suitable raw material for hammerstones, the Schöningen hominins relied on technological ingenuity to replace these critical components of the lithic *chaîne opératoire* and butchery process with objects readily available on the landscape. Fresh animal carcasses or previous kills could have served as a sort of bone quarry for immediate or later use (e.g., Hannus, 1989; Johnson, 1985, 1989; Steele and Carlson, 1989; Holen, 2006). While this behaviour may be rooted in the Early Stone Age (e.g., Backwell and d'Errico, 2004) well beyond the time of the "Spear Horizon", the Schöningen hominins display a unique relationship with horse bones as a raw material for tools on an unprecedented scale. This may seem a trivial side note in hominin prehistory, but recognising the utility of bone, and not just a sterile byproduct of a meal, constitutes a major leap forward in hominin behavioural evolution.

As the Schöningen metapodials were likely used to break bones for marrow and in lithic manufacture, it has been suggested that these implements may constitute "the first clear evidence of multi-purpose bone tools in the archaeological record" (van Kolfschoten et al., 2015b:261). We agree with the notion that these were multi-purpose tools, but caution that the Schöningen metapodial hammers can be considered multi-purpose tools only insofar as hammerstones qualify as multi-purpose tools. We prefer to interpret the use of these metapodial hammers from the perspective of their Palaeolithic handlers – as replacements for hammerstones.

The more important concern is the circumstances under which this replacement took place. Substituting bone for stone could have developed out of a necessity to find an alternative raw material for heavy-duty stone working tasks and breaking bones when suitable hammerstones were not accessible. Upon the recognition of bone as a useable resource, metapodials became a convenient substitute for hammerstones, as they would have been readily available from fresh animal carcasses or at known surface accumulations of animal bones. Perhaps stemming from this necessity and convenience, metapodial hammers came to be preferred over hammerstones for these various tasks. The circumstances that drove this innovative behaviour must have been prevalent across the greater Schöningen landscape, where hammerstones are all but absent at multiple Middle Pleistocene localities (Serangeli and Conard, 2015), yet the bone tool industry is well developed in the "Spear Horizon" and within contemporaneous archaeological layers at site complex 12II (Julien et al., 2015).

As the Schöningen 13II-4 "Spear Horizon" represents multiple hunting episodes along the shoreline of the ancient lakeshore, there is some time depth to the archaeological deposit. Therefore, the abundance of metapodial tools at the site suggests a distinct diachronic tradition transmitted through time. This technological innovation did not spread to neighboring regions and was not developed independently in other areas, but rather the use of these metapodial tools represents a truly unique feature of the Schöningen cultural landscape.

Conclusion

Building on the previous work of Voormolen (2008) and van Kolfschoten et al. (2015b) we described 46 bones with damage from use as soft hammers from the archaeological deposits at the Schöningen 13II-4 "Spear Horizon". Horse metacarpals and metatarsals were deliberately selected for use in heavy-duty hammering tasks by Middle Pleistocene hominins as evidenced by the crushing and flaking damage to the proximal and distal ends. Several horse humeri show similar damage to the distal condyles, and metapodials from bovids and cervids were also used, albeit to a limited extent. We have demonstrated the utility of these soft hammers in both stone working and bone breaking tasks. Various aspects of the faunal and lithic assemblages recovered from the "Spear Horizon" are consistent with a multi-purpose utility of these bone implements. Breakage features suggest most of these bones were used while fresh, while others may have been defatted or dry and selected from the existing bone refuse at the site. The lesser abundance of metacarpals and metatarsals relative to other limb bones in the overall assemblage suggests that some metapodials were transported away from the site for use at other localities across the Schöningen landscape. In a similar fashion, bones may have been brought to the "Spear Horizon" site from other locations. Considering the scarcity of large hammerstones at any of the Schöningen Middle Pleistocene sites, we conclude this large assemblage of metapodial hammers reflects the replacement of hammerstones with bone hammers for various stone working and breaking bones tasks.

The Schöningen 13II-4 "Spear Horizon" will be forever remembered for the hunting weapons from which the site draws its name. While these spears are truly extraordinary, there are other known Palaeolithic examples from Clacton-on-Sea, UK (Warren, 1911), and Lehringen, Germany (Movius, 1950). The metapodial hammers, on the other hand, are exclusive to Schöningen, and not just in the "Spear Horizon", but also at Schöningen 12II. At present, no comparable tools have been reported from other Palaeolithic sites in Europe, or elsewhere. This innovative replacement of hammerstones with bone hammers was driven out of necessity and demonstrates the capability of Middle Pleistocene hominins to make cultural adjustments in technology based on a particular set of available resources. The creativity displayed in the development and use of these bone tools is a hallmark of the human species, much more so than the artefacts themselves. Evidence from Schöningen reveals that this creative tendency is deeply ingrained in the behaviour of our recent hominin ancestors.

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A REAPPRAISAL OF LOWER TO MIDDLE PALAEOLITHIC BONE RETOUCHERS FROM SOUTHEASTERN FRANCE (MIS 11 TO 3)

Abstract

In southeastern France, many Final Acheulean/Early Middle Palaeolithic and Middle Palaeolithic assemblages have yielded bone retouchers. The oldest are dated to the Middle Pleistocene: from MIS 11 at Terra Amata; MIS 9 at Orgnac 3; and MIS 6-7 at Payre F, Sainte-Anne I and Le Lazaret. However, this early evidence of bone tool use only concerns a few dozen pieces among thousands of faunal and lithic remains. These retouchers indicate behavioural changes from MIS 11-9 onwards in southeastern France, associated with a mosaic of technological and subsistence changes that became more common during the Middle Palaeolithic. The frequency of these bone artefacts increases during MIS 7, becoming much more numerous after MIS 5, sometimes totaling more than a hundred items at one site, such as Saint-Marcel Cave. Bone retoucher frequency is still highly variable throughout the Middle Palaeolithic and seems to be determined by the type of occupation and activities rather than the associated lithic technologies. This broad, regional comparative analysis contributes to a better understanding of the technical behaviour developed by Neanderthals, as well as their Middle Pleistocene ancestors, and their ability to recover and use bones.

Keywords

Bone retouchers; Middle Palaeolithic; Southeastern France; Neanderthals; Pre-Neanderthals

Introduction

Bone retouchers were first discovered at the end of the 19th century (Leguay, 1877; Daleau, 1883). Discoveries continued into the beginning of the 20th century at the Middle Palaeolithic site of La Quina (Henri-Martin, 1906, 1907, 1907-1910), and retouchers are now well defined and described elements in a wide range of Palaeolithic faunal assemblages (Chase, 1990; Vincent, 1993; Patou-Mathis and Schwab, 2002). Retouchers are bone, dental or other osseous fragments bearing diagnostic features resulting from their use in lithic tool making. These include "deep, short, sub-parallel, closely clustered grooves, V-shaped in cross section" (Chase, 1990:443). The presence of parallel micro-striations within the grooves, and sometimes on the surface of the use area (sliding striations), and small, embedded lithic fragments are two other criteria confirming their identification (Rigaud, 1977; Vincent, 1993; Malerba and Giacobini, 2002; Schwab, 2002; Mallye et al., 2012; Daujeard et al., 2014; Abrams et al., 2014; van Kolfschoten et al., 2015).

The oldest occurrences of the use of bone to modify lithic tools are dated from Marine Isotope Stage (MIS) 13 at Boxgrove, UK (Roberts and Parfitt, 1999; Smith, 2013). Other early sites yielding bone retouchers are Caune de l'Arago (MIS 12; Moigne, 1996), La Micoque (MIS 12-11; Langlois, 2004; Risco, 2011) and Terra Amata (MIS 11; Moigne et al., 2016) in France; Gran Dolina TD10 in Spain (MIS 10-9; Rosell et al., 2011, 2015); Orgnac 3 (MIS 9; Sam, 2009; Sam and Moigne, 2011, Moncel et al., 2012a) and Cagny-l'Epinette (MIS 9; Tuffreau et al., 1995) in France; Bolomor Cave in Spain (MIS 9; Blasco et al., 2013a); Schöningen in Germany (MIS 9; van Kolfschoten et al., 2015); and Qesem Cave in Israel (400-200 ka; Blasco et al., 2013a, 2014). Besides the large bone tools made on proboscidean remains recovered in many European sites since MIS 9 (Gaudzinski et al., 2005; Anzidel et al., 2012; Boschian and Saccà, 2015), these early bone retouchers, mostly dated between MIS 11 and 9 and variably related to the presence of bifacial technology, confirm that the behavioural changes observed in Europe between 400 and 300 kya included bone recovery and use as a technological raw material (Rosell et al., 2011; Moncel et al., 2012a; Blasco et al., 2013a; Moigne et al., 2016). This type of bone tool appears alongside other major behavioural changes, such as the regular use of fire (Roebroeks and Villa, 2011), standardized carcass processing (Stiner et al., 2009; Blasco et al., 2013b), the targeted hunting of large ungulates (Oakley et al., 1977; Thieme, 1997), a decrease in pachyderm scavenging sites (Valensi et al., 2011; Anzidel et al., 2012; Gaudzinski et al., 2005), and lithic core technologies based on predetermined flake production (Moncel et al., 2012a). After MIS 9, from the end of Middle Pleistocene to the beginning of the Upper Pleistocene, and coinciding with the development of Middle Palaeolithic technology, many more sites have yielded bone retoucher series (Blasco et al., 2013a). Examples in France dating to the end of the Middle Pleistocene include the assemblages of Biache-Saint-Vaast (MIS 7; Auguste, 2002) and Le Lazaret (MIS 6; Valensi et al. 2013; Moigne et al., 2016). During the Upper Pleistocene, this type of bone artefact occurs at many sites (see Daujeard et al., 2014, and references therein).

In order to enhance our understanding of the circumstances surrounding the emergence of this bone technology, we explore their occurrence at a regional scale and over a broad time scale, ranging from the Final Acheulean and Early Middle Palaeolithic to the Middle Palaeolithic. In this study, we focus on a comparison of bone retoucher series from various sites in southeastern France (**Figure 1**), dating from MIS 11 to MIS 3 (**Figure 2**). Most of the sites presented here were studied recently and yielded archaeological, geological and chronological data: Terra Amata (MIS 11) along the Mediterranean coast; Orgnac 3 (MIS 9) and Payre F (MIS 7) in the Rhône Valley; Sainte-Anne I (MIS 6) in the Massif Central; and the cave of Lazaret (MIS 6) near the Mediterranean. Most of the other sites are dated to the Upper Pleistocene, from the Last Interglacial (MIS 5e at Baume Flandin), to the Early and Middle Pleniglacial Periods until MIS 3. The earliest sites (MIS 11 to MIS 6), including Terra Amata, Orgnac 3, Payre, Sainte-Anne I and Le Lazaret, yielded Acheulean and Early Middle Palaeolithic lithic assemblages, with varying quantities of bifaces. From MIS 5 to MIS 3, all the lithic assemblages clearly belong to Middle Palaeolithic techno-complexes.

These numerous series of bone retouchers are variable in age and located in a circumscribed geographical area, enabling us to compare various features of these artefacts, including frequency, type of blank (species and anatomical element) and morphology of use traces. We are also able to place them in their discovery context according to hominin species, type of occupation, faunal spectrum, environment and lithic industries, which allows us to explore chronological and geographical differences in the selection of bone elements and their use as tools. Were there specific *chaînes opératoires* and management strategies for this type of bone tool? Or, conversely, was there merely an *a posteriori* selection of some bone elements from

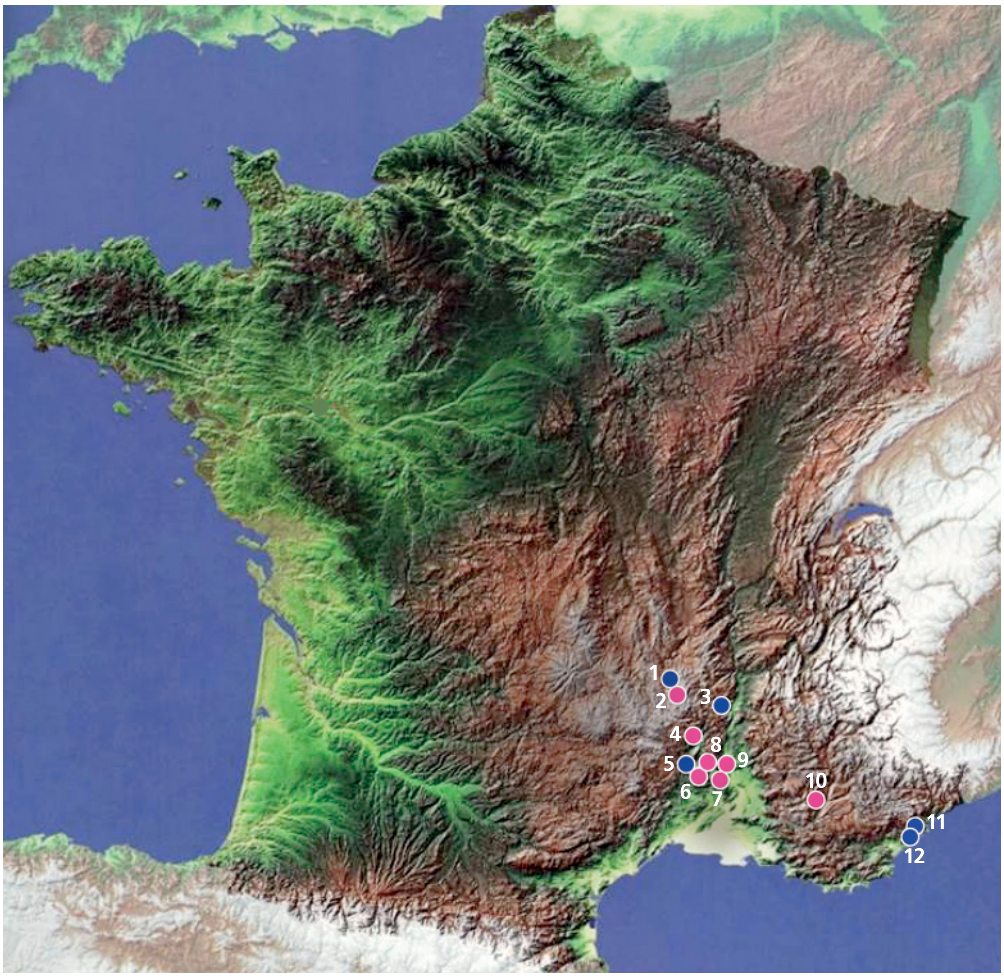

Figure 1 Location of the studied sites in southeastern France (Blue circles: Middle Pleistocene sites; Red circles: Upper Pleistocene sites). 1: Sainte-Anne I; 2: Baume-Vallée; 3: Payre; 4: Barasses II; 5: Orgnac 3; 6: Baume Flandin; 7: Le Figuier; 8: Saint-Marcel; 9: Abri du Maras; 10: Baume des Peyrards; 11: Le Lazaret; 12: Terra Amata.

among butchery remains shortly or some time after the accumulation of the deposits? Can we link the frequency, type, intensity and location of percussion marks (hash marks, grooves, cupules and striations) to any specific lithic technology (bifacial, discoid, Levallois, Quina), raw material (diverse flint types, quartzite, volcanic rocks, etc.), lithic tool management strategy and/or function (soft hammer, anvil, retoucher)? Finally, is there a relationship between the occurrence of these artefacts, activities and the type and duration of occupations?

Geographical, chronological and cultural contexts

Final Acheulean and Early Middle Palaeolithic sites

TERRA AMATA The site is an open-air locality in Nice, situated on the western slopes of Mount Boron. The archaeological deposits consist of a littoral marine formation at the base (stratigraphic unit C1a), composed of a beach of pebbles and silt (M unit), surmounted by a silt level (P4 unit), covered by a littoral barrier beach made of pebbles (CLs unit), and a large dune of sand at the top (stratigraphic unit C1b) (de Lumley et al., 1976; Pollet, 1990; de Lumley, 2013).

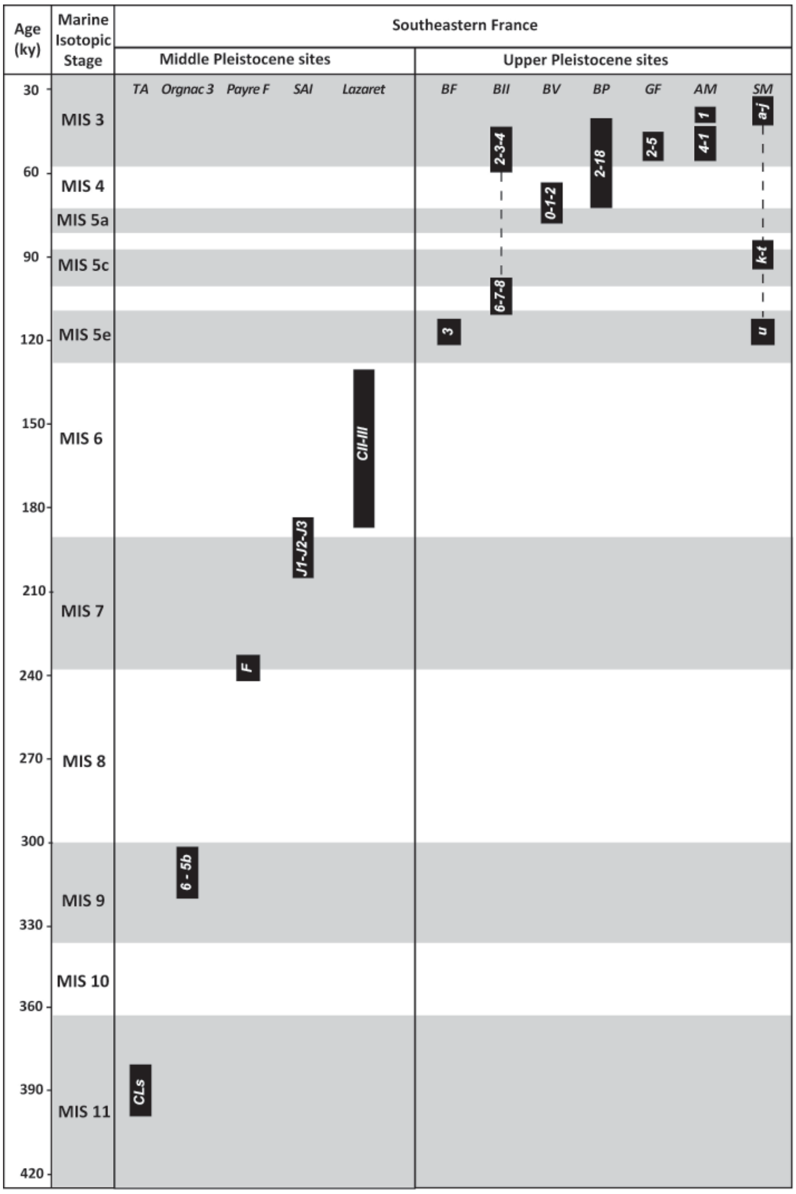

Figure 2 Chronological timespans of the various levels providing bone retouchers positioned according to the Marine Isotope Stages (MIS) (see references in text). TA: Terra Amata; Orgnac 3; Payre; SAI: Sainte-Anne I; Le Lazaret; BF: Baume Flandin; SM: Saint-Marcel; BII: Barasses II; BV: Baume Vallée; BP: Baume des Peyrards; AM: Abri du Maras; GF: Grotte du Figuier.

The large faunal assemblage is composed of eight large mammal species, with straight-tusked elephant *(Palaeoloxodon antiquus)*, red deer *(Cervus elaphus)* and wild boar *(Sus scrofa)* as the most abundant species. The other species are aurochs *(Bos primigenius)*, which is well represented in the upper levels (dune), brown bear *(Ursus arctos)*, tahr *(Hemitragus bonali)* and rhinoceros *(Dicerorhinus [Stephanorhinus] hemitoechus)*. The mammals, similar across the different levels, characterize a temperate period of the Middle Pleistocene (MIS 11 or 9) (Valensi, 2009; Valensi et al., 2011). The geology and general site context more precisely correlate Terra Amata with MIS 11 (de Lumley et al., 2001).

The taphonomic study shows that the bone assemblage from the beach levels (M, P4 and CLs units) is the best preserved. Zooarchaeological data (Valensi and El Guennouni, 2004; Valensi et al., 2011) indicate widespread red deer hunting with transportation of whole carcasses to the habitation, followed by intense processing for subsistence purposes. Deer remains show a significant number of intentional green bone fractures, cut marks and striations. Hominins also brought portions of aurochs and young elephant carcasses to the camp. Marks left by carnivores are almost nonexistent on the faunal material.

The lithic industry, described as Acheulean, is characterized by abundant products from cobble shaping (choppers, chopping-tools, bifaces and cleavers). The majority of flake tools are scrapers, with some denticulates and notches. There is no Levallois, but unipolar and centripetal core technologies are present. About twenty retouchers on soft pebbles have been recorded within the beach levels (de Lumley et al., 2008; de Lumley, 2015).

ORGNAC 3 The site of Orgnac 3 is located on a plateau near the Ardèche River. It was initially a cave site, but was transformed into a rock shelter and finally into an open-air site (Combier, 1967; Moncel et al., 2005). The sequence was divided into ten archaeological levels. The ESR-U/Th ages obtained from the lower levels (4a-8) vary within the transition between MIS 9 and MIS 8 (Shen, 1985; Falguères et al., 1988; Laurent, 1989; Masaoudi, 1995; Michel et al, 2011, 2013). The upper level 2 contains volcanic minerals from an eruption of the Mont-Dore volcano, which can be attributed to the beginning of MIS 8 (Debard and Pastre, 1988). This age is in agreement with the age obtained by Fission track dating on zircons (Khatib, 1994; Michel et al., 2013). The upper level 1 is indirectly attributed to MIS 8 due to the presence of tahr *(Hemitragus bonali)* and bear *(Ursus deningeri)*, which suggests that this level cannot be more recent than MIS 8 (Moncel et al., 2012a). Levels 2 and 1 are mainly characterized by species typical of an open landscape and mark the replacement of *Equus mosbachensis* by *Equus steinheimensis* (Forsten and Moigne, 1988). Combined biostratigraphical studies of mammal remains, microfauna and fossil pollen suggest that the layers 4a to 8, including layers 5b and 6 with bone retouchers, were deposited in a temperate context, characteristic of a Middle Pleistocene interglacial period (Guérin, 1980; Jeannet, 1981; Gauthier, 1992; El Hazzazi, 1998; Aouraghe, 1999; Sam, 2009). In these lower layers, fauna is rich and well preserved, with an abundance of cervid bones. Horse represents the second most hunted species, followed by large bovids. As the site was still a cave, carnivores were abundant, but marks on bones mainly indicate activities subsequent to those of hominins (Moncel et al., 2005, 2011, 2012a; Sam and Moigne, 2011). The lithic industry is related to the Acheulean Complex with centripetal core technology. These layers yielded eight hominin teeth with evidence of living children (de Lumley, 1981).

Recent studies of the complete lithic and faunal assemblages from the ten archaeological levels of Orgnac 3 (1959-1972 excavations) (Combier, 1967; Aouraghe, 1999; Sam, 2009; Moncel et al. 2011; 2012 a) provide an opportunity to observe the contextual evidence of some behavioural changes. The site contains records of Upper Acheulean occupations (Combier, 1967), with evidence of Middle Palaeolithic behaviour at the top of the sequence (Moncel, 1999).

PAYRE The Payre site was a small cave above the confluence of the Rhône and Payre Rivers, located at the crossroads of various biotopes (Moncel, 2008). The five metre thick stratigraphic sequence yielded eight occupation layers dated from MIS 8-7 (Valladas et al., 2008). The spectrum of ungulates throughout the sequence is mainly composed of red deer *(Cervus elaphus)*, horse *(Equus mosbachensis)*, bovines *(Bos primigenius* and *Bison priscus)* and rhinoceroses *(Dicerorhinus [Stephanorhinus] hemitoechus* and *D. kirchbergensis)*. Carnivores are especially numerous in level F. Among them, the cave bear *(Ursus spelaeus)* is predominant and associated with other carnivores, including wolf *(Canis lupus)*, hyena *(Crocuta spelaea)* and cave lion *(Panthera [leo] spelaea)*. This faunal list reveals a mildly cold climate and different biotopes, including forests, wooded prairie, steep rocky slopes (Payre canyon), as well as open steppe environments. The microfaunal remains indicate cold and steppe environments in layers G and F (Moncel, 2008).

Carnivores inhabited the site in layer F, suggesting that hominin occupations alternated with carnivore denning (Daujeard, 2008; Daujeard et al., 2011). The study of ungulate tooth microwear patterns attests to longer occupations for layer G. During the accumulation of layer F, the cave was smaller in size with reduced ceiling height, which is reflected in the small number of lithic artifacts and taphonomic features of the faunal remains. Layer F was mostly a carnivore den with shorter-term hominin occupations (Rivals et al., 2009).

In both layers, we recorded a diversity of anthropic impacts on horse, red deer and bovines, the three main hunted taxa at Payre. Ungulate bones were intensively cut marked, broken, and some were burned. The use of fire is attested in each layer, but clear hearth structures appear only in layer G. Lithic residue and use-wear analyses show evidence of fish processing in layers Fa and D, as well as the use of avian resources (Hardy and Moncel, 2011). The lithic material is attributed to the Early Middle Palaeolithic, with a discoidal and orthogonal core technology on flint and mainly scrapers and points (Moncel, 2008; Baena et al., 2017). Some heavy-duty tools, as well as bifaces and pebble tools, were made on-site or outside the site on local quartzite, limestone and basalt (Moncel, 2008). Flint was mainly collected within a radius of less than 25 km around the site, although some flint flakes came from an area 60 km south of the site, suggesting hominin mobility on the plateaus bordering the Rhône Valley (Fernandes et al., 2008).

Neanderthal remains, including teeth, a mandible and a fragment of parietal, were discovered within the sequence, with most grouped in a small area at the bottom of sub-layer Ga (Moncel, 2008). The hominin remains belong to children, sub-adults and adults, except for the mandible of one old individual. It seems that familial groups were present, unless these remains were brought to the cave by carnivores.

SAINTE-ANNE I The cave of Sainte-Anne I is a small, south-facing cavity (50 m^2) at 737 m above sea level. The stratified deposit contains several Middle Palaeolithic assemblages with bifaces. The stratigraphy preserves three main units (J1, J2 and J3) biochronologically attributed to MIS 6; however, ESR dates are younger (Raynal, 2007). The three main units contain the same ungulate species (Raynal et al. 2005, 2008; Raynal, 2007), dominated by reindeer *(Rangifer tarandus)*, horse *(Equus caballus* cf. *piveteaui)* and ibex *(Capra ibex)*. Woolly rhinoceros *(Coelodonta antiquitatis)*, bovines and other cervids complete the faunal spectrum. From a palaeoenvironmental viewpoint, the most important elements of the spectrum represent open arctic and mountain fauna groups, suggesting harsh and severe climatic conditions prevalent during MIS 6. Carnivore remains are rare, but fox *(Vulpes vulpes)*, wolf *(Canis lupus)*, lynx *(Lynx lynx)* and extinct cave lion *(Panthera [leo] spelea)* are present. Cut marks are more frequent on bones than carnivore tooth marks. Reindeer were the focus of hominin butchery activities, such as skinning, dismembering, defleshing, scraping of the metapodials and marrow extraction. Hominins consumed carcasses in the cave, and carnivores scavenged from these kills. Traces of fire are scarce. The presence of reindeer and horse deciduous teeth indicates an autumnal kill season. Data associate this site with a regular hunting camp alternately visited by carnivores.

Here, quartz, volcanic rocks and certain types of local flint exhibit complete reduction sequences, indicating that these abundant local lithic materials were flaked at the site. However, bifaces and unifacial flake-tools were produced outside the site, then brought there and used before being broken (Santagata et al. 2002; Santagata 2006, 2012; Raynal, 2007). Levallois and discoidal flaking were applied to cores made of volcanic rocks, and the occasional production of quadrangular flakes was the result of orthogonal or other unipolar flaking activity. The dense nature of the available raw materials sometimes required core reduction using bipolar anvil percussion. For all the raw materials, traditional core reduction technologies were used alongside opportunistic flaking methods. This dual approach produced flakes with functional, unmodified edges for particular subsistence activities, which explains the small number of retouched tools found at the site. Typologically, the lithics resemble the series recovered from Payre, where raw materials were chosen for their proximity to the site rather than for quality (Moncel 2003; Raynal et al. 2005; Raynal, 2007; Fernandes et al. 2008).

LE LAZARET Lazaret Cave is a vast cavity some 40 m long and approximately 15 m wide, located in Nice on Mediterranean coast. Systematic excavations brought to light 29 archaeological units in the CIII stratigraphic complex (UA 1-UA 12) and in the underlying CII complex (UA 13-UA 29) (de Lumley et al., 2004). Paleontological data concur with radiometric dating (ESR/U-Th) that correlates the CIII and CII stratigraphic complexes to MIS 6, the last glacial period of the Middle Pleistocene (Valensi and Psathi, 2004; Michel et al., 2009, 2011; Valensi, 2009; Hanquet et al., 2010). An interdisciplinary study of the fauna (amphibians, reptiles, birds and mammals) suggests a variety of continental landscapes linked to a relatively cold climate, moderated by the southern position of the site. A relative decrease in temperature and a gradual opening of the landscape occurred between complexes CII sup. (UA 13-UA 25) and CIII (Valensi et al., 2007; Hanquet et al., 2010). The spectrum of ungulates is mainly composed of red deer *(Cervus elaphus)*, ibex *(Capra ibex)*, aurochs *(Bos primigenius)* and to a lesser extent, roe deer *(Capreolus capreolus)*, alpine chamois *(Rupicapra rupicapra)* and straight-tusk elephant *(Paleoloxodon antiquus).* Among the carnivores, wolf *(Canis lupus)* is predominant relative to other species, such as cave bear *(Ursus spelaeus)*, brown bear *(Ursus arctos)*, cave lion *(Panthera [leo] spelaea)*, cave lynx *(Lynx spelaeus)*, wolverine *(Gulo gulo)* and other small carnivores.

The multidisciplinary analyses conducted at this site revealed successive occupations by groups of nomadic large herbivore hunters (mainly red deer and ibex in all the levels), who set up temporary camps and sometimes occupied the cave for more prolonged periods (M'Hamdi, 2012; Valensi et al., 2013). The CII complex contains an Acheulean lithic assemblage with numerous bifaces and some Levallois debitage (5-10%). Above this deposit, the CIII complex is attributed to an Epi-Acheulean culture (de Lumley et al., 2004; Cauche, 2012). During the various periods of site occupation, the heavy-duty tools, as well as bifaces and pebble tools, were mostly shaped from limestone pebbles collected in the river near the cave. Light-duty tools, preferentially made on siliceous raw materials are mainly composed of scrapers, points and notches. In the Acheulean levels UA28 and UA29, retouched products represent 5% and 7.5% of the assemblage, respectively (Cauche, 2012). In the different hominin occupation levels, many retouchers on small and flat pebbles have been identified (de Lumley et al., 2004).

Twenty-five Pre-Neanderthal remains have been discovered at Lazaret Cave, some of which present a transitional morphology between *Homo heidelbergensis* and *Homo neanderthalensis* (de Lumley et al., 2006).

Middle Palaeolithic sites

BAUME FLANDIN The site is a small cave near Orgnac 3, located along a small valley on the Orgnac plateau. The first archaeological investigations carried out at Baume Flandin (Orgnac l'Aven) began in the early 1950s (Gagnière et al., 1957). The excavators considered the site as a specific case study for understanding Middle Palaeolithic laminar assemblages, comparable to the nearby Abri du Maras. Faunal remains were studied by S. Gagnière, who attributed one archaeological level to a temperate period, just before the last glacial. Combier (1967) studied the sequence again and described three levels, with the hominin occupation dating to the Würm I glaciation. All the cave sediments were removed during the early excavations. In 2005, a new trench was excavated on the terrace in front of the cave (Moncel et al., 2008). Four levels were observed. The hominin presence at Baume Flandin (*in situ* level 3 and disturbed level 2) corresponds to an occupation inside the cave and on the present-day open-air terrace.

The faunal spectrum is dominated by red deer *(Cervus elaphus)* and horse that can be linked to a transitional form, *Equus germanicus (Equus* cf. *taubachensis)*. Carnivores are numerous, dominated by wolf *(Canis lupus)*, cave hyena *(Crocuta spelaea)* and fox *(Vulpes vulpes)*. The large bovid remains are attributed to the forested type *(Bison priscus mediator)*. Ibex belongs to the Alpine type, *Capra ibex cebennarum*, recognized at the Abri des Pêcheurs (Moncel et al., 2010; Crégut-Bonnoure et al., 2010). The ungulate group, especially the abundance of cervids, as well as the presence of lynx *(Lynx spelaeus)*, panther *(Panthera pardus)*, wild boar *(Sus scrofa), Bison priscus mediator* and the great wood grouse *(Tetrao urogallus)*, points to forested environmental conditions. The equid remains attest to more open areas, and the presence of *Equus hydruntinus* suggests mild climatic conditions. Hominin-induced cut marks were only found on red deer and roe deer *(Capreolus capreolus),* whereas horse and bovid remains present numerous carnivore marks.

The lithic assemblage from level 3 (outside the cave) appears to be homogeneous. The flaking sequence is complete, except for cores, which are not present on site. Most flakes are made from local Cenozoic flint. The flake tools represent 8% of the series and are mainly composed of lateral scrapers. The largest tool (115 mm long) is bifacially-worked from a flint slab. The assemblage is not exactly the same as that from inside the cave, and there is little evidence of laminar flaking. The differences observed between the inside and outside assemblages may result from different activities/occupations, or from the small size of the excavated area (Moncel et al., 2010).

BARASSES II This site is a small cavity above the Ardèche River, opening into a steep and rocky, south-facing cliff. Combier (1968) conducted the first excavations in 1967 and 1968 and recognized various Middle Palaeolithic layers. New investigations began in 2011 to gather more data on the lower part of the sequence, which was only reached in one square metre during the first excavations (Combier, 1968; Daujeard, 2014). The sequence is divided into two main lithostratigraphic parts: the lower (units 6-8) belongs to MIS 5d and the upper (units 2-4) dates between the end of MIS 4 and the beginning of MIS 3 (Richard et al., 2015). Both yielded Middle Palaeolithic industries.

The faunal list for the upper units 2-4, excavated from 2011 to 2013, shows a varied spectrum. Ibex *(Capra ibex)* largely dominate throughout the sequence, followed by cervids *(Cervus elaphus, Rangifer tarandus)*, bovines, horse *(Equus* sp.*)* and chamois *(Rupicapra rupicapra)*. Among the carnivores, which represent almost a third of the total number of identified specimens (NISP), we find mostly fox *(Vulpes vulpes)*, cave bear *(Ursus spelaeus)*, wolf *(Canis lupus)* and panther *(Panthera pardus)*. In the newly investigated lower units 6-8, the faunal list does not change, apart from the absence of panther. However, carnivores are much less abundant, especially the large predators. Alterations to this mixed faunal assemblage resulted primarily from numerous carnivore visits to the small cave, which was regularly used for hibernation and denning. Throughout the sequence, about a third of the remains display carnivore marks. Cut marks increase from the bottom to the top of the sequence. Hominins preferentially processed secondary ungulates, such as cervids, bovines and equids. Evidence of fire is very scarce. Thus, this small cave may have provided a convenient shelter for various animals during harsh weather conditions, including recurrent and brief visits by small Neanderthal groups.

The lithic assemblages are diverse, composed of debitage products with long or short cutting edges. Most of them were brought to the cave, and were produced by various core technologies outside the site. Levallois technology predominates. Rare cores are on flint flakes, except for one in basalt. Some cores are retouched as flakes or used for the complementary debitage of small flakes. Flint flake-tools are rare. Some points are broken, probably accounting for their abandonment in the cave. Flint is the main raw material, brought in from a large perimeter around the site, but the lower unit indicates a broader use of volcanic stones available at the foot of the cave along the Ardèche River. In all units, volcanic stones provided pebbles for percussion (i.e., hammerstones), pebble-tools and perhaps a bifacial tool. These were also generally knapped outside the cave. In all the units, the flint *chaînes opératoires*, as well as many of the volcanic stone *chaînes opératoires*, are partial, suggesting short-term occupations throughout the sequence. The more widespread use of volcanic stones in the lower unit may point to different types of occupations for the earliest uses of the cave.

BAUME VALLÉE The southeast-facing Baume-Vallée cliff with the Laborde rock-shelter is located at Solignac-sur-Loire in the Velay, 795 m above sea level. It lies on the left bank of the Ourzie River, which is a left bank tributary of the Loire. In its lower part, the shelter contains several stratigraphic units (0-2) belonging to the Ferrassie-type Charentian Mousterian. The stratigraphy shows that sedimentation was the result of primary and secondary frost action, particularly solifluction, which becomes increasingly evident towards the top of the Mousterian sequence and delineates a secondary strato-genesis. Dates achieved by TL and ESR give an age of around 80 kya (MIS 5a) (Raynal and Huxtable, 1989; Raynal et al. 2005).

Horse *(Equus caballus* cf. *germanicus)* is the dominant species, followed by cervids *(Cervus elaphus, Rangifer tarandus)*, ibex *(Capra ibex)*, bovines *(Bos* or *Bison* sp.*)* and other equids *(Equus hydruntinus)*, while the remainder of the assemblage is composed of bird species and indeterminate carnivore fossils (Fiore et al., 2005; Gala et al., 2005; Raynal et al. 2005). In addition to a certain displacement of the faunal remains, periglacial taphonomic processes have also caused significant surface abrasion and fragmentation of the assemblage (Guadelli, 2008). In spite of the poor state of preservation, butchery processes, including marrow extraction and defleshing, have been identified. Carnivore modification to the bone assemblage is very rare and most of the fresh bone fractures can be attributed to hominin activity. Very few burnt bones were recorded. At Baume-Vallée, hunting focused mainly on cervids and equids during the first period of hominin occupation, while equids become the dominant hunted species during later times. Data support the hypothesis that the site was used regularly as a seasonal hunting camp (Fiore et al. 2005; Raynal et al. 2005).

Flint comprises 90% of the lithic assemblage recovered from unit 1 (Fernandes et al., 2006). Despite the fact that most of the siliceous materials were gathered relatively close to the site, the geological knowledge of the inhabitants included an awareness of resources found up to 53 km from the site. Quina and Levallois knapping methods were used within both unique and composite reduction sequences, illustrating a concern for conserving lithic resources and a sophisticated technical understanding of the properties of different materials. Retouched products consist mainly of Levallois debitage or cortical Quina products and represent 20% of the assemblage in unit 1 and 35% in unit 2. Around 80% of the pre-determined Levallois flakes and 50% of the diverse cortical flakes were modified by continuous adjacent retouch. Notches represent 8% and 3% of the total in units 1 and 2, respectively, while denticulates are rare. Numerous retouchers on small and flat pebbles were identified in the different units (Raynal et al., 2005).

BAUME DES PEYRARDS The Baume des Peyrards, in Vaucluse, is a huge rock shelter situated in the east of the studied region, on the left bank of the Rhône. The site is located at 20 m above the right bank of the Aiguebrun River, facing southwest. It was first discovered by E. Arnaud in the second half of the 19th century and excavated at the beginning of the 20th century by M. Deydier and F. Lazard. In the 1950s, de Lumley (1969) excavated a large part of the terrace and recognized 29 levels distributed along13 m of stratified deposits. Hominin occupations belonging to the upper units a to d are associated with the Würm I and II, which indicate alternating cold and temperate climates. These units yielded Middle Palaeolithic industries and rich faunal series.

In the upper part of the sequence (units a to d), Ibex *(Capra ibex)* is dominant among ungulate species, followed by red deer *(Cervus elaphus)* and horse *(Equus caballus* cf. *germanicus)*. Carnivores are scarce and include some forested species, such as brown bear *(Ursus arctos)*, lynx *(Lynx pardinus)*, fox *(Vulpes vulpes)* and dhole *(Cuon alpinus europaeus)*. The faunal list in the upper units c and d is almost the same, except for an increase in cold indicators. The faunal accumulations are mostly due to hominin activities. Cut marks are prevalent and indicate the exploitation of whole ungulate carcasses. The abundance of burnt bones and green bone breakage confirm the variety of subsistence activities carried out at the rock shelter. Data point toward the use of this huge rockshelter as a residential camp (Daujeard, 2008).

Raw materials are mostly local flint. In this Ferrassie assemblage, Levallois debitage is predominant, with abundant products modified by continuous retouch on convergent edges. A particular feature of this assemblage is the thinness of some of the Levallois flakes or scrapers (de Lumley,1969; Porraz, 2002). De Lumley noted the homogeneity of the lithic industries throughout the sequence. Four Neanderthal teeth belonging to three young adults and one child (10-11 years old) were discovered in the Würm II layers (de Lumley, 1973).

LE FIGUIER Le Figuier Cave opens above the Ardèche River, with the vast porch facing to the south. The cave is composed of three chambers, the largest being the closest to the entrance. A small corridor leads to the second and third chambers 20 m from the cave entrance. Initial excavations took place in the 1940s (Combier, 1967). Two Middle Palaeolithic layers were identified at the bottom of the sequence and have been attributed to the Quina facies (Moncel, 2001). Upper Palaeolithic levels (Aurignacian to Magdalenian) overlie the Middle Palaeolithic layers and yielded remains of a *Homo sapiens* child in the first chamber.

New fieldwork in all three chambers (Moncel et al., 2012b) led to the identification of a common infilling within the cave, consisting of six sedimentary units with one main Middle Palaeolithic layer at the bottom (units 2 to 5) (Moncel et al., 2012b). Sporadic disturbances due to cave bears and hyenas are observed within each layer in chambers 2 and 3. These disturbances do not affect the whole sequence, as each layer is clearly distinct from the others. Upper Palaeolithic artefacts are not *in situ*, while Middle Palaeolithic items from the bottom of the sequence resulted from hominin occupations within the chambers. Faunal and sedimentary data for this main Middle Palaeolithic occupation indicate a cold phase of the Middle Pleniglacial (MIS 3) (Moncel et al., 2012b). A single ESR-U/Th age implies that the site was used at the end of MIS 4 and/or beginning of MIS 3 (Richard et al., 2015).

The ungulate spectrum is varied. Reindeer *(Rangifer tarandus)*, horse *(Equus caballus)* and ibex *(Capra ibex)* are dominant, indicating a cold steppe environment. In the lower levels (unit 2), fallow deer *(Dama dama)*, wild boar *(Sus scrofa)* and roe deer *(Capreolus capreolus)* highlight warmer and more humid climatic conditions. Carnivores are abundant, mostly in the smaller chambers 2 and 3, including cave bear *(Ursus spelaeus)*, cave hyena *(Crocuta spelaea)*, wolf *(Canis lupus)* and fox *(Vulpes vulpes)*, among others. Taphonomic data indicate that carnivores frequently used the cave as dens and hibernating places, particularly the deep and narrow chambers 2 and 3. A few cut marked and broken bones with percussion marks attest to some Neanderthal incursions inside the karstic system, far from the entrance. Butchery and carnivore marks are found on the same species: reindeer, red deer and horse. Zooarchaeological data suggest regular short-term hominin camps alternating with carnivore occupations (Daujeard, 2008; Daujeard and Moncel, 2010; Moncel et al., 2012b).

Excavations in chamber 1 yielded two Middle Palaeolithic levels (2 and 4), including one Quina facies. This facies was not detected in chambers 2 and 3, which are further from the present entrance. In the three chambers, the debitage is mainly discoid on small flint core-flakes. Occupations in the dark chambers were different in nature, although they display the same technological behaviour. Flaking took place in the three chambers, producing elongated and thick flakes. Core-flakes were introduced into the site; some show Quina retouch in chamber 1 and smaller retouch in chambers 2 and 3 (scrapers, points).

ABRI DU MARAS The Abri du Maras site is a large rock-shelter located in a small valley near the Ardèche River. This site was first investigated by Gilles and Combier in the 1960s, followed by Moncel since 2006 (Combier, 1967; Moncel et al., 2015). This site is famous for Middle Palaeolithic deposits bearing a Levallois laminar debitage at the top of the sequence (level 1) (Combier, 1967). The early excavations describe seven other distinct levels (levels 8-2) with Middle Palaeolithic assemblages (Combier, 1967; Moncel, 1994, 1996). Since 2006, new excavations have focused on this lower part of the sequence. Rich lithic and faunal remains and hearths characterize level 4 of the new excavations, which comprises more than 40 m^2 and contains two phases of hominin occupations. The oldest layer, named layer 5 (levels 8-6 of earlier excavations), consists of an organic brown level with a sandy-silt matrix, covering the limestone substratum. The geological study demonstrates that the shelter's roof collapsed over time and that the most recent occupations took place below a small shelter (Debard, 1988). New ESR-U/Th ages obtained on layers 4.1 and 4.2 indicate that the site was still occupied at the beginning of MIS 3, thus extending the known chronology (Moncel et al., 1994; Moncel and Michel, 2000; Richard et al., 2015).

In order of abundance, the large faunal spectrum of layer 4 is composed of reindeer *(Rangifer tarandus)*, horse *(Equus caballus* spp.*)*, red deer *(Cervus elaphus)*, bison *(Bison priscus)*, ibex *(Capra ibex)* and giant deer *(Megaloceros giganteus)*. Some lagomorphs, bird and fish remains attest to the occasional human consumption of small prey (Hardy et al., 2013). There are no carnivore remains, no carnivore gnawing marks, and no evidence of digestive corrosion. The broad faunal spectrum points to cold and open environments, which is consistent with sedimentary data and dating (Moncel et al., 1994, 2010; Daujeard and Mon3cel, 2010). Faunal remains are mainly related to Neanderthal activities. For reindeer, the most abundant prey, autumnal mortality is suggested by cementochronology and periods of tooth eruption; furthermore, the presence of mixed populations (all age classes) indicates far-sighted and organized slaughter during major autumnal migrations (Daujeard, 2008; Daujeard and Moncel, 2010). Systematic and intensive carcass processing occurred at the site. Data suggest the use of this rock shelter as a place of large seasonal gatherings for Neanderthals.

Most of the artefacts are in flint from the nearby northern and southern plateaus. The assemblages are composed of elongated Levallois flakes, points, cores and small flakes produced on small Levallois core-flakes on site. The longest products were introduced into the site. Flake-tools, such as scrapers, denticulates and points, are very rare (Moncel et al., 2014). The first analyses of microwear traces and residues (Hardy et al., 2013) indicate a variety of activities, in addition to butchery, and some evidence for projectiles.

SAINT-MARCEL This site is a vast porch cave opening to the south, situated at an altitude of 53 m above the Ardèche River. Middle Palaeolithic layers were discovered under the porch during excavations conducted by R. Gilles in the 1950s (Gilles, 1976; Debard, 1988; Moncel, 1998). According to stratigraphic and sedimentological studies, about 40 layers were identified. Radiocarbon dates, first conventional (Évin et al., 1985) followed the AMS ^{14}C method (Szmidt et al., 2010), were made in the upper layers of the sequence and yielded dates corresponding to the MIS 3 time range. Seven climatic sub-phases were identified throughout the sequence, with archaeological remains (levels u-c) and sedimentation gaps (Debard, 1988). Levels u-k, at the bottom of the upper layer, correspond to MIS 5e and the end of MIS 5. The rest of the sequence was deposited during a temperate and wet period during MIS 4/beginning of MIS 3. Levels f-c, at the top, belong to the Late Middle Palaeolithic. Hominin occupation is recurrent throughout the sequence and, except for level u, did not record behavioural change despite sedimentary breaks.

Throughout the sequence, the faunal spectra are largely dominated by cervids. Above level u, red deer *(Cervus elaphus)* is the most abundant taxon, followed by roe deer *(Capreolus capreolus)*, fallow deer *(Dama dama)*, ibex *(Capra ibex)*, giant deer *(Megaloceros giganteus)*, horse *(Equus caballus* cf. *germanicus)*, aurochs *(Bos primigenius)*, European ass *(Equus hydruntinus)* and wild boar *(Sus scrofa)*.

Carnivore remains are absent. This association indicates temperate and humid climatic conditions with a mosaic of forested, open grassland and rocky environments. The faunal accumulation is mainly due to hominid activities. Cut marks are very frequent and carnivore tooth marks are almost absent. Seasonality indices show that the red deer assemblage, mainly made up of young animals and adults killed in herds, were hunted year round, with most slaughters occurring during the autumn (Moncel et al., 2004; Daujeard, 2008; Daujeard and Moncel, 2010). Carcasses were systematically brought back whole to the shelter and were then entirely eviscerated, skinned, dismembered, filleted and the bones broken for marrow and boiling. The levels yielded a huge number of bone retouchers and burnt elements. Data suggest a succession of long-term residential camps.

Lithic analyses reveal consistent technological behaviour through time based on a discoid core technology on flint flakes, and occasionally on nodules and pebbles. The flint was gathered on the northern and southern plateaus and along the Rhône Valley. Tools are rare, made up of side scrapers and points. Retouch is marginal and does not modify the shape of the products (Moncel, 1998; Moncel et al., 2004).

Materials and methods

This comparative study includes all the bone retoucher series from the 11 studied sites presented above. The number of bone artefacts is highly variable, depending on the layers (**Table 1**). All the studied material comes from recent (after 1950s) or ongoing excavations, with the exceptions of Le Figuier (Gilles and Combier), the upper units of Abri du Maras (Gilles and Combier) and Barasses II (Combier), and Baume Flandin (Gauthier), which include the former collections present at the Orgnac Museum (Orgnac-l'Aven, Ardèche). Thus, except for the early collections from Le Figuier and Baume Flandin, our study takes into account all the faunal remains, including sieving residues. Most of the lithic and faunal data result from our own analysis and are first-hand or revised data (Fiore et al., 2005; Daujeard et al., 2014; Moigne et al., 2016). Detailed taphonomic data from the studied sites have been published in previous papers (Valensi, 2000; Fiore et al., 2005; Raynal, 2007; Daujeard, 2008; Daujeard and Moncel, 2010; Valensi et al., 2011, 2013; Moncel et al., 2012a,b; Daujeard et al., 2014).

In order to appreciate the bone retoucher frequency for each series, we present the number of bone retouchers (Nr) relative to the total number of anatomically identified specimens for ungulates (see **Table 1**). We could not provide total percentages, given that every author has a different way of calculating the total number of observed specimens (various minimum dimensions, which may or may not include illegible remains or teeth, etc.). We recorded anatomical, taxonomic, and modification data for each bone retoucher. For indeterminate fragments, we established three main size categories adapted to the ungulates in our sample: small-sized ungulates (SU) weighing less than 100 kg (chamois, roe deer, wild boar); middle-sized ungulates (MU) weighing between 100 and 300 kg (red deer, fallow deer, reindeer, ibex, European ass); and large-sized ungulates (LU) weighing between 300 and 1,000 kg (large bovids, horse and giant deer). Bone surfaces were studied with the naked eye and with a stereomicroscope (up to 80x) when necessary. For each specimen we recorded the type and location of the relevant modifications observed on legible surfaces, including those made by rodents, carnivores or hominins, as well as climatic and edaphic modifications (e.g., Behrensmeyer, 1978; Binford, 1981; Lyman, 1994; Fisher, 1995). The identification of breakage type (ancient green or dry bone fracture or recent fracture) was based on fracture colour, shape, features, angle and associated marks (Blumenschine and Selvaggio, 1991; Villa and Mahieu, 1991).

To identify the modifications resulting from hominid activity on bone retouchers, we used the criteria detailed in Patou-Mathis and Schwab (2002), Mallye et al. (2012), Daujeard et al. (2014) and Moigne et al. (2016). We noted the taxon and anatomical element for each bone artefact relative to the total

Table 1 Number and frequencies of bone retouchers and lithic tool types by site and layer. MIS = Marine Isotope Stage; Nr. = number of retouchers (%Nr. calculated on total number of ungulate remains), (+) = retouchers on pebbles; Nl. = number of total lithic remains; Nl.t. = number of lithic tools (%Nl.t. calculated on Nl); Nb. = number of bifaces (%Nb. calculated on Nl); Ns. = number of scrapers (%Ns. calculated on Nl.t.). no av. = no available data. Site abbreviations and excavations: Gauthier in 1950s at Baume Flandin (BF); Gilles and Combier in 1950s-60s at Abri du Maras (AM: levels 1 and 2-5); Combier in 1960s at Orgnac 3 and Barasses II (BII: levels 2-4); de Lumley from 1967 to 2014 at Le Lazaret, and in 1960s at Baume des Peyrards (BP) and Terra Amata (TA); Gilles in 1970s at Saint-Marcel (SM); Moncel in 1990s at Payre and since 2005 at Baume Flandin (BF), Abri du Maras (AM 4-1), Abri des Pêcheurs and Le Figuier (GF); Daujeard from 2011 to 2013 at Barasses II (BII) and Raynal in 1990s-2000s at Sainte-Anne I (SAI) and Baume Vallée (BV).

Site	Units	MIS	Nr.	%Nr.	Nl.	Nl.t.	%Nl.t.	Nb.	%Nb.	Ns.	%Ns.
SM	a to j	3	274	7.3	3753	184	3.7-6.4	0	0.0	177	96.2
SM	k to t	5 s.l.	12	4.6	924	26	0-7	0	0.0	13	50.0
SM	u	5e	17	2.9	215	21	9.8	0	0.0	18	85.7
GF	2 to 5	3	3	1.1	304	33	10.9	0	0.0	17	51.5
AM	1	3	2	2.4	3695	45	1.2	0	0.0	26	57.8
AM	2 to 5	3	7	5.1	1989	144	7.2	0	0.0	82	56.9
AM	4-1	3	1	0.03	1864	50	2.7	0	0.0	15	30.0
BP	Upper	4-3	102	1.8	no av.	no av.	no av.	no av.	no av.	no av.	no av.
BV	0	5 s.l.	2 (+1)	0.8	89	3	3.4	0	0.0	2	66.7
BV	1	5 s.l.	11 (+4)	2.6	1602	320	20.0	0	0.0	285	89.1
BV	2	5/4	7 (+10)	1.7	956	335	35.0	0	0.0	295	88.1
BV	sup	3	0 (+22)	0.0	2977*	153	5.1	0	0.0	146	95.4
BII	2 to 4	3	4	1.1	173	10	5.8	0	0.0	7	70.0
BII	6 to 8	5 s.l.	5	1.2	618	8	1.3	0	0.0	3	37.5
BF	3	5e	5	4.0	136	11	8.1	1	0.7	7	63.6
SAI	J1-E1	6	37	2.1	4368	141	3.2	8	0.2	90	63.8
SAI	J2-E2	6	29	1.6	6734	93	1.4	0	0.0	64	68.8
SAI	J3-E3	6	7	2.5	680	19	2.8	0	0.0	12	63.2
SAI	Ind.	6	13	1.2	no av.	no av.	no av.	no av.	no av.	no av.	no av.
Lazaret	CIII	6	4	0.1	24916	1189	4.8	19	0.08	521	43.8
Lazaret	CII	6	14	0.2	56089	2366	4.2	311	0.6	1332	56.3
Payre	F	7	15	0.4	3700	422	11.6-30.6	6	0.2	193	45.7
Orgnac 3	5b	9	3	0.3	4174	447	10.7	28	0.7	209	46.8
Orgnac 3	6	9	5	0.4	2288	337	14.7	5	0.2	136	40.4
TA	CLs	11	1	no av.	6811	1263	18.5	8	0.1	52	4.1

*Nl for the upper levels of BV including the fine fraction

NISP present in the faunal assemblages. For the dimensions, we recorded the length (L), width (W) and thickness (T) of the artefacts in millimetres (mm) and give L/W ratios when available.

For the use marks, we listed the number of use areas by artefact and classified the type of use marks as follows (nomenclature adapted from Mallye et al., 2012; Daujeard et al., 2014; Moigne et al., 2016): hash marks or grooves and scores (hatched areas); cupules or pits (pitted areas) and sliding striations (comet striations) (Daujeard et al., 2014). One of the main criteria for identifying percussion marks is the presence of perpendicular micro-striations inside the retouching marks, which are similar to the sliding marks on surfaces (Vincent, 1993; Daujeard, 2014; van Kolfschoten et al., 2015). We measured the maximum length of the use areas and categorized them into three classes: < 10 mm, 10-20 mm,

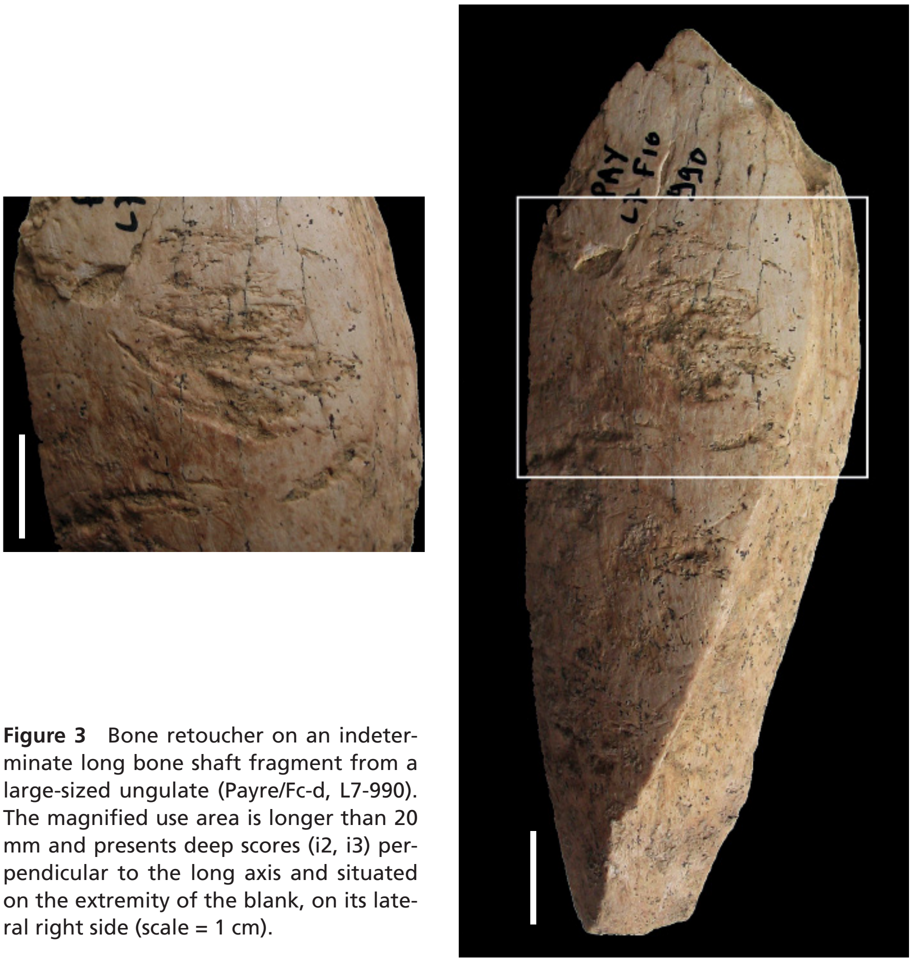

Figure 3 Bone retoucher on an indeterminate long bone shaft fragment from a large-sized ungulate (Payre/Fc-d, L7-990). The magnified use area is longer than 20 mm and presents deep scores (i2, i3) perpendicular to the long axis and situated on the extremity of the blank, on its lateral right side (scale = 1 cm).

> 20 mm. According to Mallye et al. (2012:1133), for the orientation of the retoucher and the localization of the marks, "the long axis of the retoucher is defined as its greatest length, and its apical part that on which the traces are located. When a retoucher has several areas with traces, it is reoriented for the analysis of each of them." We thus localized the use marks on two axes. Relative to length, the use marks were identified as apical (extremity of the piece) or centred. In relation to width, use marks were categorized as centred, covering or lateral (right or left). The orientations of the marks relative to the long bone axis were recorded as perpendicular and/or oblique when possible. We used three categories to describe the distribution and depth of use marks within the use areas: dispersed (i1); concentrated (i2); or superimposed (i3). Finally, we noted all existing or directly associated marks, including scraping marks, cutmarks, cortical notches or heating marks.

Results

Frequency of bone retouchers in the context of lithic technology

For the early series of Final Acheulean and Early Middle Palaeolithic industries dated to MIS 11, 9 and 7, from Terra Amata, Orgnac 3 and Payre, we observe similar low rates of bone artefacts in relation to the number of ungulate remains (see **Table 1**). At Terra Amata, the only identified bone retoucher comes from a pebble layer or barrier beach (CLs), in which shaping and knapping activities took place. At Orgnac 3, bone artefacts are present at the bottom of the sequence, in layers 6 and 5b with bifaces and no Levallois cores. At Payre, the 19 bone retouchers come from a layer containing large, heavy-duty lithic tools. The technology is based on discoidal and orthogonal flint cores, with mainly scrapers and points. In sites with Early Middle Palaeolithic industries dated to MIS 6, bone retoucher series occasionally become much more abundant, such as at Sainte-Anne I, where 87 bone artefacts are distributed throughout the three main units. There are some rare introduced bifaces at Sainte-Anne I, where Levallois and discoidal flaking were applied to cores made of volcanic rocks. There are many bifaces in the lower units at Le Lazaret (unit CII), which has provided more bone retouchers than the upper units (CIII) where bifaces become scarcer. Sequences containing Middle Palaeolithic industries dating from MIS 5 to 3, bone retouchers become more widespread, with marked variability in frequencies, regardless of core technology.

Types and dimensions of bone retoucher raw materials

At Terra Amata, the sole bone artefact is made on a red deer femur shaft, which is the main hunted species at the site. At Orgnac 3, distribution of retouchers by taxa is closely correlated to the overall faunal spectrum, with red deer, bovine and equid bone fragments (see **Supplementary data**). At Payre, we observed more selective behaviour with the predominant use of large or very large-sized ungulate remains (**Figure 3**). This differs from the relative proportions of the total spectrum, where red deer is dominant. Except for one distal epiphysis of a horse humerus at Payre, all the bone artefacts are various types of long bone shaft fragments. For those three sites, all the bone retouchers are made on very large fragments, with a mean length of about 100 mm (**Table 2**, **Figure 4**). At Payre, one bone retoucher made on a proboscidean ulna shaft is 285 mm long. For Sainte-Anne I and Le Lazaret, species distribution follows that of the total faunal spectrum (see **Supplementary data**). Reindeer and horse are the most represented taxa at Sainte-Anne I, and red deer was mostly used at Le Lazaret. Elongated long bone shaft fragments are also preferred, especially tibias and metapodials (see **Table 2**). A few rib fragments were used at Sainte-Anne I, where the dimensions of the bone artefacts are among the smallest observed. Some of the small fragments may have been longer during use, given that frost action impacted the faunal assemblages from this mid-mountain site. Nonetheless, some small elements without truncated retouching areas or post-depositional fractures have been documented.

For the Upper Pleistocene series, bone artefacts generally follow the overall ungulate spectrum distribution (see **Supplementary data**). At Baume Flandin and Barasses II, red deer remains, mostly accumulated by hominins, were widely used for bone

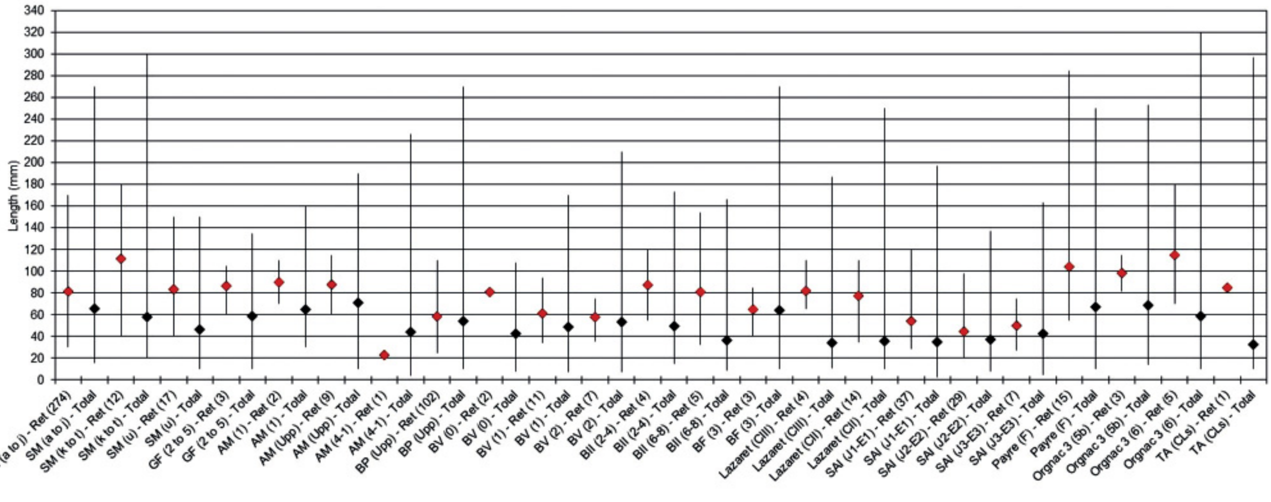

Figure 4 Minimum, maximum and mean lengths of the bone artefacts (red) compared to the lengths of the total bone remains for each series (black). See **Table 1** for site abbreviations.

Table 2 Description of the studied bone retouchers. Anatomical element data shown as % and (Nr) (Hum: humerus; Rau: radio-ulna; Rad: radius; Metc: metacarpal; Fem: femur; Tib: tibia; Mett: metatarsal; Metp: metapodial; Mand: mandible; LB: indeterminate long bone); Portion (SF: shaft fragment; EP: epiphysis); Breakage (GBB: green bone breakage); Nr burnt (number of burnt bone retouchers); Nr cut (number of cut marked bone retouchers); Dimensions (L: Length; W: Width; T: Thickness). no av. = no available data. See Table 1 for site abbreviations.

Site	Units	Anatomical element	Portion	Breakage	Nr. burnt	Nr. cut	Dimensions			
							L (mm)	W (mm)	T (mm)	L/W
SM	a to j	Tib: 19.3 (53), Rau: 11.3 (31), Metc: 11 (30), Hum: 11 (30), Fem: 7.3 (20), Mett: 6.6 (18), Metp: 5.5 (15), LB: 28.1 (77)	SF	Mostly GBB	17	40	81.6 (30-170)	no av.	no av.	no av.
SM	k to t	Tib: 6, Rau: 2, Fem: 2, Metc: 1, Hum: 1	SF	Mostly GBB	4	10	111.7 (40-180)	no av.	no av.	no av.
SM	u	Tib: 7, Metc: 3, Rau: 2, Hum: 2, Fem: 1, Mett: 1, LB: 1	SF	GBB	1	12	83.5 (40-150)	no av.	no av.	no av.
GF	2 to 5	Tib: 1, LB: 2	SF	GBB		1	86.7 (60-105)	no av.	no av.	no av.
AM	1	Rad: 1, LB: 1	SF	GBB		2	90 (70-110)	no av.	no av.	no av.
AM	2 to 5	Hum: 2, Fem: 1, Tib: 1, LB: 3	SF	GBB		2	87.9 (60-115)	no av.	no av.	no av.
AM	4-1	LB	SF	Ind.	1		23	8	no av.	2.9
BP	Upper	Tib: 21.6 (22), Fem: 20.6 (21), Hum: 15.7 (16), Rau: 4.9 (5), Metc: 3.9 (4), Mett: 1.9 (2), LB: 31.4 (32)	SF (1 EP)	Mostly GBB	2	85	58.6 (25-110)	no av.	no av.	no av.
BV	0	Tib: 1, Metc: 1	SF	GBB		2	81 (79-83)	28-29	7-7	2.8-2.9
BV	1	Hum: 3, Tib: 1, LB: 7	SF	GBB, frost		3	61.3 (34-94)	29.8 (20-44)	8.5 (2-14)	2.1 (1.3-3.4)
BV	2	Fem: 2, Tib: 1, LB: 4	SF	GBB, frost		5	57.9 (36-75)	31.9 (20-46)	11.4 (7-16)	1.8 (1.6-2.2)
BII	2 to 4	Fem: 1, Rad: 1, LB: 2	SF	GBB		1	87.5 (55-120)			
BII	6 to 8	Rib: 2, Tib: 1, Hum: 1, LB: 1	SF	Mostly GBB		1	81 (33-154)	23.8 (14-33)	6.8 (6-8)	3.5 (2.4-6.7)
BF	3	Tib: 2, Metc: 2, LB: 1	SF	GBB		4	65 (40-85)			
Lazaret	CIII	Metc: 3, LB: 1	SF: 3, EP: 1	Mostly GBB		1	82 (66-110)	25.5 (20-30)	19.5 (12-30)	3.3 (2.3-3.8)
Lazaret	CII	Tib: 5, Fem: 3, Hum: 1, Metc: 1, LB: 4	SF	Mostly GBB	7	2	77.5 (35-110)	23.9 (16-40)	14.6 (5-40)	3.2 (2.2-4.4)
SAI	J1-E1	Tib: 5, Mett: 4, Rib: 3, Rau: 3, Fem: 1, Metc: 1, Mand: 1, Ind. LB: 19	SF	GBB, frost		31	54.3 (29-120)	19.9 (9-42)	7.3 (2-21.1)	2.9 (1.3-8.6)
SAI	J2-E2	Tib: 2, Mett: 2, Rib: 2, Hum: 2, Metc: 2, Ind. LB: 19	SF	GBB, frost		23	44.7 (20-98)	17.7 (10-26)	5.4 (3-12)	2.6 (1.4-4.9)
SAI	J3-E3	Hum: 1, Metc: 1, Metp: 1, Ind. LB: 4	SF	GBB, frost		5	50.1 (27-75)	22.6 (12-41)	no av.	2.5 (1.6-5)
SAI	Ind.	Tib: 3, Hum: 3, Ind. LB: 7	SF	GBB, frost		10	65.2 (30-90)	27 (11-47)	9.1 (4-14)	2.5 (1.7-3.5)
Payre	F	Hum: 4, Ulna: 2, Tib: 1, Mett: 1, Metp: 1, LB: 7	SF: 15, EP: 1	Mostly GBB		8	104.3 (55-285)			
Orgnac 3	5b	Tib: 1, Metc: 1; Rad: 1	SF	GBB		1	98.5 (82-115)	26.5 (23-30)	21.5 (16-27)	3.7 (3.6-3.8)
Orgnac 3	6	Tib: 3, Mett: 1, Fem : 1	SF	GBB		1	115 (70-180)	32 (25-39)	21 (10-32)	5.1 (3.1-7.2)
TA	CLs	Fem	SF	GBB			85	27	20	3.1

retouchers. Conversely, the remains of other species that occur frequently in the assemblages but which were accumulated by carnivores or natural deaths, such as bovines or ibex, were not used. At Baume des Peyrards, ibex and red deer remains were preferentially selected. At Abri du Maras, horse and reindeer remains, the two dominant species, were also both selected. At Baume Vallée, bone artefacts are mainly on medium and large ungulate remains, following the same distribution as the faunal spectrum, with a majority of horse and cervids. Likewise, at Saint-Marcel, most of the bone retouchers are made of cervid remains (fallow deer, red deer, roe deer and giant deer, depending on the layers), which are far from the most important taxa in the sequence. Finally, in these youngest sites (MIS 5-3), almost all the retouchers are made on elongated long bone shaft fragments (see **Table 2**). We only noted the exceptional presence of a utilized ibex femoral head at Baume des Peyrards. Tibias or femurs are the most represented long bones. Apart from the assemblage of Baume-Vallée, which was impacted by frost, Baume des Peyrards and Baume Flandin are the only sites where bone retouchers have a mean length lower than 80 mm.

Nearly all of the bone artefacts present green bone fractures and various types of carcass processing cut marks (**Figure 5**, see also **Table 2**), and thus probably selected from butchery waste. For example, one bone artefact at Baume des Peyrards presents some use marks overlapping the fracture edge, indicating that this bone artefact was used

Figure 5 Bone retoucher on a red deer tibia shaft fragment bearing cut marks and green bone fractures (Baume Flandin, n. 45, coll. Gauthier). The use area presents concentrated deep scores (i2; 10-20 mm) oriented perpendicular to the long axis, situated on the extremity of the blank on its lateral left side, and appears to have been broken during use (truncated area) (scale = 1 cm).

Figure 6 Bone retoucher on an indeterminate shaft fragment of a medium-sized ungulate (Sainte-Anne I, R26-727). The use area presents widespread deep scores (i2) on the small bone surface (> 20 mm) and was probably truncated by a green bone fracture during use. Numerous associated scraping marks are also present (scale = 1 cm).

Figure 7 Bone retoucher on a burnt metacarpal shaft fragment of a red deer (Le Lazaret, Laz10-Q12-4567). The use marks are dispersed scores within a large area (i1; > 20 mm), perpendicular to the long axis and situated on the extremity of the blank (scale = 1 cm).

after the bone fracturing process (Daujeard et al., 2014). In a few cases, broken modified areas show that use may have caused the break (**Figure 6**, see also **Figure 3**). However, in the absence of systematic refitting, it remains difficult to discern the intentionality of bone fracturing and/or shaping for the use of bone remains as retouchers.

In the lower Acheulean unit CII at Le Lazaret, half of the bone retouchers are burnt (**Figure 7**, see also **Table 2**), either as a result of being thrown in the fire after use or prior to heating, accidentally or intentionally. The presence of some scaled zones on these artefacts seems to indicate a loss of freshness, which lends support to the latter hypothesis. Compared to Le Lazaret, the Upper Pleistocene samples contain very few burnt artefacts, and it is difficult to establish the precise sequence of events.

Number, position and description of the use areas and associated retouching marks

Pitted or hatched areas are visible on the oldest series of Terra Amata and Orgnac 3 retouchers (**Table 3**), with marks mostly perpendicular to the bone axis and on the extremities of the blanks, characteristic of retouching/resharpening the lithic edges by percussion. At Orgnac 3, only two bone retouchers present two use areas; all others have a single retouching zone. This is also the case at Payre, where most of the artefacts bear a single use area. Two have use marks at both ends of the blank and one has four use areas. Payre provides the most robust and longest artefacts, with the deepest and most extensive use marks. Some retouchers have associated cortical notches, demonstrating a powerful striking action (**Figure 8**, see also **Table 3**). More than a third of the use areas on the Payre retouchers bear circumscribed scraping marks indicating that the surface was cleaned before use. At Le Lazaret, the 18 bone retouchers have one or two use areas with shallow hash marks and pits on their edges, perpendicular or slightly oblique to the bone axis. Unlike at Payre, the widespread presence of scraping marks on the blanks from Le Lazaret unit CII suggests a link to butchery activities (fracture process) rather than the cleaning of the areas used for retouching. At Sainte-Anne I, which provided the smallest blanks, the retouch marks are among the shallowest observed. In this sample, we recorded a particularly high number of pitted areas associated with sliding striations, or what we call comet striations (cf. Daujeard et al., 2014). Many of these are situated on the mesial part of the blanks (centred), which is quite rare for the hatched areas, and may be related to a specific action still unknown.

Finally, among the Upper Pleistocene series, most of the marks are shallow hash marks present on blank extremities perpendicular to the long axis (see **Table 3**). A few examples from Baume Vallée (unit 1), Saint-Marcel (k-t) and Abri du Maras (upper units) bear numerous use areas with deep hash marks (i3). Some others, including Baume des Pey-

Table 3 Description of the use areas. Na (number of use areas); Na/blank (number of use areas per blank: 1, 2 or > 2); Type of marks (sc: scores; pit: pitted areas; stri: sliding striations); Lmax (maximum length of the use area); Orientation of marks (perp: perpendicular; obl: oblique; no: no orientation for cupules); Distribution and depth of marks (i1: dispersed; i2: concentrated; i3: superimposed); Location on blank (ap: apical; cent: centered; cov: covering); Position on the width (cent: centered; cov: covering; lat: lateral; R: right; L: left); Associated marks (Scr: scraping marks; Perc: notches or green bone fractures; Tr: truncated). no av. = no available data. See Table 1 for site abbreviations.

Sites	Units	Na	Na/blank	Type of marks	Lmax (mm)	Orientation of marks	Distribution and depth of marks	Location on blank	Position on width	Associated marks		
										Scr	Perc	Tr
SM	a to j	188	1:115, 2:27, >2:6	sc:154, pit:30, stri:4	<10:65, 10-20: 88, >20:35	perp:114, obl:40, no:34	i2:74, i1:65, i3:49	ap:178, cent:10	no av.	12	7	
SM	k to t	20	1:5, 2:6, >2:1	sc:14, sc-pit:6	<10:4, 10-20:7, >20:9	perp:10, obl:1, perp-obl:9	i2:10, i3:6, i1:4	ap:20	no av.	8		
SM	u	23	1:13, 2:2, >2:2	sc:19, sc-pit:2, pit-stri:1, sc-stri:1	<10:9, 10-20: 13, >20:1	perp:16, obl:4, perp-obl:2, no:1	i1:12, i2:10, i3:1	ap:23	no av.	5	1	1
GF	2 to 5	4	1:2; 2:1	sc:3, pit:1	10-20: 4	perp:1, obl:2, no:1	i1:2, i2:1, i3:1	ap	cent:2, no av.:2	2	1	1
AM	1	3	1:1; 2:1	sc-pit:2, sc:1	10-20:2, >20:1	perp:3	i1:2, i2:1	ap:3	cent:2, lat R:1	2	1	1
AM	2 to 5	12	1:5; >2:2	sc:10, sc-pit:2	10-20:8, >20:4	perp:7, obl:3, perp-obl:2	i3:7, i2:3, i1:2	ap:10, cent:1, ap-cent:1	cent:9, cov:1, lat R:1, lat L:1	2		3
AM	4-1	1	1:1	sc-pit-stri	<10	perp	i1	ap	no av.			
BP	Upper	118	1:102, 2:14, >2:2	sc:111, pit:5, stri:2	<10:15, 10-20: 87, >20:16	perp:90, obl:23, no:5	i2:58, i1:46, i3:14	ap:99, cent:19	no av.	29	3	
BV	0	3	1:1; 2:1	sc:1, sc-pit:1	10-20:1:>20:2	obl:2; perp-obl:1	i1:1, i2:1, i3:1	ap:3	cent:1, lat L:2		1	
BV	1	12	1:10; 2:1	sc:8, sc-pit:4	10-20:9:>20:3	perp:6, obl:5; perp-obl:1	i3:7, i1:3, i2:2	ap:12	cent:6, lat L:2, lat R:4	4	5	
BV	2	7	1:7	sc:5, sc-pit:1, pit:1	10-20:7	perp:3, obl:3; perp-obl:1	i1:4, i3:2, i2:1	ap:7	cent:5, lat L:2	1	4	
BII	2 to 4	5	1:3; 2:1	sc:5	<10:1, 10-20:2, >20:2	perp:3, obl:1, perp-obl: 1	i2:3, i1:2	ap:3, cent:2	cent:5	1	1	
BII	6 to 8	6	1:4; 2:1	pit-stri:3, sc:2, sc-pit:1	<10:3, 10-20:2, >20:1	perp:1, obl:3, no:2	i1:5, i2:1	ap:3, cent: 3	no av.	2	1	
BF	3	8	1:3; 2:1; >2:1	sc:6, sc-pit:2	10-20:4, >20:4	perp:6, perp-obl:2	i2:5, i1:2, i3:1	ap:8	lat L:5, cent:2, lat R:1	7	3	5
Lazaret	CIII	5	1:3; 2:1	sc:3, sc-pit:2	10-20:4, >20:1	perp:2, perp-obl:3	i1:4, i2:1	ap:5	lat L:3, cent:1, cov:1	1	1	1
Lazaret	CII	18	1:10; 2:4	sc:12, sc-pit:5, sc-pit-stri:1	<10:3, 10-20:8, >20:7	perp:7, obl:5, perp-obl:1, no:5	i1:9, i2:5, i3:4	ap:13, cent:4, ap-cent:1	cent:13, lat R:3, cov:2	5	4	1
SAI	J1-E1	43	1:30, 2:4, >2:3	stri:14, sc:10, pit:6, sc-pit:5, sc-stri:5, sc pit-stri:3	<10:4, 10-20: 22, >20:17	perp:25, obl:1, perp-obl:2, no:15	i1:30, i2:8, i3:5	cent:18, ap:15, cov:9, Ind:1	no av.	2	3	
SAI	J2-E2	29	1:29	sc:8, pit:5, sc-pit:7, stri:5, sc-stri:1, sc-pit-stri:3	<10:4, 10-20: 11, >20:14	perp:17, obl:1, perp-obl:2, no:9	i1:19, i2:8, i3:2	cent:10, ap:10, cov:9	no av.	4	2	
SAI	J3-E3	7	17	sc:5, sc-pit:2	10-20:6, >20:1	perp:7	i1:4, i2:2, i3:1	ap:4, cent:2, cov:1	no av.	1		
SAI	Ind.	20	1:11, 2:3, >2:1	sc:7, sc-pit:6, sc-stri:2, stri:3, pit:1, sc-pit-stri:1	<10:2, 10-20: 12, >20:6	perp:16, perp-obl:2, no:2	i1:7, i2:7, i3:6	ap:12, cent:5, cov:2, Ind:1	no av.	2		
Payre	F	20	1:13, 2:1, >2:1	sc:13, sc-pit:4, pit:3	<10:1; 10-20:9, >20:10	perp:17, perp-obl:1, no 2	i3:9, i2:7, i1:4	ap:11, cent:8, cov:1		6	7	5
Orgnac 3	5b	4	1:3; 2:1	sc-pit:3, sc:1	>20:4	perp:4	i2:3, i1:1	ap:2, cent:1	cent:3, lat R:1		3	
Orgnac 3	6	6	1:5; 2:1	sc-pit:6	10-20:3, >20:3	perp:4, perp-obl:2	i2:5; i3:1	ap:4, cent:2	cent:6		5	1
TA	CLs	1	1:1	sc:1		perp:1	i3:1	ap:1	lat L:1		1	

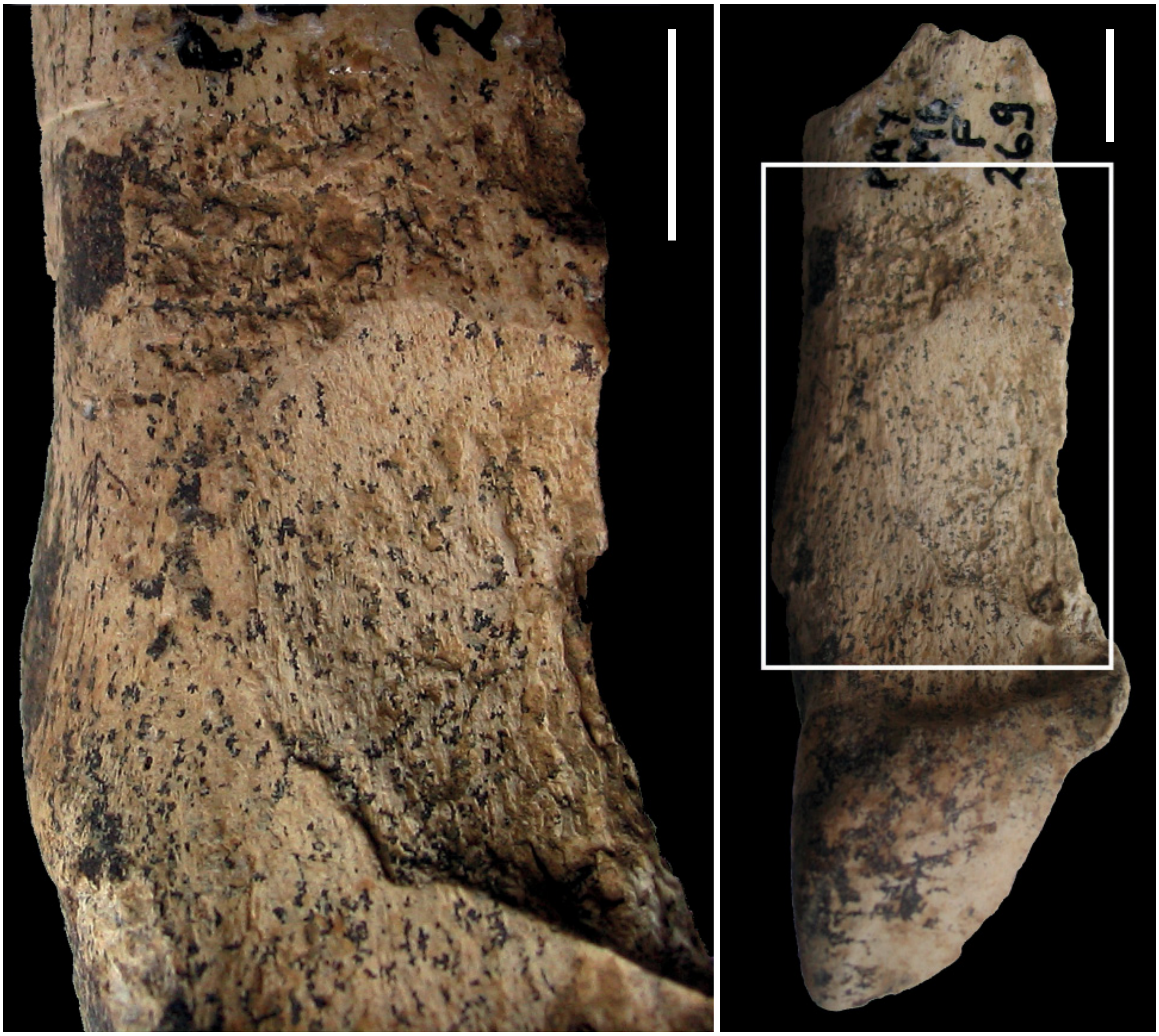

Figure 8 Bone retoucher on the distal part of a horse metapodial shaft fragment (Payre/Fc-d, M6-269). The use area present deep scores (i3) perpendicular to the long axis and concentrated on the extremity of the blank in its central part. The retouching area is associated with a percussion notch (scale = 1 cm).

rards, Saint-Marcel and Les Barasses II, show cupules (pits) associated with sliding striations (comet striations). With the exception of Baume Flandin, Baume Vallée (unit 1) and Saint-Marcel (k-t), where the majority of the use areas were "cleaned" beforehand, associated scraping marks are generally poorly represented (**Figure 9**; see also Daujeard et al., 2014). Finally, most of the recent series display some rare elements with deep grooves associated with notches or green bone fractures resulting from violent percussion (Daujeard et al., 2014).

Discussion

The main focus of this study was to analyze bone retoucher variability in relation to the faunal and cultural remains found in late Lower and Middle Palaeolithic sites in southeastern France, on both sides of the Middle Rhône valley. The large sample of bone retouchers studied here allows for a regional analysis of variability among these tools. Beyond that, we are able to extend our comparative approach to a wider European scale.

Figure 9 Bone retoucher on a tibia shaft fragment of a large-sized ungulate (Baume Vallée, unit 1, H6_811). The used area presents deep and concentrated scores on the extremity of the blank, associated with anterior scraping marks (see also Fiore et al., 2005 for the use mark description) (scale = 1 cm).

Variations in bone retoucher frequency

The main difficulty involved in comparative analyses concerns differences in counting faunal remains, which depend on the researcher (see Materials and methods). To overcome this, we compare the number of bone retouchers with the NISP of ungulates, which is a stable count in our faunal analyses (**Figure 10**, see also **Table 1**). The identification of retouching marks represents another difficulty. We listed in the method section the various criteria used to distinguish the marks caused by the use of bone to shape lithic tools, but sometimes doubts persist. This is the case for incipient percussion marks concentrated on circumscribed surfaces that could be mistaken with intentional retouching marks. Another important point relates to the observation process itself. We only recognize the marks we expect to find, so it is likely that such use marks for earlier sites went unnoticed.

Nonetheless, based on current data, the oldest bone retouchers we studied are dated to MIS 11.

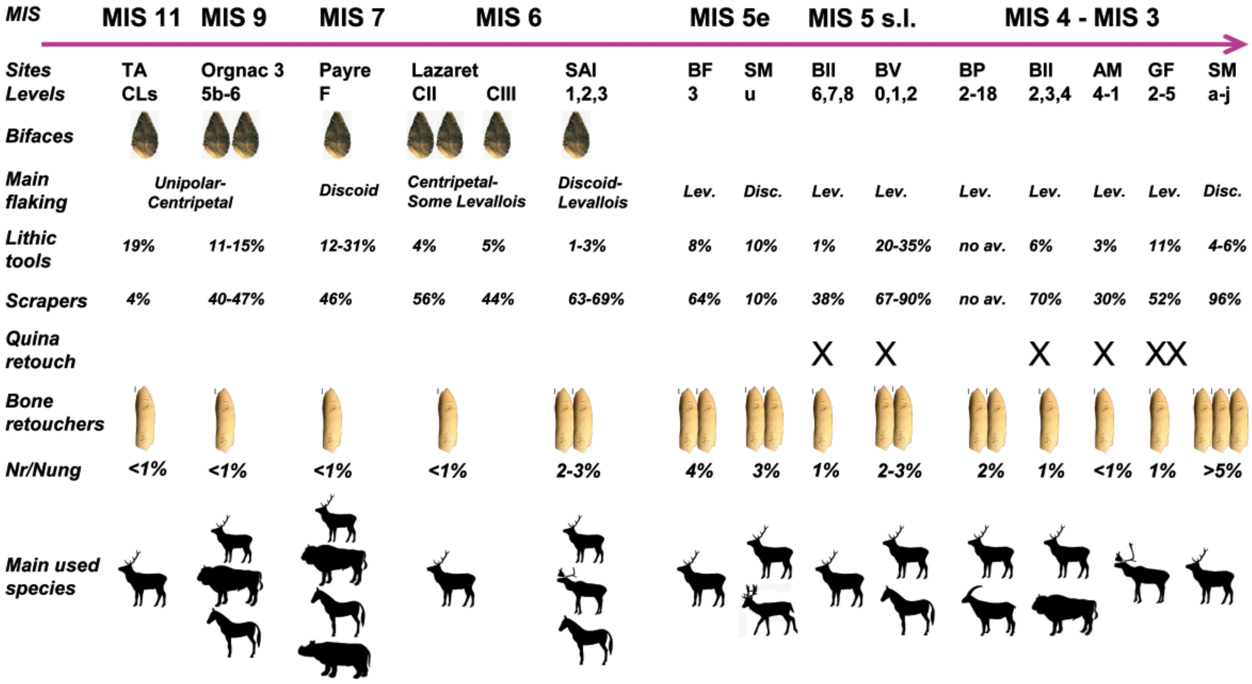

Figure 10 Contextual data for sites with bone retouchers in southeastern France: presence of bifaces; main flaking technology; percentages of lithic tools relative to the overall lithic assemblages; percentages of scrapers relative to overall number of tools; presence of Quina or semi-Quina retouch; frequency of bone artefacts; equivalence or non-equivalence with total ungulate spectra; and main used species. TA: Terra Amata; Orgnac 3; Payre; SAI: Sainte-Anne I; Le Lazaret; BF: Baume Flandin; SM: Saint-Marcel; BII: Barasses II; BV: Baume Vallée; BP: Baume des Peyrards; AM: Abri du Maras; GF: Grotte du Figuier.

From MIS 11-7, bone retouchers remain rare in the Final Acheulean and Early Middle Palaeolithic assemblages (see references in the Introduction). The number of these bone artefacts increases with the onset of Middle Palaeolithic technology, from the end of MIS 7 to MIS 5, for example at Sainte-Anne I in south-central France or Biache-Saint-Vaast in northern France (Auguste, 2002). Then, when the Middle Palaeolithic becomes widespread, with distinct regional traditions after MIS 5, these bone artefacts become ubiquitous. The sites with the highest numbers of bone artefacts, sometimes totaling several hundred pieces, are contemporaneous with the Late Middle Palaeolithic, such as the upper levels of Saint-Marcel (Nr = 274), level 22 at Jonzac (Nr = 202; Beauval, 2004) or Les Pradelles Facies 4a (Nr = 497; Costamagno et al., 2018) in France, Axlor (Nr = 492; Mozota, 2009, personal communication) in Spain or Kůlna in the Czech Republic (Nr = 248; Vincent, 1993; Auguste, 2002). Blasco et al. (2013a) also underline this link between the emergence of bone retouchers and the development of post-Acheulean, Middle Palaeolithic technology, and further suggest that the latter technology required more retouching than the Acheulean (new or different lithic management strategy).

Nevertheless, from MIS 7 onwards, we observe great variations in the number of bone retouchers in each occupation layer throughout southeastern France, and Europe as a whole, and the reasons for this variability remain unknown.

Looking at the Orgnac 3 and Le Lazaret series, we could question the relationship between the presence of bone retouchers and bifacial technology, given that the bone artefacts are more numerous in the lower units. Yet, the frequencies of bone retouchers remain very low in these layers, and numerous bone retouchers series at other sites are associated with lithic industries devoid of or comprising very few bifaces, for example at Sainte-Anne I or in all the youngest Middle Palaeolithic assemblages (see **Figure 10**). At the beginning of MIS 3 at Abri du Maras, which presents Levallois core technology, bone retouchers are rare. In contrast, many bone retouchers are associated with the mainly Levallois core technology at Baume-Vallée and Baume des Peyrards (MIS 5-3), as well as at Biache-Saint-Vaast (MIS 7). The site of Saint-Marcel (MIS 3), with discoid lithic technology, yielded abundant bone retouchers, as did the site of Le Rozel in northern France (Sévêque and Auguste, 2018). Finally, the sites of Les Pradelles and Qesem Cave in Israel, both with Quina technology and numerous Quina scrapers, also contain many bone retouchers (Blasco et al. 2013a; Rosell et al., 2015; Costamagno et al., 2018). Given that the presence of a high number of bone artefacts is associated with various types of lithic technology, bone retouchers cannot be linked to specific debitage modes.

The number of bone retouchers is also not related to the tool ratios and the type of lithic tools recovered in the assemblages. At Saint-Marcel, we observed some of the lowest ratios of stone tools and the highest ratios of bone retouchers. These very low ratios of tools compared to the richness of the bone retouchers cannot solely be explained by the export of some tool kits or by the unexcavated parts of the site (Daujeard et al., 2014). Regarding scraper production and re-sharpening, some series contain a very small number of retouched tools (Saint-Marcel and Sainte Anne I), while others, like Baume-Vallée, contain a high number of retouched tools that are essentially scrapers; nevertheless, both have the richest series of bones retouchers. In the rare sites with Quina or semi-Quina retouch (Le Figuier, Abri du Maras, Barasses II and Baume-Vallée; see **Figure 9**), bone retouchers are not proportionally more abundant and there is no clear difference in their surface modifications.

Overall, we observe similar rates of bone retouchers for different sorts of raw material, for example the volcanic rocks at Sainte-Anne I and Baume Vallée compared to the various types of flint at the Middle Palaeolithic sites of Ardèche. Abri des Pêcheurs, which yielded mainly quartz artefacts, may be one exception regarding the absence of bone retouchers in the Middle Palaeolithic.

Finally, could the frequency of bone retouchers be related to the type of hominin occupation and activities? For example, at Saint-Marcel, associated with long-term hominin occupations, we observe the most numerous retoucher series. In contrast, in the contemporaneous bivouac occupations of Les Barasses II or Les Pêcheurs, bone retouchers are rare or absent.

To conclude on the varying frequencies of bone retouchers studied on regional and temporal scales, it remains difficult to find a suitable explanation for their presence/absence or abundance/scarcity based on a single factor. Scraper production and re-use, the mobility strategy of the artefacts, the type of activities performed in and immediately surrounding the sites, or even the occupation duration, may all be taken into account in a multi-factorial attempt to explain patterns. Therefore, this question requires further investigation through more extensive data sets at a larger geographical and chronological scale (up to the Upper Palaeolithic); or, on the contrary, at a reduced scale with more information about very local subsistence strategies.

What about variations in the type of bone elements?

The same types of bone elements were used from MIS 11 to MIS 3: mainly long bone shaft fragments, usually on medium- or large-sized ungulate remains. They are sometimes, but not always, proportionate to the total faunal spectra and the long bone elements present in the faunal assemblages (see **Supplementary data**). Red deer is by far the most frequently used taxon (see **Figure 10**), but small- and other medium-sized ungulates such as roe deer, chamois, fallow deer, reindeer or ibex are frequent and were used for retouchers at Saint-Marcel, Abri du Maras and Baume des Peyrards. Large and even very large ungulates, such as bovines, horse, giant deer and rhinoceros offered suitable raw material for retouchers at Orgnac 3, Payre-F, Sainte-Anne I and Baume-Vallée. The only bone retouchers produced on an articular portion of the skeleton were recorded at Baume des Peyrards (on the femoral head of an ibex) and at Payre (on a distal end of a horse humerus). Except at Le Lazaret, no retouchers on antlers or animal teeth were discovered among our assemblages, nor did we observe any retouchers made on rare elements, such as human or carnivore remains. Generally, in southeastern France, no specific *chaîne opératoire* for the production of bone retouchers was recorded. They appear to have been selected *a posteriori* from discarded butchery remains, depending on how they fit in the hand, their physical properties and their surface characteristics, as well as cultural or individual preferences. In our earliest series, we observed the most robust bone artefacts, which may be related to specific needs, such as the manufacturing of heavy-duty tools at Payre or Orgnac 3 (pebble-tools and bifacial tools). In addition to these bone artefacts, some Middle Palaeolithic assemblages from the Iberian Peninsula (Cuartero, 2014), the site of Arma dell Manie in Italy (Cauche, 2007), Terra Amata (de Lumley, 2015), Le Lazaret (Darlas, 1994; de Lumley et al., 2004), Baume-Vallée (Raynal et al., 2005) and Champ Grand (Nicoud, 2008; Roux, 2008) in southeastern France, contain many small and flat pebbles used as retouchers. These are sometimes as frequent as bone retouchers and bear similar striations and hash marks. All these sites are distinct, both in terms of raw lithic materials and lithic industries. Furthermore the use of stone pebbles, as well as the use of bone, teeth, antlers or eventually wood for the same purposes, may indicate human preferences rather than functional requirements. Similarly, the use of cervid antlers is rarely observed during the Middle Palaeolithic, in contrast to the Acheulean or Early Middle Palaeolithic and Upper Palaeolithic periods. Is the use of antler also related to cultural aspects, or linked to functional purposes, perhaps handaxe shaping?

As for the morphology and size of the used blanks, they are usually elongated, with a mean length ranging from 50 to 120 mm – always greater than that of the total bone assemblages (see **Figure 4**). The oldest series include the largest bone artefacts. At Sainte-Anne I, Baume Vallée and Baume des Peyrards, we recorded the smallest retouchers. Yet, it is difficult to determine if used blanks were fractured before, during or after use. For example, at the two mid-mountain sites of Sainte-Anne I and Baume-Vallée, post-depositional frost action may have caused fractures, reducing the dimensions of some pieces. Nonetheless, in some cases the small dimensions of the blanks can be considered as intentional, based on the position and completeness of the use marks on the piece. This is the case for Qesem Cave, where Rosell et al. (2015; see also Blasco et al., 2013a, 2014) observed very small bone retouchers mainly made on cervid remains and associated with Quina technology. Another example is the site of La Quina itself, which has yielded many reindeer first phalanges used as retouchers (Valensi, 2002). This introduces the question of dedicated *chaînes opératoires* for the production of bone retouchers, as we now know that bones are sometimes considered as a raw material for debitage. Some specific items, such as refitted bones, may allow us to study the manufacture and/or use histories of retouchers in the same way as lithic production. Such specific bone artefacts do exist in the Middle Palaeolithic, but are scarce; for example the bone retouchers on refitted cave bear elements from Scladina (Abrams et al., 2014) and from Fate Cave (Valensi and Psathi, 2004) or on brown bear remains at Biache-Saint-Vaast (Auguste, 2002) and Fumane Cave (Jéquier et al., 2012). There are also a few examples of bone retouchers made on Neanderthal remains: a parietal fragment at La Quina (Verna and d'Errico, 2011), femur shaft fragments at Krapina (Patou-Mathis, 1997) and Les Pradelles (Mussini, 2011), and on femur and tibia fragments at Goyet (Rougier et al., 2016). Indeed, the majority of Middle Palaeolithic bone retouchers seem to have been selected *ad hoc* from discarded butchery remains (i.e., recycling). However, this is only a cautious assumption, as systematic refits are usually not available.

In the same way, some authors observed splinters/flakes at the extremity of the bone retouchers, indicating the possible use of the bone as an intermediate tool or shaping to obtain flakes better adapted for handling (Abrams et al., 2014; Costamagno et al., 2018; Toniato et al., 2018). Therefore, it appears necessary to study or revise bone retouchers series accordingly, by considering bone blanks as part of a complete *chaîne opératoire* (cf. Abrams et al., 2014) and not as "unmodified bone tools used for a particular purpose" (Rosell et al., 2011:125).

What about variations of the type and location of the percussion and associated marks?

The type of marks observed on bone artefacts may depend on either the use (e.g., anvil, hammer, retouching Quina or non-Quina scrapers, resharpening primary non-retouched lithic edges, etc.), intensity of use or the type of worked stone.

We mainly observed circumscribed use areas including slight hash marks with a V-shaped section situated on one extremity of the blank. Following the work of many authors who conducted experiments (Vincent, 1993; Armand and Delagnes, 1998; Tartar, 2002, 2009, 2012; Mozota, 2009, 2013; Mallye et al., 2012; among others and our unpublished data), these marks are characteristic of the short, once-off use of bone to resharpen or retouch lithic edges, producing marginal micro-retouch or to shape and re-shape semi-Quina or Quina scrapers. Some rare artefacts were used for vigorous percussion, scraping or pressure, or used as an anvil. Associated notches and green bone fractures, like at the sites of Payre-F, Baume Vallée or Saint-Marcel, may be the result of such use. The abundance of the use marks known as "comet striations" at Sainte-Anne I may possibly be linked to a particular function.

The depth and dispersal of retouching marks, as well as the number of use areas by blank (sometimes up to four), indicate the intensity and longevity of the utilization of some bone artefacts. The great majority of single and dispersed use areas indicate that bone artefacts generally have a short lifecycle. Nevertheless, in some cases, probably influenced more by the choice of the knapper than by the availability of faunal raw materials, bone artefacts seem to have been recycled, either by scraping the use area or by interchanging the used extremity.

Some experimental studies successfully differentiated the lithic raw materials struck by the retouchers based on retouching marks (e.g., Rosell et al., 2011; Mallye et al., 2012). The bone retouchers from Payre are robust and bear deep crushing marks, perhaps as a result of the particular resilience of the flint on which they were used; yet, the production of heavy-duty tools cannot be ruled out. At Sainte-Anne I, the widespread use of basalt and phonolite may also partly explain why the bone retouchers bear numerous pitted areas and sliding striations (comet striations).

The presence of circumscribed areas with associated retouching and scraping marks are indicative of periosteum removal before use and therefore of the fresh state of the blanks (Tartar, 2009). Except for the cleaning of the bone surfaces, which is recurrent among the series, no particular modifications were made after breakage, which may have been intentionally produced or a result of marrow recovery.

What type of nomenclature?

What type of nomenclature can we use for these ubiquitous bone artefacts? Should we opt for nomenclature based on function? Can we identify blank utilization through the experimental use of bone hammers, pressure flakers, anvils (use marks located on the mesial parts of the element), etc.? The broad category of "soft knapping tools" (van Kolfschoten et al., 2015) could represent a good compromise, as it takes into account the similarity of these bone tools throughout time and the difficulty involved in clearly associating them with a specific function. However, the term "knapping" appears to be too simplistic.

It may be more appropriate to use a broader categorization, based more on the morphology of the observed marks than on function, as proposed by Patou-Mathis (2002). In that work, which includes the analyses of bone artefact series dating from various periods of the Palaeolithic, the main distinction is based on the type of anatomical support: long bone fragments, cervid antlers, articular portions, teeth, etc., rather than on the type of use marks, grouped under the term *impressions et éraillures*. In most cases, bone artefacts were active tools used to strike lithic products in order to thin, retouch or resharpen flake/tool edges. In such cases, they can be called "retouchers" or "hammers". It is only appropriate to use the terms "compressors" or "pressure flakers" in a few cases, particularly for Upper Palaeolithic periods.

Conclusion

In southeastern France, as well as elsewhere in Europe, the use of bone to retouch or shape lithic products can be related to the emergence of the Middle Palaeolithic and to new behaviours between MIS 11 and MIS 9. Their frequency increases after MIS 7 and becomes almost omnipresent after MIS 5, but is still highly variable throughout the Middle Palaeolithic. This variability in southeastern France seems to depend more on the type of occupations than on the associated lithic technologies. A regional study of these bone artefacts should be developed in the future to elucidate this point, taking into account occupation durations as well as the activities occurring in and around the sites.

This comparative work is still exploratory and should be completed and further developed by adding more archaeological as well as experimental data. Nevertheless, it highlights the widespread use of this bone tool and the similarity of these artefacts across Late Acheulean/Early Middle Palaeolithic to Middle Palaeolithic assemblages.

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Supplementary data

Number of identified specimens of ungulates (NISPu) and indeterminate ungulate remains (NRu) (LU: large ungulates; MU: middle-sized ungulates; SU: small ungulates), number of bone retouchers (Nr), number of identified specimens per ungulate taxa relative to all identified ungulate remains (%NISPu), and rates of bone retouchers based on the NISP of each ungulate taxon (1) and on the total number of ungulates (2). Standard errors and (Confidence Intervals with lower and upper confidence bounds) shown for percentage values.

Sites (1)	Saint-Marcel (a to j)					Saint-Marcel (k to t)				Saint-Marcel (u)			
	NISPu	Nr	%NISPu	%Nr(1)	%Nr(2)	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr (1)
Proboscideans													
Suids													
Rhinocerotids										3		0.7 0.8 (-0.1-1.5)	
Equids	17	1	0.9 0.4 (0.5-1.4)	5.9 11.2 (-5.3-17.1)	0.4 0.7 (-0.3-1.1)	18		10.8 4.7 (6.1-15.6)		2		0.5 0.6 (-0.2-1.1)	
Megaloceros	4	1	0.2 0.2 (0-0.4)	25.0 42.4 (-17.4-67.4)	0.4 0.7 (-0.3-1.1)	3	2	1.8 2 (-0.2-3.8)	66.7 53.3 (13.3-120)	2		0.5 0.6 (-0.2-1.1)	
Reindeer													
Red deer	1624	158	90.6 1.4 (89.2-91.9)	9.7 1.4 (8.3-11.2)	57.7 5.9 (51.8-63.5)	99	7	59.6 7.5 (52.2-67.1)	7.1 5 (2-12.1)	84	9	19.2 3.7 (15.5-22.9)	10.7 6.6 (4.1-17.3)
Fallow deer	3		0.2 0.2 (0-0.4)			18	3	10.8 4.7 (6.1-15.6)	16.7 17.2 (-0.5-33.9)	272	7	62.1 4.5 (57.6-66.6)	2.6 1.9 (0.7-4.5)
Roe deer	108	8	6.0 1.1 (4.9-7.1)	7.4 4.9 (2.5-12.3)	2.9 2 (0.9-4.9)	23		13.9 5.3 (8.6-19.1)		67		15.3 3.4 (11.9-18.7)	
Bovines	10		0.6 0.3 (0.2-0.9)							1		0.2 0.4 (-0.2-0.7)	
Caprines	27		1.5 0.6 (0.9-2.1)			5		3.0 2.6 (0.4-5.6)		7		1.6 1.2 (0.4-2.8)	
Rupicaprines													
LU	73	7	3.7 0.8 (2.9-4.5)	9.6 6.8 (2.8-16.3)	2.6 1.9 (0.7-4.4)	4		4.1 4 (0.2-8.1)		2		1.4 1.9 (-0.5-3.3)	
MU	1823	99	92.4 1.2 (91.2-93.6)	5.4 1.0 (4.4-6.5)	36.1 5.7 (30.4-41.8)	93		95.9 4 (91.9-99.8)		143	1	98.6 1.9 (96.7-100.5)	0.7 1.4 (-0.7-2.1)
SU	77		3.9 0.9 (3-4.8)										
Total NISPu	1793	168		9.4 1.3 (8-10.7)	61.3 5.8 (55.5-67.1)	166	12		7.2 3.9 (3.3-11.2)	438	16		3.7 1.8 (1.9-5.4)
Total NRu	1973	106		5.4 1 (4.4-6.4)	38.7 5.8 (32.9-44.5)	97				145	1		0.7 1.3 (-0.7-2)
Total UNG	3766	274		7.3 0.8 (6.4-8.1)	100.0	263	12		4.6 2.5 (2-7.1)	583	17		2.9 1.4 (1.6-4.3)

Sites (2)	Abri du Maras (1)				Abri du Maras (2 to 5)				Abri du Maras (4-1)			
	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr (1)
Proboscideans												
Suids												
Rhinocerotids												
Equids	9		22 12.7 (9.3-34.6)		30	3	21.7 6.9 (14.9-28.6)	10 10.7 (-0.7-20.7)	75		6.6 1.4 (5.1-8)	
Megaloceros									20		1.7 0.8 (1-2.5)	
Reindeer	19	1	46.3 15.3 (31.1-61.6)	5.3 10 (-4.8-15.3)	87	1	63 8.1 (55-71.1)	1.1 2.2 (-1.1-3.4)	1030		90 1.7 (88.3-91.8)	
Red deer	5		12.2 10 (2.2-22.2)		7		5.1 3.7 (1.4-8.7)		6		0.5 0.4 (0.1-0.9)	
Fallow deer												
Roe deer												
Bovines	8		19.5 12.1 (7.4-31.6)		6	1	4.3 3.4 (0.9-7.8)	16.7 29.8 (-13.2-46.5)	8		0.7 0.5 (0.2-1.2)	
Caprines					8		5.8 3.9 (1.9-9.7)		5		0.4 0.4 (0.1-0.8)	
Rupicaprines												
LU	6	1	14.6 10.8 (3.8-25.5)	16.7 29.8 (-13.2-46.5)	4	2	10 9.3 (0.7-19.3)	50 49 (1-99)	215		8.6 1.1 (7.5-9.7)	
MU	35		85.4 10.8 (74.5-96.2)		36	2	90 9.3 (80.7-99.3)	5.6 7.5 (-1.9-13)	2247	1	90.2 1.2 (89-91.3)	0.04 0.1 (0-0.1)
SU									30		1.2 0.4 (0.8-1.6)	
Total NISPu	41	1		2.4 4.7 (-2.3-7.2)	138	5		3.6 3.1 (0.5-6.7)	1144			
Total NRu	41	1		2.4 4.7 (-2.3-7.2)	40	4		10 9.3 (0.7-19.3)	2492	1		0.04 0.1 (0-0.1)
Total UNG	82	2		2.4 4.7 (-2.3-7.2)	178	9		5.1 3.2 (1.8-8.3)	3636	1		0.03 0.1 (0-0.1)

Sites (3)	Grotte du Figuier (2 to 5)				Baume des Peyrards (Upper)				
	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr(1)	%Nr(2)
Proboscideans									
Suids									
Rhinocerotids									
Equids	20		11.3 4.7 (6.6-16)		182	1	3.9 0.6 (3.4-4.5)	0.5 1.1 (-0.5-1.6)	1 1.9 (-0.9-2.9)
Megaloceros									
Reindeer	96	1	54.2 7.3 (46.9-61.6)	1 2 (-1-3.1)					
Red deer	8		4.5 3.1 (1.5-7.6)		492	14	10.6 0.9 (9.7-11.5)	2.8 1.5 (1.4-4.3)	13.7 6.7 (7-20.4)
Fallow deer	3		1.7 1.9 (-0.2-3.6)						
Roe deer					135		2.9 0.5 (2.4-3.4)		
Bovines	7		4 2.9 (1.1-6.8)		23		0.5 0.2 (0.3-0.7)		
Caprines	41		23.2 6.2 (16.9-29.4)		3752	54	80.7 1.1 (79.5-81.8)	1.4 0.4 (1.1-1.8)	52.9 9.7 (43.3-62.6)
Rupicaprines	2		1.1 1.6 (-0.4-2.7)		68	1	1.5 0.3 (1.1-1.8)	1.5 2.9 (-1.4-4.3)	1 1.9 (-0.9-2.9)
LU	24	1	24.5 8.5 (16-33)	4.2 8 (-3.8-12.2)	55	1	6.3 1.6 (4.7-7.9)	1.8 3.5 (-1.7-5.3)	1 1.9 (-0.9-2.9)
MU	74	1	75.5 8.5 (67-84)	1.4 2.6 (-1.3-4)	796	31	90.8 1.9 (88.8-92.7)	3.9 1.3 (2.6-5.2)	30.4 8.9 (21.5-39.3)
SU					26		3 1.1 (1.8-4.1)		
Total NISPu	177	1		0.6 1.1 (-0.5-1.7)	4652	70		1.5 0.3 (1.2-1.9)	68.6 9 (59.6-77.6)
Total NRu	98	2		2 2.8 (-0.8-4.8)	877	32		3.6 1.2 (2.4-4.9)	31.4 9 (22.4-40.4)
Total UNG	275	3		1.1 1.2 (-0.1-2.3)	5529	102		1.8 0.4 (1.5-2.2)	100

Sites (4)	Baume Vallée (0)				Baume Vallée (1)				Baume Vallée (2)			
	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr (1)
Proboscideans												
Suids												
Rhinocerotids												
Equids	18		35.3 13.1 (22.2-48.4)		55	1	65.5 10.2 (55.3-75.6)	1.8 3.5 (-1.7-5.3)	116		83.5 6.2 (77.3-89.6)	
Megaloceros												
Reindeer												
Red deer	25	1	49 13.7 (35.3-62.7)	4 7.7 (-3.7-11.7)	9		10.7 6.6 (4.1-17.3)		9		6.5 4.1 (2.4-10.6)	
Fallow deer												
Roe deer												
Bovines	2		3.9 5.3 (-1.4-9.2)		5		6 5.1 (0.9-11)		3		2.2 2.4 (-0.3-4.6)	
Caprines	6		11.8 8.8 (2.9-20.6)		15		17.9 8.2 (9.7-26)		11		7.9 4.5 (3.4-12.4)	
Rupicaprines												
LU	80		37.7 6.5 (31.2-44.3)		166	6	47.8 5.3 (42.6-53.1)	3.6 2.8 (0.8-6.5)	178	3	63.3 5.6 (57.7-69)	
MU	128	1	60.4 6.6 (53.8-67)	0.8 1.5 (-0.7-2.3)	174	4	50.1 5.3 (44.9-55.4)	2.3 2.2 (0.1-4.5)	102	4	36.3 5.6 (30.7-41.9)	1.7 1.9 (-0.2-3.6)
SU	4		1.9 1.8 (0.1-3.7)		7		2 1.5 (0.5-3.5)		1		0.4 0.7 (-0.3-1.1)	3.9 3.8 (0.2-7.7)
Total NISPu	51	1		2 3.8 (-1.8-5.8)	84	1		1.2 2.3 (-1.1-3.5)	139			
Total NRu	212	1		0.5 0.9 (-0.5-1.4)	347	10		2.9 1.8 (1.1-4.6)	281	7		2.5 1.8 (0.7-4.3)
Total UNG	263	2		0.8 1 (-0.3-1.8)	431	11		2.6 1.5 (1.1-4)	420	7		1.7 1.2 (0.4-2.9)

Sites (5)	Barasses II (2-4)				Barasses II (6-8)				Baume Flandin (3)			
	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr (1)
Proboscideans												
Suids												
Rhinocerotids												
Equids	4		2.6 2.5 (0.1-5.1)		5		3.2 2.8 (0.4-6)		11		12.4 6.8 (5.5-19.2)	
Megaloceros												
Reindeer	7		4.6 3.3 (1.3-7.9)						1		1.1 2.2 (-1.1-3.3)	
Red deer	12	1	7.8 4.3 (3.6-12.1)	8.3 15.6 (-7.3-24)	31	2	20.1 6.3 (13.8-26.5)	6.5 8.6 (-2.2-15.1)	57	4	64 10 (54.1-74)	7 6.6 (0.4-13.6)
Fallow deer									2		2.2 3.1 (-0.8-5.3)	
Roe deer									13		14.6 7.3 (7.3-21.9)	
Bovines	7	1	4.6 3.3 (1.3-7.9)	14.3 25.9 (-11.6-40.2)	5		3.2 2.8 (0.4-6)		5		5.6 4.8 (0.8-10.4)	
Caprines	123		80.4 6.3 (74.1-86.7)		100		64.9 7.5 (57.4-72.5)					
Rupicaprines					13		8.4 4.4 (4.1-12.8)					
LU	11	2	5.6 3.2 (2.4-8.9)	18.2 22.8 (-4.6-41)	16	1	6.2 3 (3.3-9.2)	6.3 11.9 (-5.6-18.1)	2		5.4 7.3 (-1.9-12.7)	
MU	182		93.3 3.5 (89.8-96.8)		201	2	78.2 5 (73.2-83.3)	1 1.4 (-0.4-2.4)	35	1	94.6 7.3 (87.3-101.9)	2.9 5.5 (-2.7-8.4)
SU	2		1 1.4 (-0.4-2.4)		40		15.6 4.4 (11.1-20)					
Total NISPu	153	2		1.3 1.8 (-0.5-3.1)	154	2		1.3 1.8 (-0.5-3.1)	89	4		4.5 4.3 (0.2-8.8)
Total NRu	195	2		1 1.4 (-0.4-2.4)	257	3		1.2 1.3 (-0.1-2.5)	37	1		2.7 5.2 (-2.5-7.9)
Total UNG	348	4		1.1 1.1 (0-2.3)	411	5		1.2 1.1 (0.2-2.3)	126	5		4 3.4 (0.6-7.4)

Sites (6)	Sainte-Anne I (J1-E1)					Sainte-Anne I (J2-E2)					Sainte-Anne I (J3-E3)			
	NISPu	Nr	%NISPu	%Nr(1)	%Nr(2)	NISPu	Nr	%NISPu	%Nr(1)	%Nr(2)	NISPu	Nr	%NISPu	%Nr (1)
Proboscideans	2		0.7 1 (-0.3-1.7)			2		0.5 0.7 (-0.2-1.2)			14		10.1 5 (5.1-15.1)	
Suids														
Rhinocerotids	1		0.4 0.7 (-0.3-1)			12		3 1.7 (1.3-4.7)			22		15.8 6.1 (9.8-21.9)	
Equids	113	4	40.1 5.7 (34.4-45.8)	3.5 3.4 (0.1-6.9)	10.8 10 (0.8-20.8)	145	2	36.2 4.7 (31.5-40.9)	1.4 1.9 (-0.5-3.3)	6.9 9.2 (-2.3-16.1)	52	1	37.4 8 (29.4-45.5)	1.9 3.7 (-1.8-5.7)
Megaloceros														
Reindeer	140	6	49.6 5.8 (43.8-55.5)	4.3 3.4 (0.9-7.6)	16.2 11.9 (4.3-28.1)	190	4	47.4 4.9 (42.5-52.3)	2.1 2 (0.1-4.1)	13.8 12.6 (1.2-26.3)	34		24.5 7.1 (17.3-31.6)	
Red deer	5	1	1.8 1.5 (0.2-3.3)	20 35.1 (-15.1-55.1)	2.7 5.2 (-2.5-7.9)	12	1	3 1.7 (1.3-4.7)	8.3 15.6 (-7.3-24)	3.4 6.6 (-3.2-10.1)	7	1	5 3.6 (1.4-8.7)	14.3 25.9 (-11.6-40.2)
Fallow deer														
Roe deer														
Bovines	1		0.4 0.7 (-0.3-1)											
Caprines	18	1	6.4 2.9 (3.5-9.2)	5.6 10.6 (-5-16.1)	2.7 5.2 (-2.5-7.9)	37		9.2 2.8 (6.4-12.1)			8		5.8 3.9 (1.9-9.6)	
Rupicaprines	2		0.7 1 (-0.3-1.7)			3		0.7 0.8 (-0.1-1.6)			2		1.4 2 (-0.5-3.4)	
LU	145	13	10 1.5 (8.5-11.6)	9 4.7 (4.3-13.6)	35.1 15.4 (19.8-50.5)	188	4	13 1.7 (11.3-14.7)	2.1 2.1 (0.1-4.2)	13.8 12.6 (1.2-26.3)	48	2	33.8 7.8 (26-41.6)	4.2 5.7 (-1.5-9.8)
MU	1286	12	89 1.6 (87.4-90.6)	0.9 0.5 (0.4-1.5)	32.4 15.1 (17.3-47.5)	1251	18	86.6 1.8 (84.8-88.3)	1.4 0.7 (0.8-2.1)	62.1 17.7 (44.4-79.7)	92	3	64.8 7.9 (56.9-72.6)	3.3 3.6 (-0.4-6.9)
SU	14		1 0.5 (0.5-1.5)			6		0.4 0.3 (0.1-0.7)			2		1.4 1.9 (-0.5-3.3)	
Total NISPu	282	12		4.3 2.4 (1.9-6.6)	32.4 15.1 (17.3-47.5)	401	7		1.7 1.3 (0.5-3)	24.1 15.6 (8.6-39.7)	139	2		1.4 2 (-0.5-3.4)
Total NRu	1445	25		1.7 0.7 (1.1-2.4)	67.6 15.1 (52.5-82.7	1445	22		1.5 0.6 (0.9-2.2)	75.9 15.6 (60.3-91.4)	142	5		3.5 3 (0.5-6.6)
Total UNG	1727	37		2.1 0.7 (1.5-2.8)	100.0	1846	29		1.6 0.6 (1-2.1)	100.0	281	7		2.5 1.8 (0.7-4.3)

Sites (7)	Lazaret (CIII)				Lazaret (CII)				Payre (F)			
	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr (1)
Proboscideans	2		0.03 0.04 (-0.01-0.08)		5		0.1 0.1 (0-0.2)		12	1	0.7 0.4 (0.3-1)	8.3 15.6 (-7.3-24)
Suids									12		0.7 0.4 (0.3-1)	
Rhinocerotids	15		0.2 0.1 (0.1-0.4)		2		0.03 0.05 (0-0.1)		225	2	12.3 1.5 (10.8-13.8)	0.9 1.2 (-0.3-2.1)
Equids	67		1.1 0.3 (0.8-1.3)		13		0.2 0.1 (0.1-0.3)		302	2	16.5 1.7 (14.8-18.2)	0.7 0.9 (-0.3-1.6)
Megaloceros	7		0.1 0.1 (0-0.2)		5		0.1 0.1 (0-0.2)		4		0.2 0.2 (0-0.4)	
Reindeer	15		0.2 0.1 (0.1-0.4)									
Red deer	4877	2	77.8 1 (76.7-78.8)	0.04 0.06 (-0.02-0.1)	4899	8	80 1 (79-81)	0.2 0.1 (0.1-0.3)	761	2	41.7 2.3 (39.4-43.9)	0.3 0.4 (-0.1-0.6)
Fallow deer					1		0.02 0.03 (-0.02-0.05)		26		1.4 0.5 (0.9-2)	
Roe deer	22		0.4 0.1 (0.2-0.5)		66		1.1 0.3 (0.8-1.3)		87		4.8 1 (3.8-5.7)	
Bovines	91	1	1.5 0.3 (1.2-1.7)	1.1 2.1 (-1-3.2)	293	1	4.8 0.5 (4.2-5.3)	0.3 0.7 (-0.3-1)	296	2	16.2 1.7 (14.5-17.9)	0.7 0.9 (-0.3-1.6)
Caprines	1161		18.5 1 (17.6-19.5)		755	1	12.3 0.8 (11.5-13.2)	0.1 0.3 (-0.1-0.4)	94		5.1 1 (4.1-6.2)	
Rupicaprines	14		0.2 0.1 (0.1-0.4)		85		1.4 0.3 (1.1-1.7)		7		0.4 0.3 (0.1-0.7)	
LU	2		0.7 0.6 (0.1-1.3)		3		1 0.7 (0.2-1.7)		704	5	45.5 2.5 (43-48)	0.7 0.6 (0.1-1.3)
MU	276	1	98.6 0.9 (97.7-99.5)	0.4 0.7 (-0.3-1.1)	273	4	87.8 2.5 (85.3-90.2)	1.5 1.4 (0-2.9)	844	1	54.5 2.5 (52-57)	0.1 0.2 (-0.1-0.4)
SU	2		0.7 0.6 (0.1-1.3)		35		11.3 2.4 (8.9-13.6)					
Total NISPu	6271	3		0.05 0.05 (-0.01-0.1)	6124	10		0.2 0.1 (0.1-0.3)	1826	9		0.5 0.3 (0.2-0.8)
Total NRu	280	1		0.4 0.7 (-0.3-1.1)	311	4		1.3 1.3 (0-2.5)	1548	6		0.4 0.3 (0.1-0.7)
Total UNG	6551	4		0.1 0.06 (0-0.12)	6435	14		0.2 0.1 (0.1-0.3)	3374	15		0.4 0.2 (0.2-0.7)

Sites (8)	Orgnac 3 (5b)				Orgnac 3 (6)				Terra Amata	
	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr	%NISPu	%Nr(1)	NISPu	Nr
Proboscideans									13	
Suids	18		3.5 1.6 (1.9-5.1)		28		5.1 1.8 (3.2-6.9)		3	
Rhinocerotids	13		2.5 1.4 (1.2-3.9)		17		3.1 1.4 (1.6-4.5)		1	
Equids	152	1	29.5 3.9 (25.5-33.4)	0.7 1.3 (-0.6-1.9)	134	2	24.2 3.6 (20.6-27.8)	1.5 2.1 (-0.6-3.5)		
Megaloceros	1		0.2 0.4 (-0.2-0.6)		2		0.4 0.5 (-0.1-0.9)			
Reindeer					1		0.2 0.4 (-0.2-0.5)			
Red deer	157	2	30.4 4 (26.5-34.4)	1.3 1.8 (-0.5-3)	215		38.8 4.1 (34.8-42.9)		32	1
Fallow deer	73		14.1 3 (11.1-17.2)		66		11.9 2.7 (9.2-14.6)		1	
Roe deer	10		1.9 1.2 (0.7-3.1)		8		1.4 1 (0.5-2.4)			
Bovines	84		16.3 3.2 (13.1-19.5)		70	3	12.6 2.8 (9.9-15.4)	4.3 4.7 (-0.5-9)	2	
Caprines	8		1.6 1.1 (0.5-2.6)		8		1.4 1 (0.5-2.4)		2	
Rupicaprines					5		0.9 0.8 (0.1-1.7)			
LU	212		48 4.7 (43.3-52.6)		278		36.4 3.4 (33-39.8)			
MU	210		47.5 4.7 (42.9-52.2)		414		54.2 3.5 (50.7-57.7)		3	
SU	20		4.5 1.9 (2.6-6.5)		72		9.4 2.1 (7.4-11.5)			
Total NISPu	516	3		0.6 0.7 (-0.1-1.2)	554	5		0.9 0.8 (0.1-1.7)	54	1
Total NRu	442				764				3	
Total UNG	958	3		0.3 0.4 (0-0.7)	1318	5		0.4 0.3 (0-0.7)	57	1

NOÉMIE SÉVÊQUE · PATRICK AUGUSTE

FROM WEST TO EAST: LOWER AND MIDDLE PALAEOLITHIC BONE RETOUCHERS IN NORTHERN FRANCE

Abstract

At the end of the Lower Palaeolithic and into the Middle Palaeolithic, Neanderthals inhabited northern France, and many archaeological sites preserve accumulations of various lithic industries, sometimes associated with bones. From a few sites, the faunal remains show traditional marks of anthropic activities linked with butchery, including skinning, dismembering, meat filleting and marrow extraction. Some bones also present surface modifications characteristic of utilisation as tools; these are called retouchers or *retouchoirs*. The oldest site, the Acheulean occupation at Cagny-l'Épinette (Somme), yielded only six retouchers. In comparison, the main collection of the Middle Palaeolithic site of Biache-Saint-Vaast (Pas-de-Calais) contained 333 of these objects. Here, we also present new data on the retouchers from two more recent Middle Palaeolithic sites: Le Rozel (Manche) and Mutzig (Bas-Rhin). A regional synthesis of previously published and unpublished archaeological materials allows for new insights into the functionality of bone retouchers from northern France. This study suggests a relative homogeneity and standardization in Neanderthal behaviour and bone tool utilization for tens of thousands of years, with some differences from site to site. Most retouchers were made from herbivore limb bone diaphyses, but also on brown bear at Biache-Saint-Vaast. At le Rozel, a red deer mandible was used as retoucher. The pattern of utilization of the bones is variable, ranging from only a few clustered scores to a huge loss of cortical bone material linked to intense activity, and sometimes with up to four use areas on the same bone. In this study, we explore the many factors that may account for these differences.

Keywords

Neanderthals; Lower Palaeolithic; Middle Palaeolithic; Retouchers; Northern France

Introduction

During recent decades, many archaeological sites with Middle Palaeolithic occupations have been discovered in northern France. Some of these sites are important for understanding the lifeways of fossil hominids, especially for Neanderthal (and pre-Neanderthal) subsistence behaviour, territorial mobility and land use strategies. In some cases, faunal remains are found associated with lithic industries,

Figure 1 Locations of the sites in northern France.

providing evidence for hunting and butchery activities in the form of cut marks, scraping marks, helical fractures and bones used as retouchers.

Mentioned for the first time in 1883 (Daleau, 1884), retouchers were officially defined by G. and A. de Mortillet (1900) in their publication on prehistory. A few years later, L. Henry-Martin (1906, 1907, 1907-1910) discovered and studied retouchers from La Quina, then started discussions about their functionality. After that, discoveries of retouchers greatly expanded, mainly in French sites. More recently, a number of referential works about retouchers were compiled and published by the *Commission de nomenclature sur l'industrie de l'os préhistorique* (Patou-Mathis, 2002). A complete study of the 333 retouchers from Biache-Saint-Vaast was described in that volume (Auguste, 2002). Subsequently, new discoveries were made and new technological approaches were developed, including advances in experimental archaeology (e.g., Jéquier et al., 2012; Mallye et al., 2012; Daujeard et al., 2014). New data from Cagny-l'Épinette show that these bone tools were present in northern France since at least the end of Lower Palaeolithic (Moigne et al., 2016).

For the present study, the bone retouchers from four archaeological sites located in northern France are described (**Figure 1**): Cagny-l'Épinette (Somme), Biache-Saint-Vaast (Pas-de-Calais), Le Rozel (Manche), and Mutzig (Bas-Rhin). All the sites preserve hominin occupations dating to the Lower and Middle Palaeolithic (**Figure 2**). The aim of this paper is to offer a new interpretation for the historic retoucher series from Cagny-l'Épinette and Biache-Saint-Vaast and to present the two unpublished retoucher series from Le Rozel and Mutzig.

Material and methods

Taphonomic and zooarchaeological studies have been published for Cagny-l'Épinette and Biache-Saint-Vaast, and are in progress for Le Rozel and Mutzig. The study of these retouchers is part of a broader zooarchaeological research programme covering northern France. We examined the type of bone blanks used as retouchers (species, skeletal element, bone portion), the active use areas (number, shape, pits and scores, location on the bone) and other associated anthropic marks. Finally, the retouchers were analysed with respect to their specific archaeological contexts.

The observation of retouchers was first made macroscopically, then with a stereomicroscope when necessary. Photographs were made of each retoucher, using the stereomicroscope and software CombinZM at the University of Lille or the microscope from the University of Basel.

For the study of these retouchers, we used the definitions and vocabulary established in 2002 by the *Commission de nomenclature sur l'industrie de l'os préhistorique* (Patou-Mathis, 2002). Experimental replication by Mallye et al. (2012) served as a reference for understanding the possible gestures involved in the use of these retouchers.

MIS	Date	Stratigraphy	Biozone	Cultural contest	Northern France sites
2		Weichselian	26	Final Palaeo. Upper Palaeo.	Conty / Dourges
3	60 ky			Middle Palaeolithic	Hénin-sur-Cojeul Beauvais / Ault
4					Bettencourt-Saint-Ouen
5a à 5d	110 ky				Mont-Dol Mutzig Le Rozel
5e	130 ky	Eemian	25		Caours
6	190 ky	Saalian	24		Gentelles / Arques / La Cotte de St-Brelade Piégu / Tourville D / Montières / Moru / Sempigny
7	240 ky				Biache-Saint-Vaast / Ranville
8	300 ky				Argoeuves
9			23		Cagny-l'Épinette / Cléon
10	400 ky		22	Lower Palaeolithic	
11		Holsteinian			Cagny-la-Garenne II / La Celle Cagny-la-Garenne I
12	500 ky	Elsterian			
13 à 22	900 ky	Cromerian	21		Abbeville (Carpentier / Léon) Wissant Grâce
23 à 31	1,1 M	Bavelian	20		Saint-Prest

Figure 2 Chronostratigraphic and cultural positions of the sites (after Auguste, 2009).

Results

Cagny-l'Épinette

The open-air site of Cagny-l'Épinette is located in the Somme Valley, in a terrace of the Avre River near the city of Amiens (Tuffreau et al., 1986, 1995, 1997). Locally, ten different alluvial sheets have been recognized (Antoine, 1994); number IV is the l'Epinette system. Each alluvial sheet represents an interglacial/glacial cycle, the oldest of which is the Grâce alluvial sheet with an age older than the Bruhnes-Matuyama paleaomagnetic boundary (781 ka). This position is supported by the palaeontology (Auguste, 1995a), silty cover, ESR, U/Th and magneto-stratigraphy (Bates, 1993; Laurent et al., 1994).

The fluvial deposits at l'Epinette, were dated by ESR to 296 ± 53 ka (Laurent et al., 1994), which is in agreement with the characteristics of the large mammal assemblage (Tuffreau et al., 1995; Auguste, 2009), especially red deer and horse. In the thin fluvial deposits of the middle terrace that correspond to the MIS 10/9 transition, level I1 (**Figure 3**) covered a surface of 148 m² and yielded roughly 3000 lithics artefacts associated with teeth and bones of large mammals (Auguste, 2012).

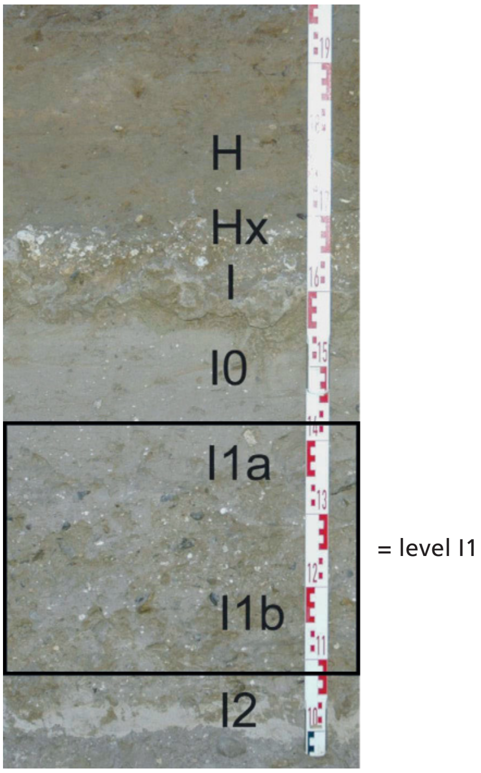

Figure 3 Cagny-l'Épinette. Thin fluvial deposits (I to I2) and upper levels (H and Hx) (after Tuffreau et al., 2008).

Flint is the only raw material used as toolstone. The rarity of tested nodules and cores compared to the large number of handaxe fragments and bifacial tools made on gelifracts identify the site as a kill and butchery site (Lamotte and Tuffreau, 2001).

Aurochs *(Bos primigenius)* is the main taxa at Cagny-l'Épinette (**Table 1**); red deer *(Cervus elaphus)* is the second most abundant. *Equus* cf. *mosbachensis* is also present but with fewer remains. Other taxa are present but rare: a large cervid, likely giant deer *(Megaloceros giganteus)*; fallow deer *(Dama dama clactoniana)*; European ass *(Equus hydruntinus)*; narrow-nosed rhinoceros *(Stephanorhinus hemitoechus)*; straight-tusked elephant *(Palaeoloxodon antiquus*); hyena (cf. *Crocuta spelaea)*; and fox *(Vulpes* sp.).

The huge quantity of bones with no taphonomic modifications favours the interpretation of a rapid burial of the accumulation. Some aurochs and red deer bones show marks caused by water flow and carnivore gnawing; many more bones exhibit cut marks indicating dismembering, defleshing, tongue extraction and detachment of tendons. Long bones reveal typical breakage patterns characterised by direct percussion on fresh bone to extract marrow. Bones of other species exhibit no anthropic modifications and possibly no relationship with Neanderthal activities.

The six bone retouchers from Cagny-l'Épinette (**Table 2**) are among the oldest known retouchers in Europe, and are fully described by Auguste (in Moigne et al., 2016). The bone tools originate from levels I1A and I1B. Four retouchers were made from aurochs bones and two from horse. No bones of red deer were used despite their abundance at the site.

Three retouchers were made on distal humeri: one from horse and two from aurochs (**Figure 4A, 4C**). The use areas of the three humerus retouchers are situated on the medial part of the distal epiphysis, similar to those in the La Quina historical collec-

Table 1 Inventory of the large mammals from Cagny-l'Épinette level I1, with NISP (number of identified specimens) and MNI (minimum number of individuals).

Taxon	NISP	MNI
Bos primigenius	1642	61
Cervus elaphus	664	35
Equus cf. *mosbachensis*	54	15
Dama clactoniana	17	6
Paleoloxodon antiquus	4	2
Megaloceros giganteus	2	1
Stephanorhinus hemitoechus	2	1
Equus hydruntinus	1	1
Crocuta spelaea	1	1
Vulpes sp.	-	-
Total	2387	123

tion. In addition to retouching activities, their use is hypothesised to relate to the shaping of handaxes or bifacial tools (Vincent, 1993). However, the damage to the humeri does not suggest a particular method of use. The bones were not used as anvils, as the stigmata are located on the trochlea and not on the cranial face (Moigne et al. 2016). Some of the diaphysis remains on two of the humeri, but this did not offer much for gripping the bone or provide for good rotation of the wrist. Nevertheless, the use of these humerus fragments as retouchers is possible (Vincent, 1993).

The pits and scores appear different on each bone. For the horse humerus, the use area on the trochlea features deep, triangular pits, all oriented perpendicular to the medial-lateral axis of the distal articulation. This retoucher has a second use area on the diaphysis, with large, ovoid and triangular pits oriented perpendicular to the long axis of the bone. On this scaled area, some large, oblique and rectilinear scores are also noted. These scores have rough sides and were imparted after the initial intensive utilization as a retoucher. Concerning one of the two aurochs humeri, the pits are triangular rather than ovoid; the scores are rectilinear and smooth. The other aurochs humerus presents deep and superimposed triangular pits, all oriented perpendicular to the medial-lateral axis of the distal articulation; the scores are rectilinear and generally smooth.

About the three other retouchers, two are made on horse and aurochs metatarsals and the last is on an aurochs humerus diaphysis (see **Figure 4B**). The numerous scores on the horse metatarsal are deep and rectilinear, with rough and asymmetrical sides, and sometimes covered by deep triangular pits. This may indicate the bone was of intermediate freshness (Mallye et al., 2012). The location of the use area, centred on the diaphysis, is different than on the aurochs metatarsal and humerus, which exhibit a more typical use area location positioned toward the extremity of the bone (Mallye et al., 2012).

In conclusion, the main features of the retouchers from Cagny-l'Épinette are the use of thick bones from large herbivores (aurochs and horse) and a clear pattern of retouchers on humerus and metatarsal diaphyses. The distal articulation of the humerus was also used, which may have required more strength and skill than with the diaphysis fragments (Vincent, 1993). Based on characteristics of the pits and scores, the retouchers were intensively used. Moreover, there is a diversity of pits and scores, even

Table 2 Inventory and general data on the retouchers from Cagny-l'Épinette (after Moigne et al., 2016). Length (L), width (W) and thickness (T) dimensions are in mm.

Inventory number	Level	Taxon	Bone	Use area location	L	W	T
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

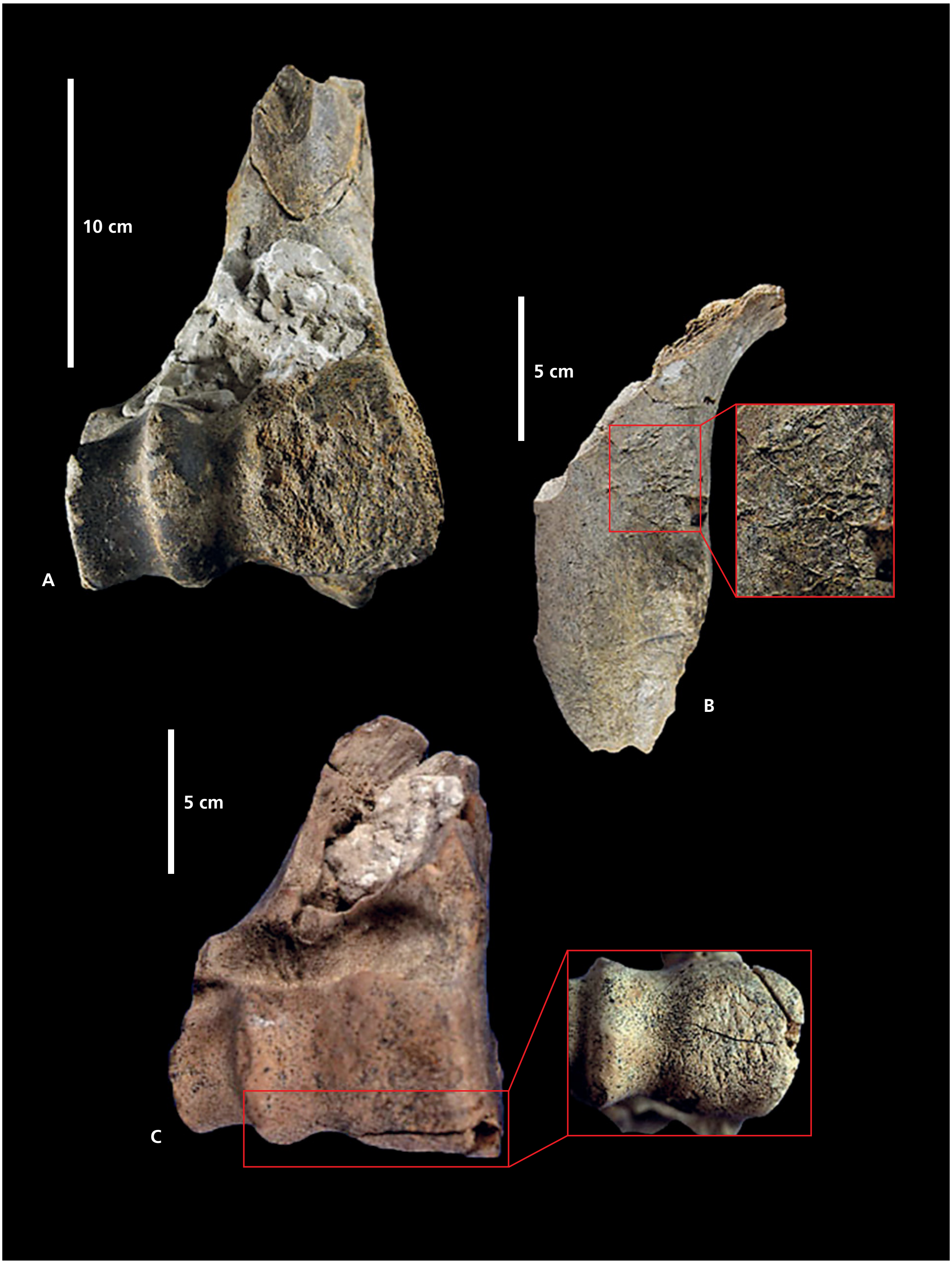

Figure 4 Cagny-l'Épinette. A) Aurochs right humerus (Ep 2007.1647, I1A) with one use area on the trochlea, cranial view (photos by Noémie Sévêque). B) Aurochs right humerus (Ep 2008.26I/J-2342, I1B) with a helical fracture and one use area, cranio-medial view (photos by Noémie Sévêque). C) Aurochs right humerus (Ep 2000.25O-318, I1B) with a helical fracture and one use area on the trochlea, distal view (photos by Patrick Auguste, modified by Noémie Sévêque).

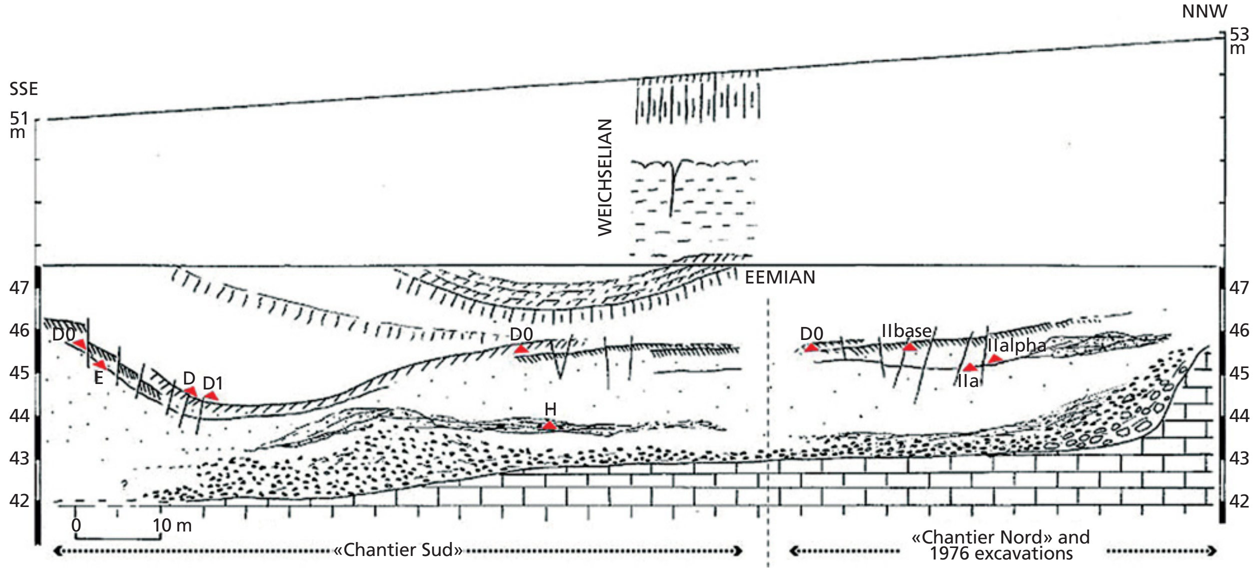

Figure 5 Biache-Saint-Vaast. Synthetic representation of the sedimentary sequence and locations of the archaeological levels (Hérisson 2012, after Tuffreau and Sommé, 1988).

though flint was the only worked raw material. This could be explained by the use of bones of variable freshness, from green to moderately fresh (Mallye et al., 2012; Moigne et al. 2016).

Biache-Saint-Vaast

The site of Biache-Saint-Vaast, excavated between 1976 and 1982 under the direction of Alain Tuffreau, revealed eleven levels of hominin occupation within the terraces of the river Scarpe (Tuffreau and Sommé, 1988). The stratigraphy shows a succession of overlapping fluvial and slope deposits capped by a loess sequence (**Figure 5**). Level IIa delivered tens of thousands of large mammal bone remains, many lithic artefacts, as well as two Neanderthal skulls. Teeth and bones submitted for ESR dating returned ages of 229 ± 27 ka and 230 ± 24 ka (Bahain et al., 1993, 2007), which coincides with the beginning of MIS 7.

The lithic artefacts discovered at Biache-Saint-Vaast constitute one of the oldest Middle Palaeolithic assemblages. Levallois *chaîne opératoire* flake production is present in all levels, and flint was the only raw material. Level IIa also yielded a large assemblage of this Mousterian lithic technology dominated by scrapers and elongated flakes (Hérisson, 2012).

The assemblage of 214,860 faunal remains was studied in its totality (Auguste, 1995b); however, only 20,655 were identified to skeletal part and taxon. The list of the large mammals identified in the whole fluvial sequence (levels I to D0) at Biache-Saint-Vaast includes twenty taxa (**Table 3**). The large mammals from the loess sequence (levels D1 and D) are less numerous than from the fluvial deposits and include only seven taxa. In total, 626 individual animals were identified.

For the fluvial sequence (levels I to D0), the fauna is very homogeneous and corresponds to a mixed woodland and meadow environment with a temperate and humid climate. In contrast, the fauna from the loess sequence (levels D1 and D) indicates a colder, drier and more continental climate. The environment was more open and the steppe began to appear.

Aurochs *(Bos primigenius)* is the most represented species in the combined levels at Biache-Saint-Vaast (**Figure 6**), with 31.3% of the total minimum number of individuals (MNI). The aurochs population is represented by a minimum of 196 individuals, and adults dominate the mortality profile (**Figure 7**). Following the aurochs, the brown bear *(Ursus arctos)* is the second most represented species, with 13.9% of the MNI. Narrow-nosed rhinoceros *(Stephanorhi-*

Table 3 Composition of the large fauna from all levels at Biache-Saint-Vaast (after Auguste, 2012), with NISP (number of identified specimens) and MNI (minimum number of individuals).

	D		D1		D0		IIb		IIalpha		IIa		En		F		G		H		I		HS		Total	
Taxon	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Coelodonta antiquitatis	12	3	22	2																					34	5
S. hemitoechus					2	1	21	4	77	8	942	54	12	3	3	1			8	3	1	1	4	3	1070	78
S. kirchbergensis					1	1	4	2	8	3	101	12	4	2					3	2			2	2	123	24
Stephanorhinus sp.					17	3	37	4	98	5	1703	28	52	4			5	2	9	3			2	1	1923	50
Capreolus capreolus					1	1	12	1			36	4	1	1											50	7
Cervus elaphus	13	1	17	1	18	3	33	5	6	1	133	12									1	1	2	1	223	25
Megaloceros giganteus					1	1	1	1	2	2	90	6							1	1					95	11
Castor fiber																			2	1					2	1
Canis lupus											2	1													2	1
Equus cf. *achenheimensis*	28	3	15	2	15	2	26	3			74	5	1	1	1	1	1	1			4	2	1	1	166	21
Equus hydruntinus	3	1	1	1	1	1	7	2			13	1	1	1	1	1									27	8
Felis silvestris											8	1													8	1
Aonyx antiqua											19	2													19	2
Martes cf. *martes*											2	1													2	1
Palaeoloxodon antiquus			1	1							13	1	1	1	1	1			6	1			1	1	23	6
Panthera spelaea											3	1													3	1
Sus scrofa					8	2			3	1	85	8	4	1											100	12
Vulpes vulpes	1	1									2	1													3	2
Ursus arctos					19	3	30	2	108	12	2050	63	15	1			1	1	17	2			3	3	2243	87
Ursus deningeri							17	2	15	1	189	16	5	1											226	20
Ursus sp.							58	5	210	7	4240	48	32	3	1	1					1	1	2	2	4544	67
Bos primigenius	48	4	29	4	35	4	268	10	572	18	8616	140	99	4	5	1			66	5	18	1	13	5	9769	196
Total	105		85	11	118	22	514	41	1099	58	18321	405	227	23	12	6	7	4	112	18	25	6	30	19	20655	626

nus hemitoechus) accounts for 12.5% of the MNI (see **Figure 6**). The brown bear mortality profile also shows a dominance of adults, which indicates selective hunting by Neanderthals (see **Figure 7**), but the rhinoceros shows a different mortality structure, with more young and old individuals (Auguste, 1995c).

Systematic butchery activities are observed on the aurochs assemblage; butchery is less systematic on brown bear and rhinoceros (Auguste, 2012). For the fluvial deposits, Neanderthals broke almost all aurochs long bones. Overall, cut marks on aurochs, brown bear and rhinoceros are numerous in level IIa, and indicate defleshing, tongue extraction and skinning.

Biache-Saint-Vaast provided a total of 333 retouchers (**Table 4**), one of the largest collections of these bone tools from the Palaeolithic. Auguste (2002) provided a full description of the Biache-Saint-Vaast retoucher assemblage, together with those from Kůlna Cave, Czech Republic. The majority (303) of retouchers from Biache-Saint-Vaast derive from level IIa.

Roughly 57% of the retouchers were made on aurochs long bones (**Table 5**); only 6% were made on bear bones. It is important to note that at Biache-Saint-Vaast, the brown bear remains are not intrusive, but rather bear was hunted and consumed like the herbivores, and the bones preserve all the same butchery and skinning marks. Moreover, brown bear is the second most abundant species at the site, with a minimum of 87 individuals. Four rhinoceros long bones were also used as retouchers.

Nearly all (96%) retouchers are on long bones. Tibia diaphyses are the most represented, with 17.1% of the total, and radio-ulna diaphyses account for a further 9.7%. These frequencies are similar across all species and seem to represent a deliberate choice made by Neanderthals. Other bones used as retouchers include mandible, vertebra, rib, scapula, os coxa, and the distal epiphysis of a femur (Auguste, 2002).

The majority (84%) of the bone tools from Biache-Saint-Vaast present only one use area (**Table 6**; **Figures 8-12**), while 14% include two use areas

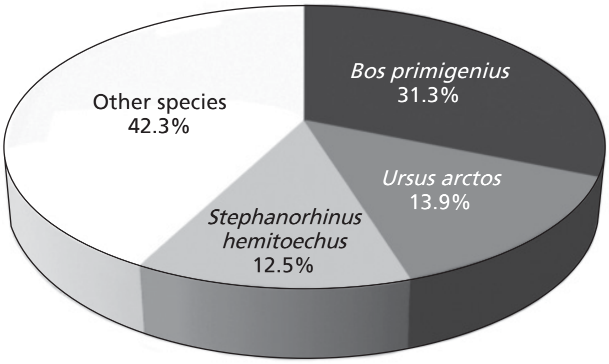

Figure 6 Biache-Saint-Vaast. Composition of the large fauna in MNI (minimum number of individuals) for all levels (after Auguste, 2012).

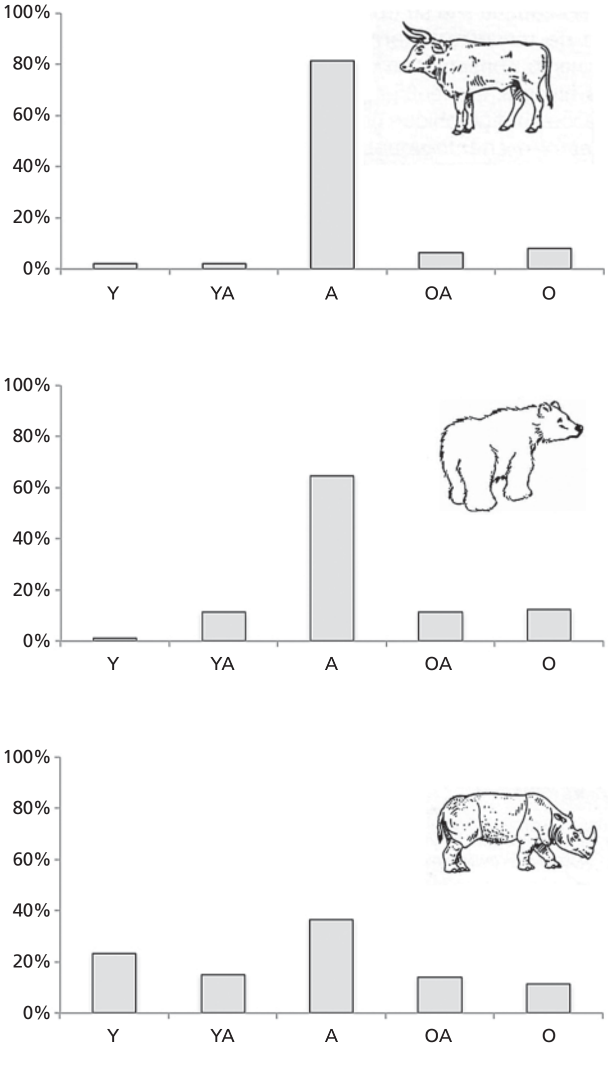

Figure 7 Biache-Saint-Vaast. Mortality profiles of aurochs (top), bear (middle) and rhinoceros (bottom) from all levels (after Auguste, 1995c). Y = young; YA = young adult; A = adult; OA = old adult; O = old.

Table 4 Inventory of retouchers on long bones and other bones by level at Biache-Saint-Vaast (after Auguste, 2002), with NISP (number of identified specimens).

	Long bones		Others bones	
Level	NISP	%	NISP	%
II a	291	90.65	12	100
II alpha	26	8.1	0	0
II b	4	1.25	0	0
Total	321	100	12	100

Table 5 Inventory of retouchers on long bones and other bones by species at Biache-Saint-Vaast (after Auguste, 2002), with NISP (number of identified specimens).

	Long bones		Others bones	
Taxon	NISP	%	NISP	%
Bos primigenius	184	57.32	11	91.67
Ursus arctos	20	6.23	0	0
Stephanorhinus hemitoechus	4	1.25	0	0
Undetermined	113	35.20	1	8.33
Total	321	100	12	100

Table 6 Inventory of retouchers on long bones and other bones by number of use areas at Biache-Saint-Vaast (after Auguste, 2002), with NISP (number of identified specimens).

Number of use areas	Long bones		Others bones	
	NISP	%	NISP	%
1	271	84.4	12	100
2	48	14.9	0	0
3	2	0.63	0	0
Total	321	100	12	100

(**Figures 13, 14**). Three use areas are visible only on two retouchers. In cases with multiple use areas, stigmata are located on the same face of the bone, but on opposite edges. The overall shapes of stigmata are homogeneous, with numerous pits and rectilinear scores of different depths and lengths. Almost 72% of the stigmata are oriented perpendicular to the main axis of the bone. For the other retouchers, the stigmata are more oblique to the long axis, ranging from 30-60° and 90-120°.

Of the 333 retouchers, additional modifications have been identified on 212 bones. Scraping marks occur on 43% of the retouchers, 22% include cut marks, and 5% have helical fractures. Only two bones present all of these modifications together. The data indicate that at Biache-Saint-Vaast there are modifications linked to butchery activities and the preparation of the bones surfaces before their use as retouchers. Indeed, cut marks and helical fractures are typical elements of butchery, and they are identified on a many bones unrelated to retouchers. On the other hand, the predominance of scraping marks indicates an intentional preparation of the bones for their use as retouchers.

Le Rozel

The site of Le Rozel, discovered in 1963 by Yves Roupin owing to coastal erosion, is located on the west coast of the Cotentin Peninsula, close to Surtainville Beach. Neanderthals occupied one of the rockshelters of the cliff during the early stages of the last glaciation, dating to 115-70 ka by OSL. Frédéric Scuvée directed the first excavations in 1968 (Scuvée and Vérague, 1984; van Vliet-Lanoë, 1988; van Vliet-Lanoë et al., 2006). Due to the increased threat of coastal erosion at the site, it was decided to initiate new excavations in 2011 before its destruction. Dominique Cliquet now directs the excavations. This new research indicates that Le Rozel is an exceptional Middle Palaeolithic site with at least three different Neanderthal occupations (**Figure 15**) (Cliquet and Tribouillard, 2015). The state of preservation of the archaeological remains is very good. Currently, there are more than 200 Neanderthal footprints, well-preserved hearths, insect remains, potential anvils, and thousands of large and small mammal remains preserved as a result of the calcareous sandstone.

Flint is the principal raw material for stone tools in all the three levels, but quartz and sandstone were exploited as well. So far, five knapping areas have been discovered, four of which are associated with butchery areas. Three types of debitage were used: Levallois, direct and laminar knapping. The only tools are scrapers.

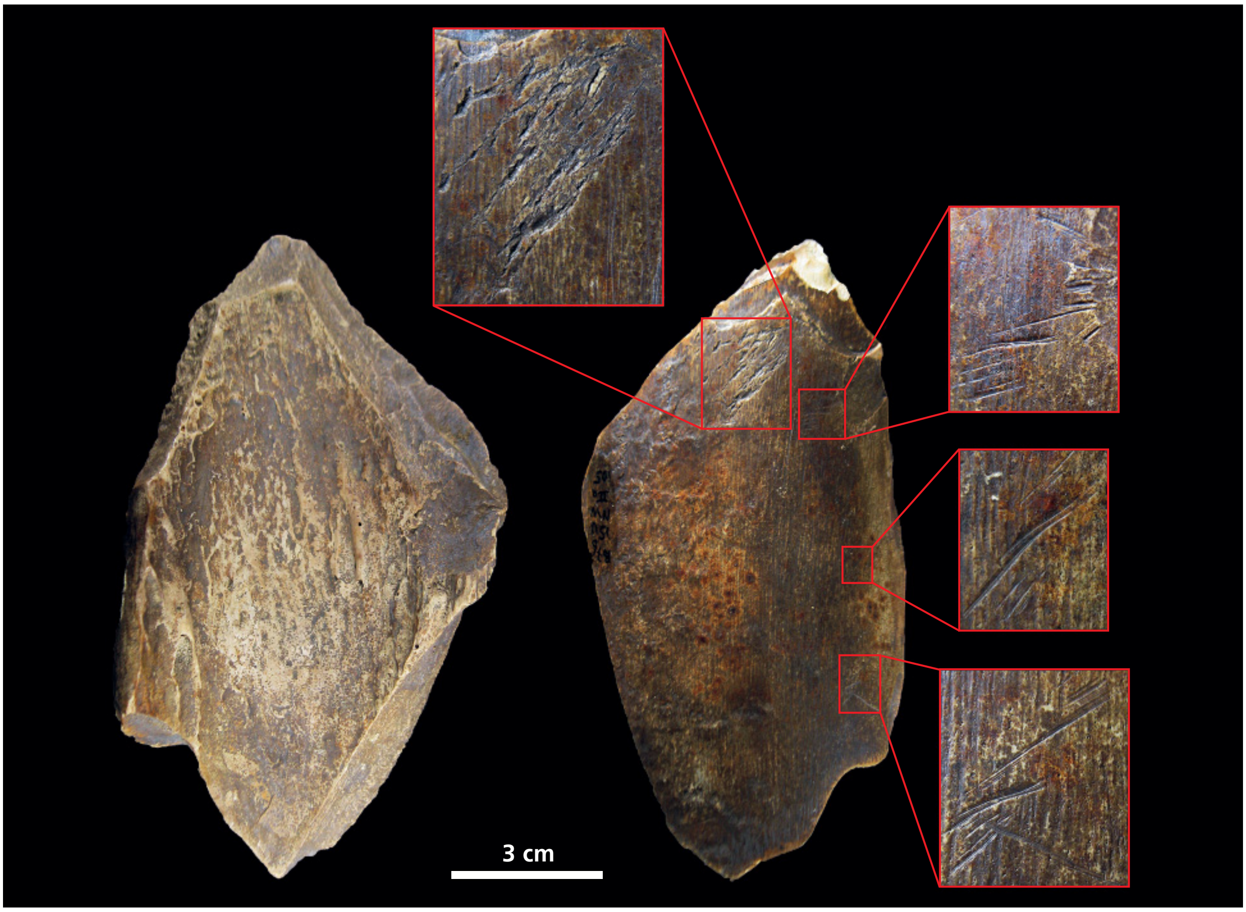

Figure 8 Biache-Saint-Vaast. Aurochs femur (B76, IIa , 15U NW, 105) with a helical fracture, impact notch, negative flake scar, cut marks and one use area; medullary (left) and cortical (right) views (photos by Noémie Sévêque).

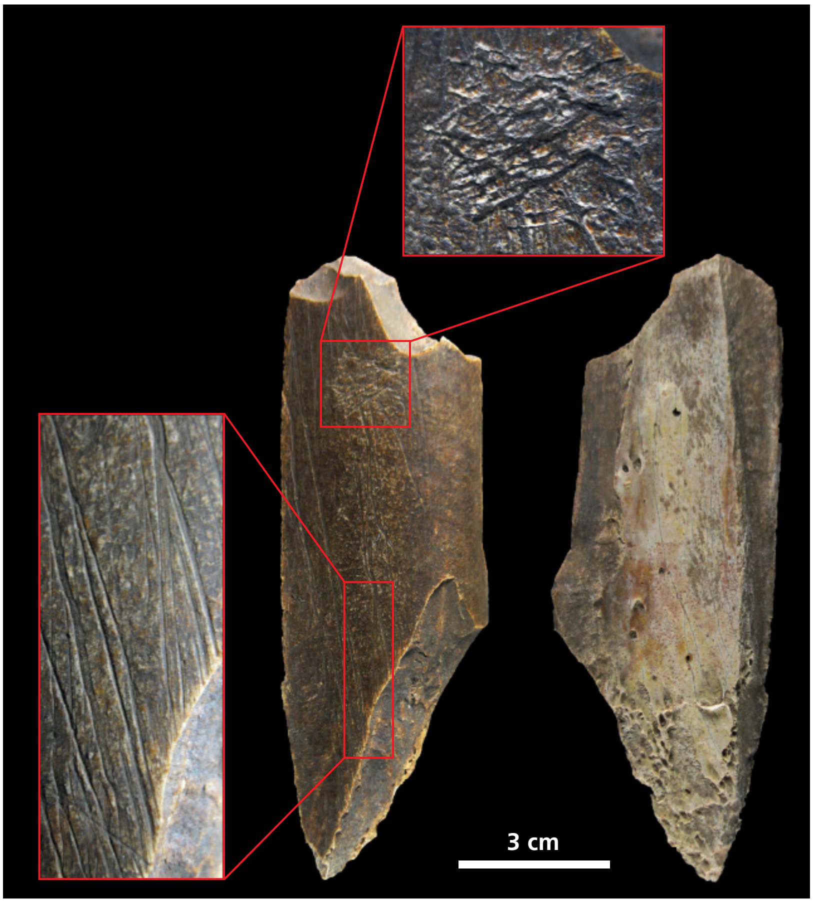

Figure 9 Biache-Saint-Vaast. Aurochs tibia (B76, IIa, 31Y) with a helical fracture, cut marks, scraping marks and one use area; cortical (left) and medullary (right) views (photos by Noémie Sévêque).

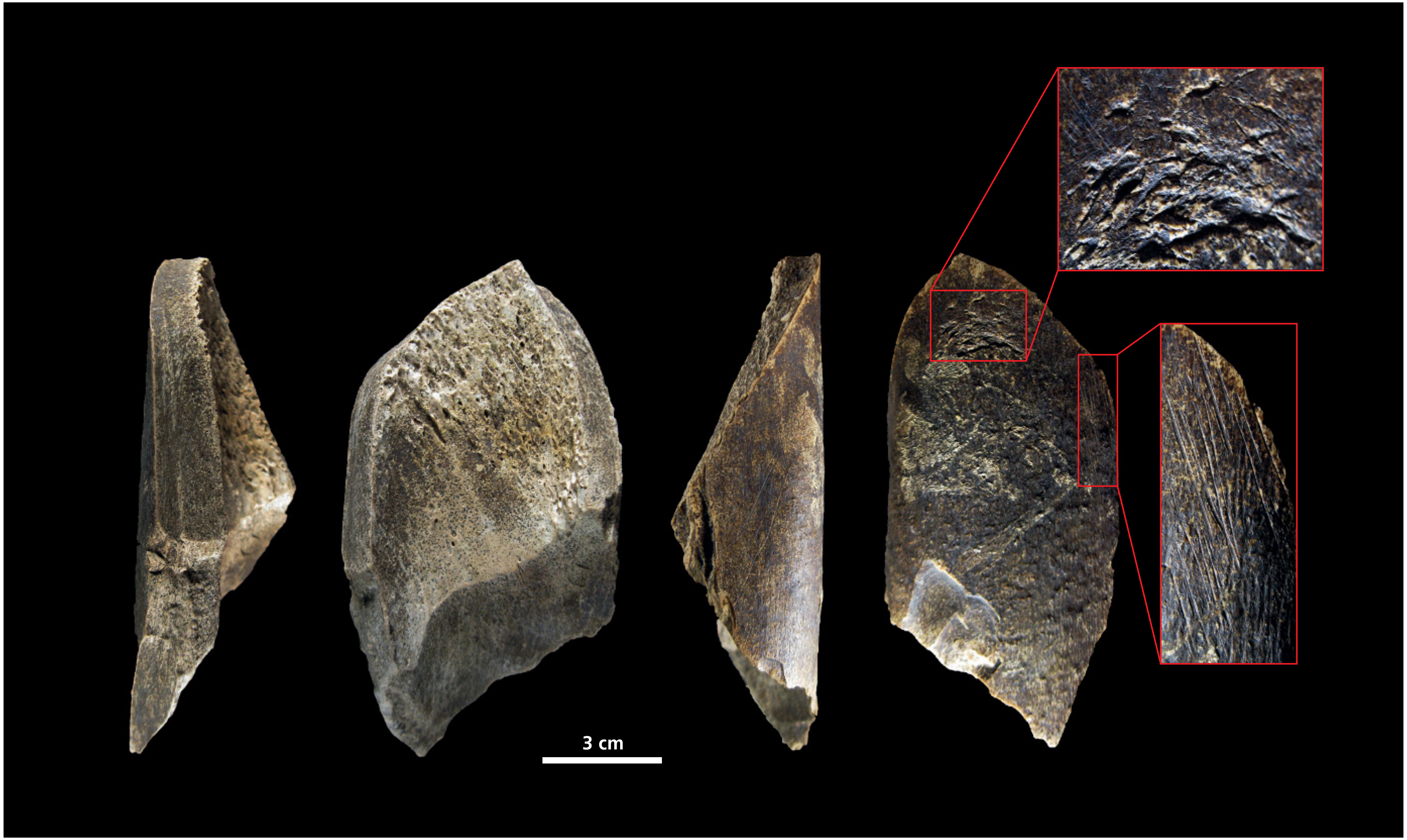

Figure 10 Biache-Saint-Vaast. Aurochs tibia or radius (B76, IIa, 33V) with a helical fracture, cut marks and one use area; lateral, medullary, lateral and cortical views (from left to right) (photos by Noémie Sévêque).

Figure 11 Biache-Saint-Vaast. Aurochs long bone (B76, IIa, 28V SW) with a helical fracture, cut marks and one use area; medullary (left) and cortical (right) views (photos by Noémie Sévêque).

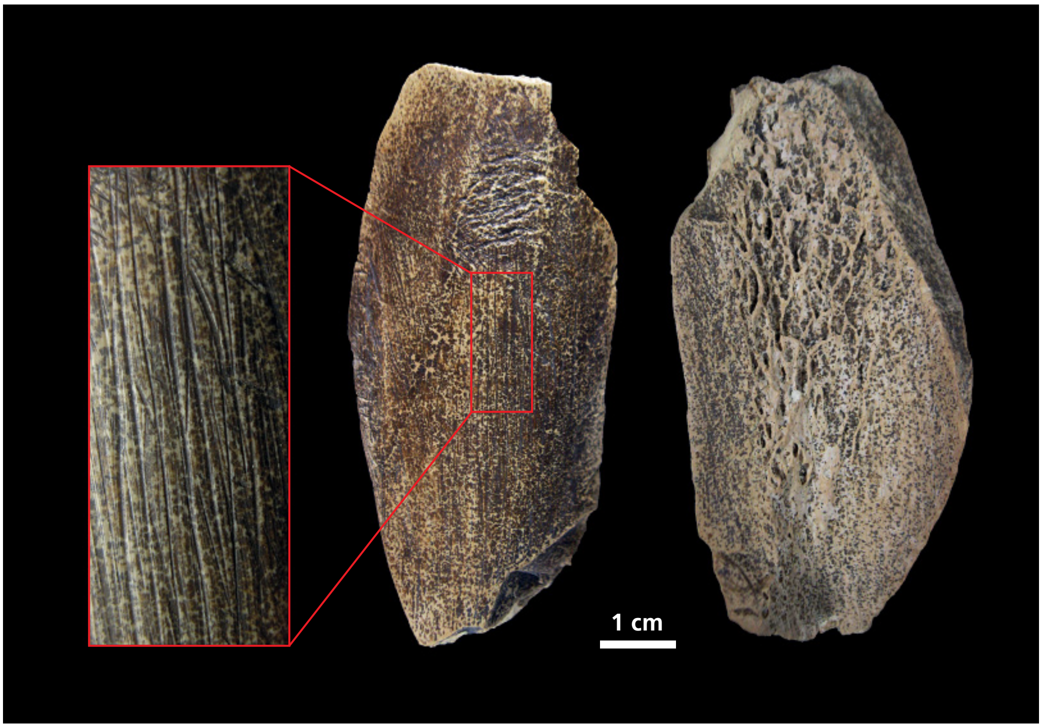

Figure 12 Biache-Saint-Vaast. Bear long bone (B76, IIa, 27G, 17) with a helical fracture, cut marks, scraping marks and one use area; cortical (left) and medullary (right) views (photos by Noémie Sévêque).

Figure 13 Biache-Saint-Vaast. Aurochs tibia (B76, IIa, 34R, 5) with a helical fracture, impact notch, negative flake scar, cut marks, scraping marks and two use areas; cortical, lateral and medullary views (from left to right) (photos by Noémie Sévêque).

Figure 14 Biache-Saint-Vaast. Aurochs left radius (B76, IIa, 11I, R8994) with a helical fracture, cut marks, scraping marks and two use areas; dorsal, lateral and palmar views (from left to right) (photos by Noémie Sévêque).

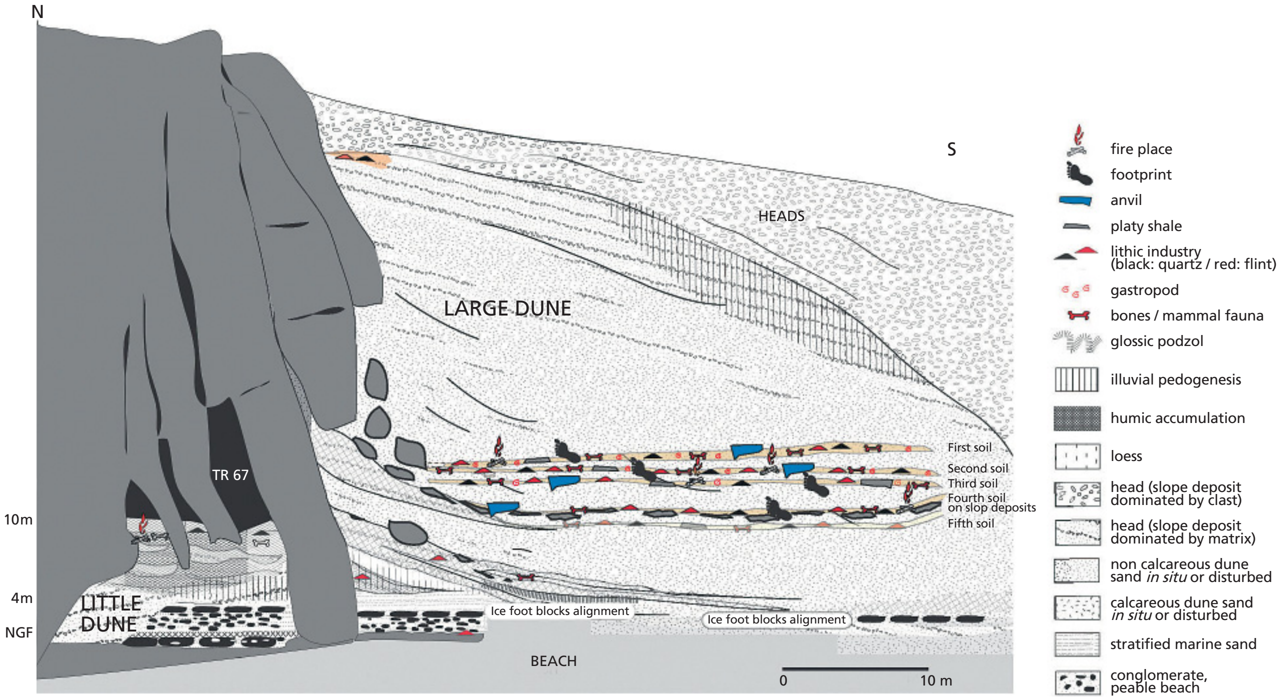

Figure 15 Le Rozel. Synthetic section of sedimentary deposits and locations of the archaeological levels (after Cliquet and Tribouillard, 2015).

To date, 4711 faunal remains have been studied (Cliquet and Tribouillard, 2015). The preservation of bones is extraordinary, making for a high percentage of identifiable remains. The large mammal spectrum (**Table 7**) includes a minimum of 12 red deer *(Cervus elaphus)*, five horses *(Equus* sp.), one aurochs *(Bos primigenius)*, one roe deer *(Capreolus capreolus)*, one rhinoceros (cf. *Stephanorhinus hemitoechus)*, one elephant (cf. *Palaeoloxodon antiquus)* and one rabbit *(Oryctolagus cuniculus)*. Seasonality was established on mandibles of two red deer fawns (six to eight months old) and one horse foal (ten months old). The season of occupation coincides with winter and the beginning of spring (December-April).

Butchery activities are clear at this site, with hundreds of faunal remains showing breakage for marrow extraction, cut marks and scraping marks. The long bones of red deer are almost always broken for marrow extraction. Breakage is less systematic on aurochs and horse long bones, but still prevalent. Various cut marks related to defleshing, skinning and tongue extraction are present on 225 bones. Scraping marks are observed on 37 bones, 12 of which were also used as retouchers.

Figure 16 Le Rozel. Red deer left femur (LR 2012, n°2028) with a helical fracture, cut marks and one use area; cortical (left) and medullary (right) views (photos by Noémie Sévêque).

So far, 38 retouchers have been found in only three years of excavations running from 2012 to 2014. Red deer limb bones were the most used (**Figures 16-19**), with 28 retouchers (**Table 8**). A mandible from a red deer was also used. Besides cervid, four retouchers were made with aurochs limb bones (**Figure 20**), three with horse limb bones (**Figure 21**) and two with indeterminate large herbivore bones. Considering we identified only one aurochs and five horse individuals in the assemblage, it is notable that there are more aurochs than horse bones used as retouchers. Neanderthals seem to have preferred to utilize the aurochs carcass compared to the horses.

Concerning the anatomical elements used (**Figure 22**), retouchers are better represented on hind limbs (12 tibiae and seven femora) than on fore limbs (one humerus and three radii). But, metacarpals outnumber metatarsals (5:3). This pattern does not necessarily reflect a deliberate choice, since there is a significant difference in the ratio of hind limb (91 fragments of femur and tibia) to fore limb (42 fragments of humerus, radius, and ulna) in the

Table 7 Inventory of the large mammals from Le Rozel, with NISP (number of identified specimens) and MNI (minimum number of individuals).

Taxon	NISP	MNI	Details of MNI
Cervus elaphus	570	12	9 adults, 3 young
Equus sp.	50	5	4 adults, 1 young
Bos primigenius	25	1	1 adult
Capreolus capreolus	3	1	1 adult
cf. *Stephanorhinus hemitoechus*	20	1	1 young
cf. *Palaeoloxodon antiquus*	1	1	1 adult
Oryctolagus cuniculus	3	1	1 adult
Total	672	22	

Table 8 Inventory of retouchers on long bones and other bones by species at Le Rozel, with NR (number of remains).

	Long bones		Others bones	
Taxon	NR	%	NR	%
Cervus elaphus	28	77.78	1	50
Bos primigenius	4	11.11	0	0
Equus sp.	3	8.33	0	0
Large herbivore	1	2.78	1	50
Total	36	100	2	100

Figure 17 Le Rozel. Red deer femur (LR 2012, n°1214) with a helical fracture, cut marks and two use areas; cortical, lateral, medullary and lateral views (from left to right) (photos by Noémie Sévêque).

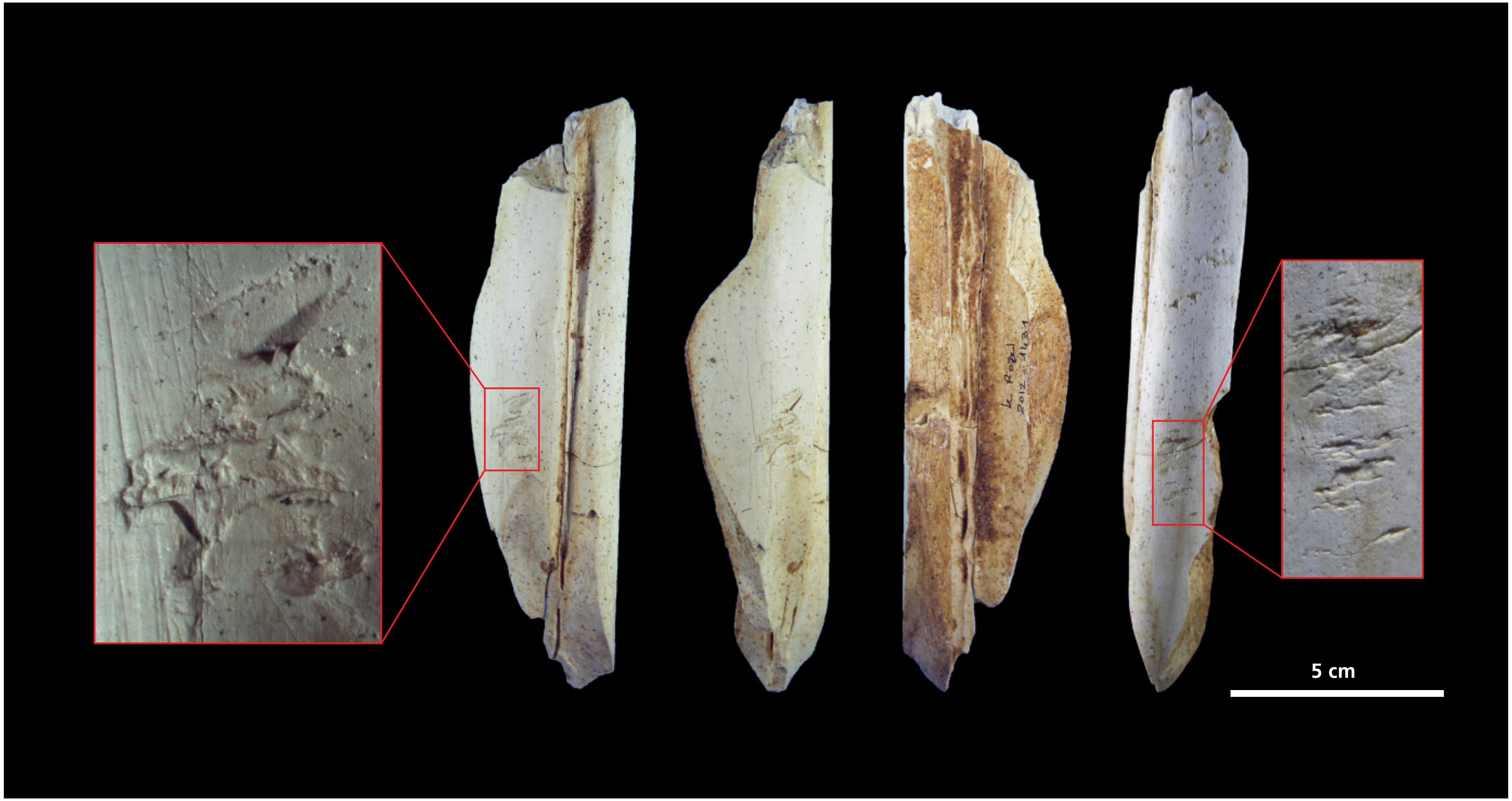

Figure 18 Le Rozel. Red deer metatarsal (LR 2012, n°1431) with a helical fracture, cut marks, scraping marks and three use areas; dorsal, lateral, palmar and lateral views (from left to right) (photos by Noémie Sévêque).

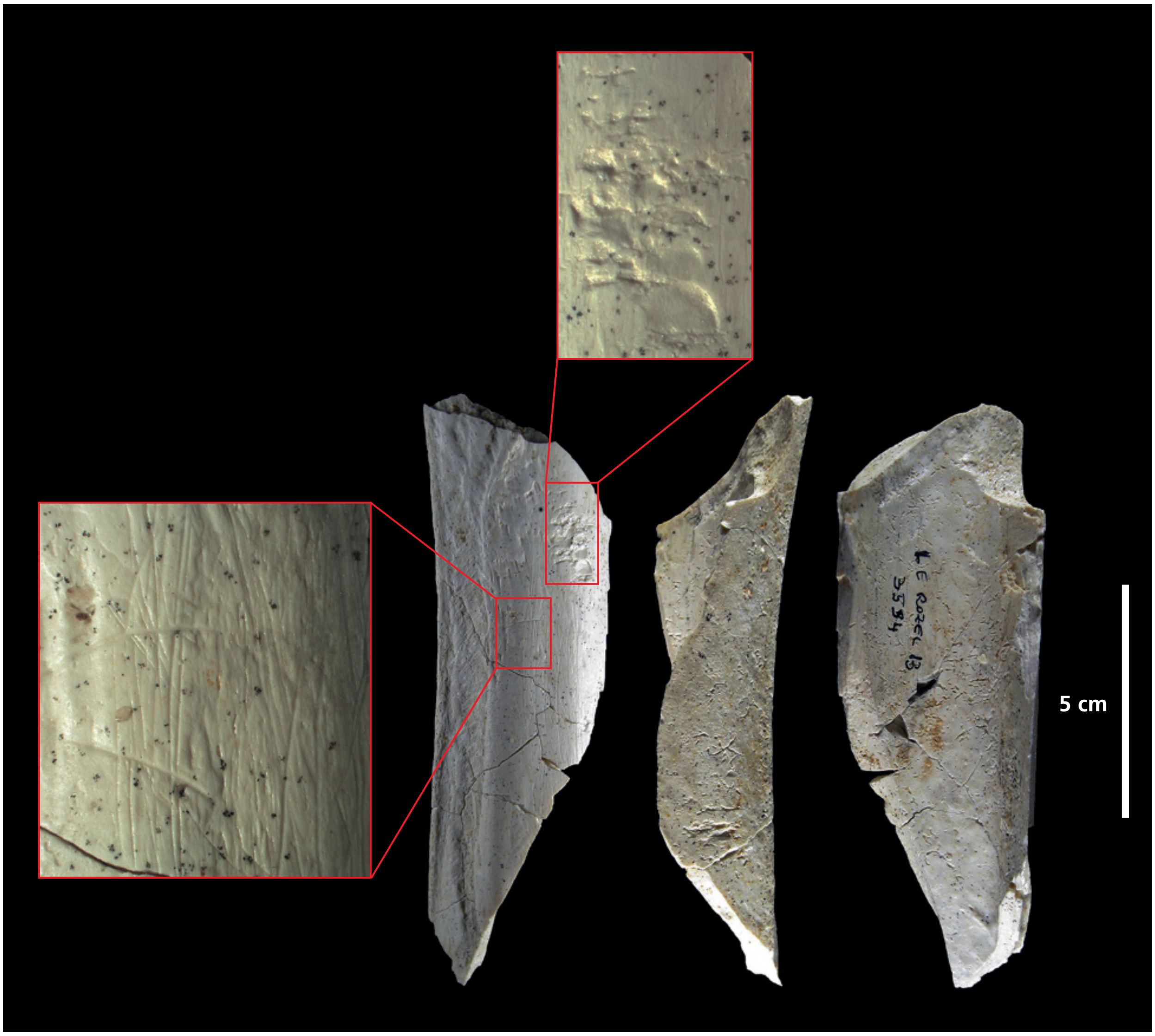

Figure 19 Le Rozel. Red deer left femur (LR 2013, n°3594) with a helical fracture, impact notch, negative flake scar, cut marks, scraping marks and two use areas; medial, lateral and medullary views (from left to right) (photos by Noémie Sévêque).

whole assemblage. Thus, the elements used for retouchers merely reflect the anatomical composition of the faunal assemblage.

Concerning the utilised red deer mandible, the area of retouching is situated on the lingual part of the bone, below the first premolar (**Figure 23**). The scores are numerous. Despite the thin appearance, the bone did not break during the action of retouching. Other sites also include similar implements, like the utilised reindeer mandible at La Quina (Verna and d'Errico, 2011), three aurochs mandibles from Biache-Saint-Vaast (Auguste, 2002) and a giant deer mandible at De Nadale Cave (Jéquier et al., 2015). Even if long bone diaphyses are often the most used (Vincent, 1993; Armand and Delagnes, 1998; Daujeard, 2014), the use of mandibles is not so rare.

At Le Rozel, the general pattern of retoucher use is the same as at Biache-Saint-Vaast: there is no selection for species or skeletal parts. Neanderthals used the species and the bones that were the most abundant.

Looking to the limb bones, only the diaphyses were used as retouchers. In most cases, pits and scores are situated on the extremities of the fragments, even if there are multiple use areas. When the retouchers are small or less elongated, the use

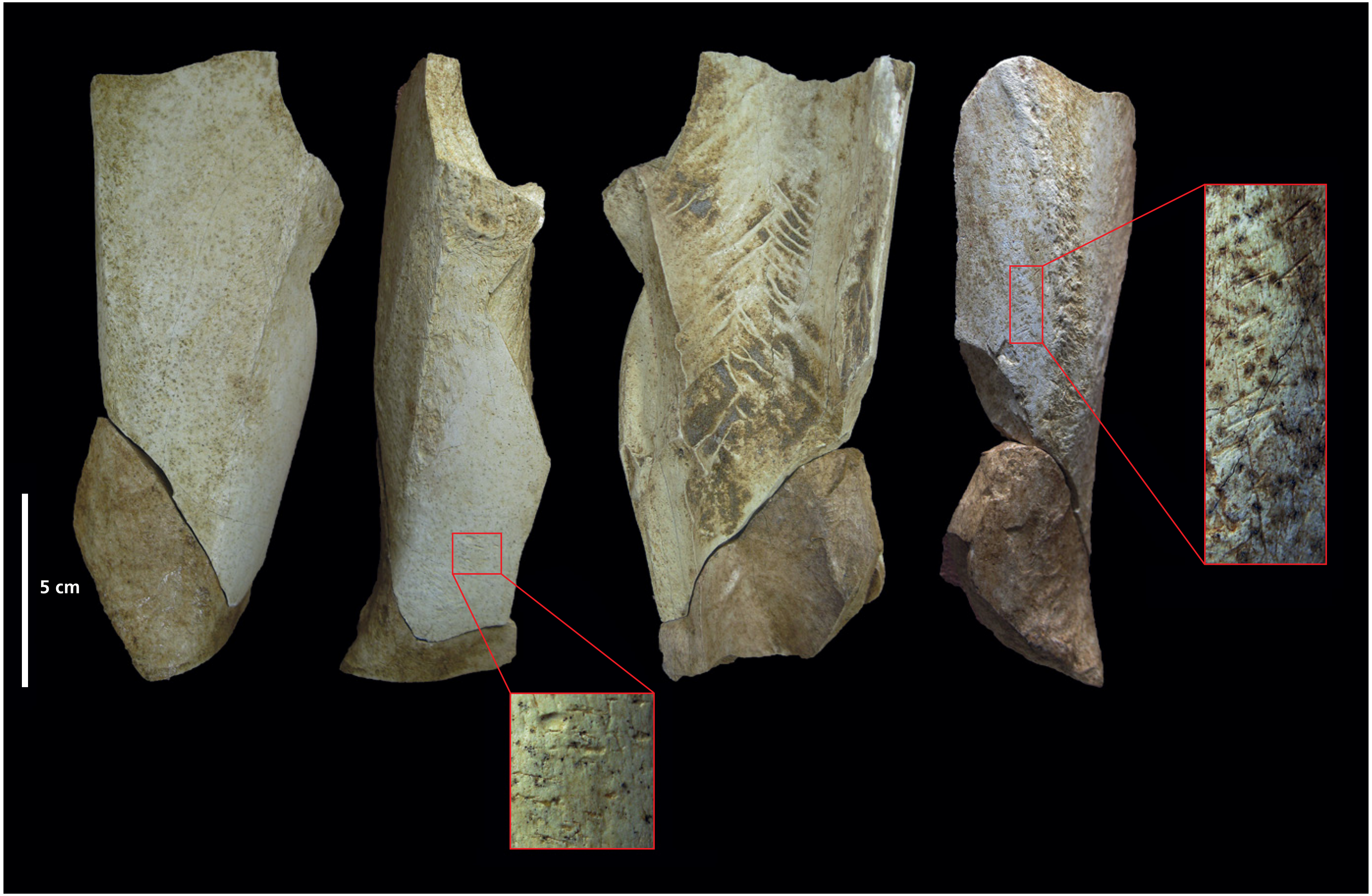

Figure 20 Le Rozel. Aurochs right humerus (LR 2013, n°6629+6912) with a helical fracture, cut marks and one use area; cranial, lateral, medullary and medial views (from left to right) (photos by Noémie Sévêque).

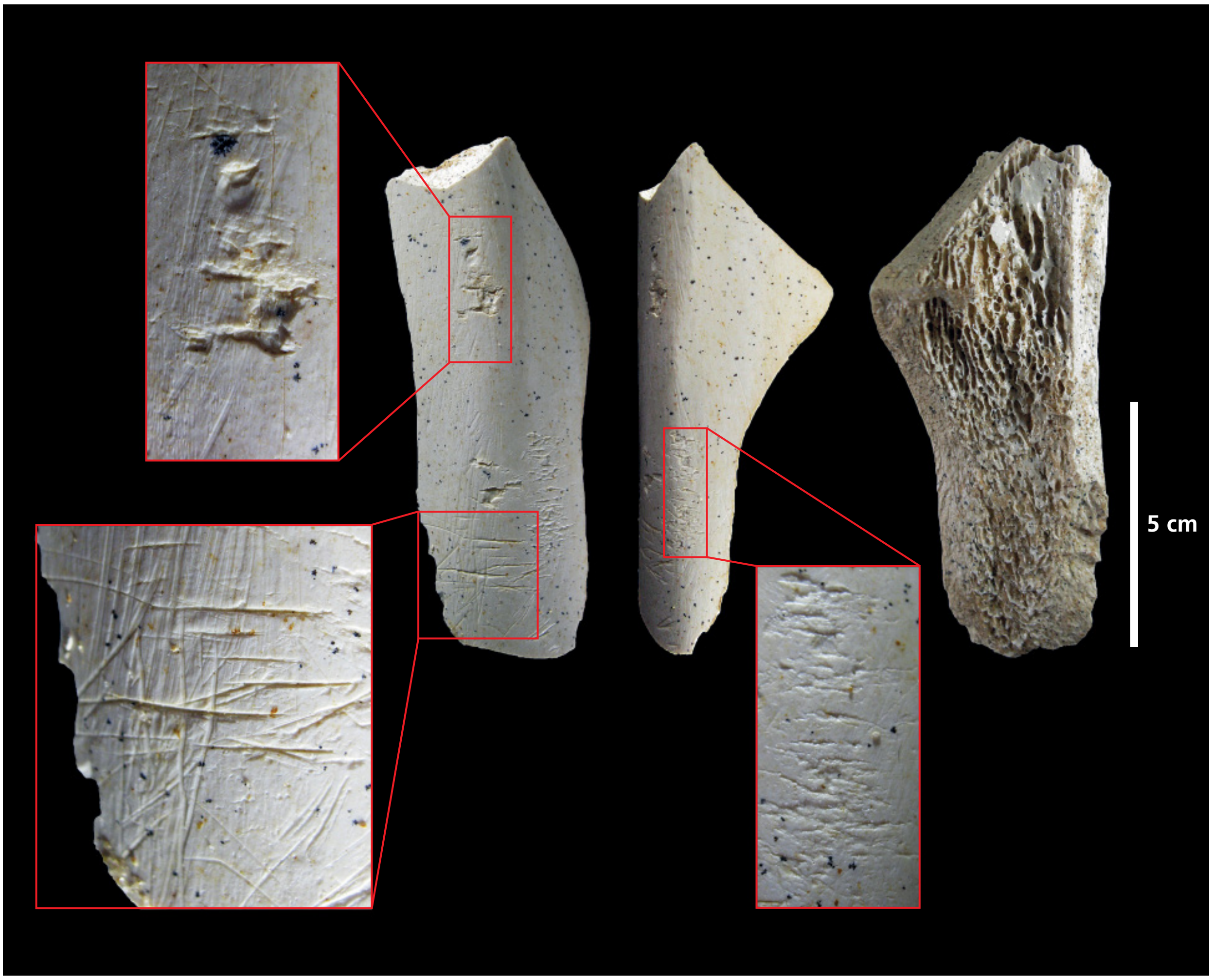

Figure 21 Le Rozel. Horse long bone (LR 2013, n°3559) with a helical fracture, cut marks, scraping marks and three use areas; cortical, lateral and medullary views (from left to right) (photos by Noémie Sévêque).

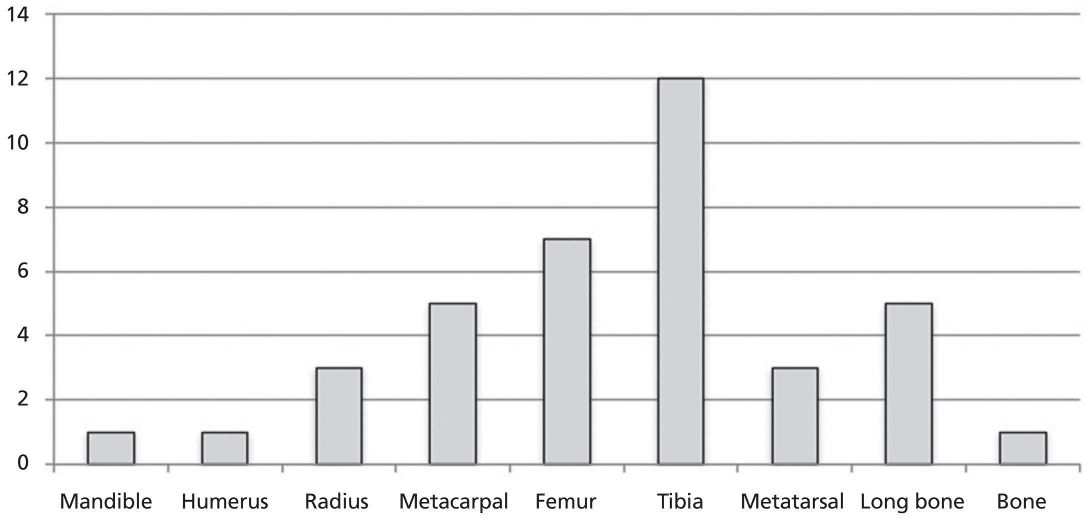

Figure 22 Number of specimens by anatomical element used as retouchers.

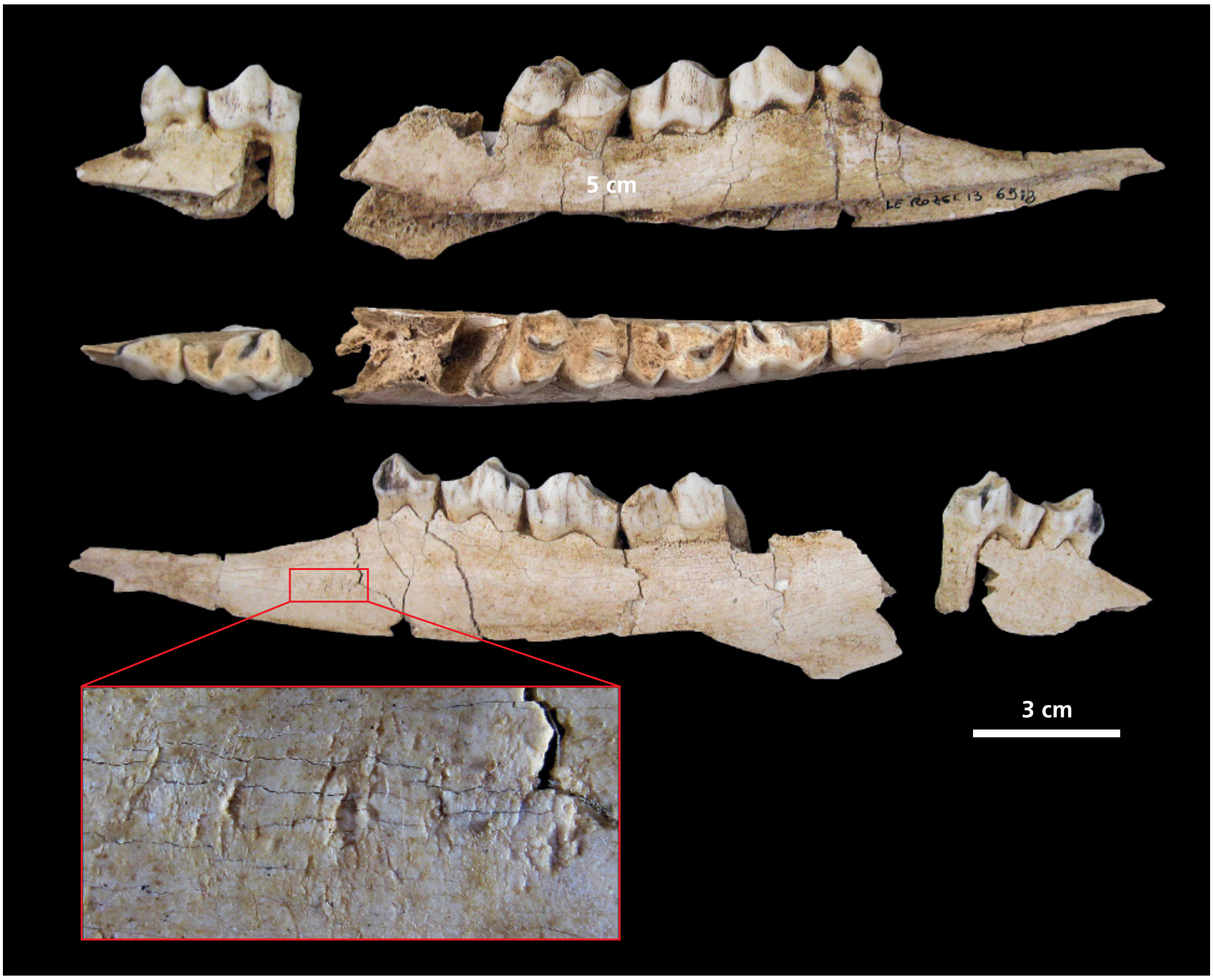

Figure 23 Le Rozel. Red deer left mandible (LR 2013, n°6703+6918) with one use area; vestibular, occlusal and lingual views (from top to bottom) (photos by Noémie Sévêque).

areas are located toward the centre of the bones. The surfaces where the stigmata are located are slightly convex or flat. For tibia diaphyses, the angles created by the different faces of the shaft often separate multiple use areas or mark the limits of the lone use area (**Figure 24**). Up to four retouching areas have been observed on a single bone (**Figure 25**), but one use area is the most common pattern, occurring on 25 of the 38 retouchers at Le Rozel. Nine retouchers present two use areas, and three others have three use areas (**Figure 26**). Differences can be seen in the use areas: some present only a few scores (**Figure 27**), while others show a much higher number (**Figure 28**).

Retouching areas also occur frequently with other anthropic modifications, such as helical fractures, cut marks and scraping marks. Thirty-five retouchers present helical fractures made on green bones before their use as retouchers, 29 bone tools are cut-marked (**Figure 29**), and 12 have scraping marks. Cut and scraping marks were identified together on eleven retouchers. One interesting point is that all retouchers with three and four use areas, and two of nine with two use areas, present scraping marks on the surface. In contrast, only one of the 25 retouchers with one use area shows scraping damage. Scraping marks are usually made while preparing the bone surfaces for use as retouchers. At Le Rozel, it is clear that scraping is almost exclusive to retouchers with multiple use areas. This may imply that Neanderthals knew from the onset whether the bone would be used multiple times as a retoucher.

If it was to be used only once, scraping the bone surface was not necessary. On the other hand, if the bones were to be used again, scraping was necessary to prepare the entire cortical surface. This may suggest intentional preparation and predetermination by Neanderthals.

Mutzig

The site of Mutzig is located in Alsace, near the Vosges Mountains, at the end of the Bruche Valley. Mutzig is one of the few Middle Palaeolithic sites from northeastern France, thus essential for the comprehension of Neanderthal behaviour in this part of Europe.

After its discovery in 1992, Jean Sainty directed several surveys over the next four years (Sainty et al., 1993). Part of the sediment deposit was in open-air context and the remainder was under a sandstone rockshelter that had collapsed and covered the site with rocks from the Felsbourg Hill. This rockfall and the calcareous water coming from the hill protected many of the artefacts from destruction. In 2009, Jean Detrey and Thomas Hauck continued the surveys and made systematic excavations (**Figure 30**), since 2013 directed by Héloïse Koehler.

At least seven archaeological levels are present (5, 7a, 7c1, 7c2, 7d, 8, 9/10), dated to ca. 90 ka by OSL (Detrey and Hauck, 2011; Koehler and Wegmüller, 2015). In each level, hundreds of faunal and lithic artefacts are associated with hearth remains. Thus far, in terms of raw material and technology, the lithic industry is quite consistent throughout all the levels. Fifteen different raw materials were used, all coming from within 15 km surrounding the site (Koehler and Wegmüller, 2015; Koehler et al., 2016). Almost 7% of the lithic remains are tools.

At present, 2368 faunal remains have been studied (Koehler and Wegmüller, 2015; Koehler et al., 2016). The species present in Mutzig are: reindeer

Figure 24 Le Rozel. Red deer tibia (LR 2012, n°1179) with a helical fracture, cut marks and one use area; medullary (left) and cortical (right) views (photos by Noémie Sévêque).

Figure 25 Le Rozel. Red deer tibia (LR 2013, n°4334+4335) with a helical fracture, cut marks, scraping marks and four use areas; cortical, lateral and medullary views (from left to right) (photos by Noémie Sévêque).

(Rangifer tarandus); horse *(Equus* sp.); woolly mammoth *(Mammuthus primigenius)*; steppe bison (cf. *Bison priscus)*; woolly rhinoceros *(Coelodonta antiquitatis)*; a small bovid, possibly chamois *(Rupicapra rupicapra)*; wolf *(Canis lupus)*; fox (cf. *Alopex lagopus)*; bear *(Ursus* cf. *arctos)*; and beaver *(Castor fiber)*. Reindeer is the most represented species (**Table 9**), with a minimum of 24 individuals: nine juveniles, one young adult, thirteen adults and one old adult. Horse is the second most abundant species, with twelve individuals: five juveniles, five adults and one old adult could be reliably identified. Mammoth is represented by nine individuals based on teeth, which are overrepresented compared to the post-cranial skeleton. Few remains have been attributed to bison, but five individuals are represented among all the archaeological levels. Rhinoceros is represented by two individuals: one juvenile and one adult. Except for wolf, which has an MNI of two, all other species are represented by only one individual.

The material found in 2015 and 2016 allows for estimating the seasonality of occupation within the different levels at Mutzig (**Table 10**). For example, levels 7c2 and 9/10 show selective hunting of young reindeer (**Figure 31**), whereas levels 5 and 7c1 present no selectivity in hunting of any large mammals (Koehler and Wegmüller, 2015).

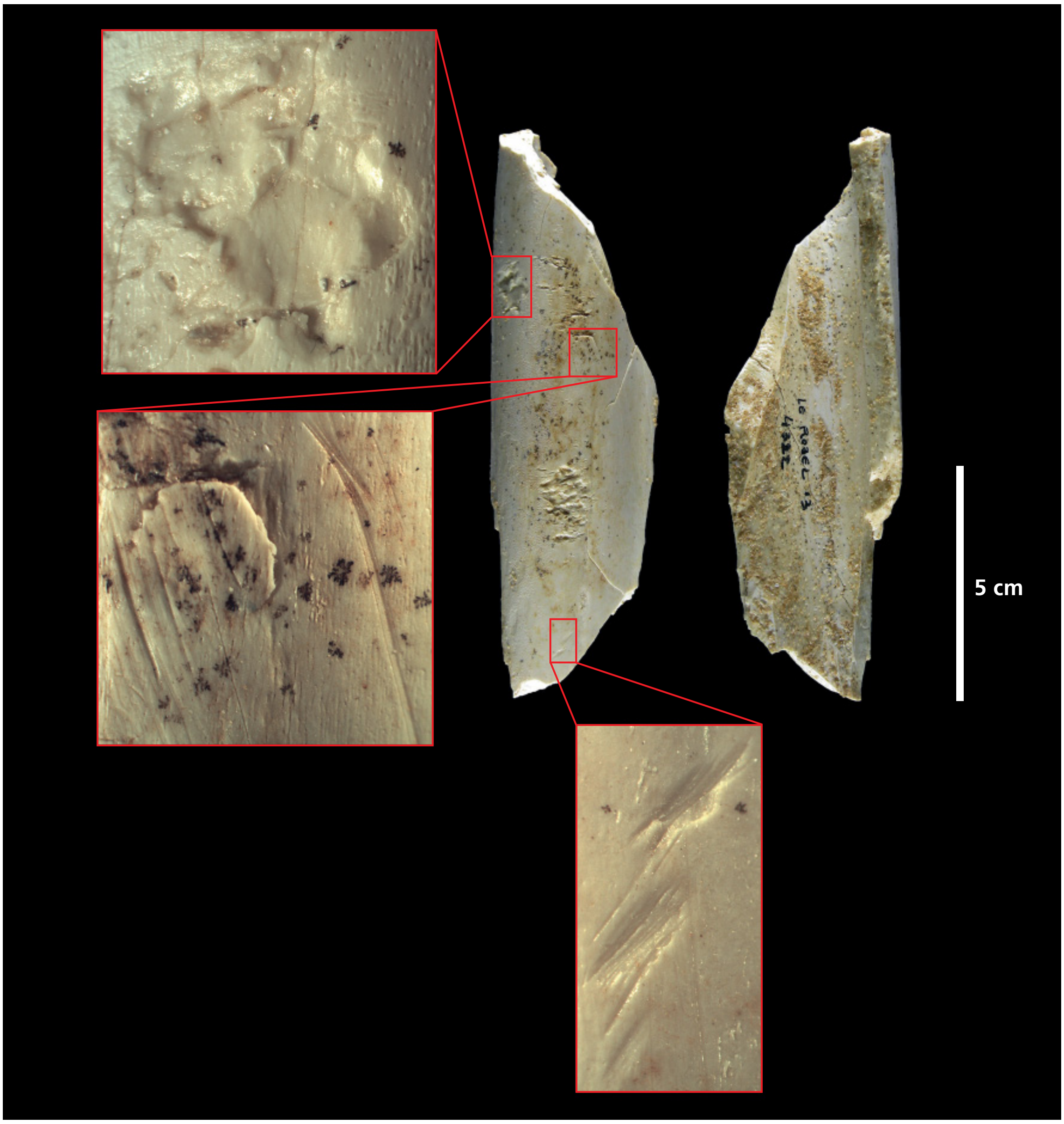

Figure 26 Le Rozel. Red deer tibia (LR 2013, n°4322) with a helical fracture, impact notch, negative flake scar, cut marks, scraping marks and three use areas; cortical (left) and medullary (right) views (photos by Noémie Sévêque).

The state of preservation of the faunal remains is variable. Some are very well preserved and others are weathered due to the acidity of the sediments. This could have prevented the identification of some butchery marks and retouch stigmata. So far, 1163 anthropic marks have been inventoried. Helical fractures are very common on reindeer long bones, but cut marks are quite rare. Scraping marks occur on only one bone.

So far, we identified only three retouchers from Mutzig. Two were discovered during the previous excavations in 1993 and 1994, the third came from the recent excavations in 2013. The retouchers were made with large mammal bones: two from red deer bones and the other from horse.

One reindeer tibia presents two areas of retouching located on the extremities of the bone (**Figure 32**). The pits are numerous and oriented roughly perpendicular to the long bone axis. Some pits are deep and large, indicating the use of substantial force. This bone also presents a helical fracture from marrow extraction.

Figure 27 Le Rozel. Red deer metacarpal (LR 2013, n°3976) with a helical fracture, impact notch, negative flake scar, cut marks and one use area; cortical, dorsal and medullary views (from left to right) (photos by Noémie Sévêque).

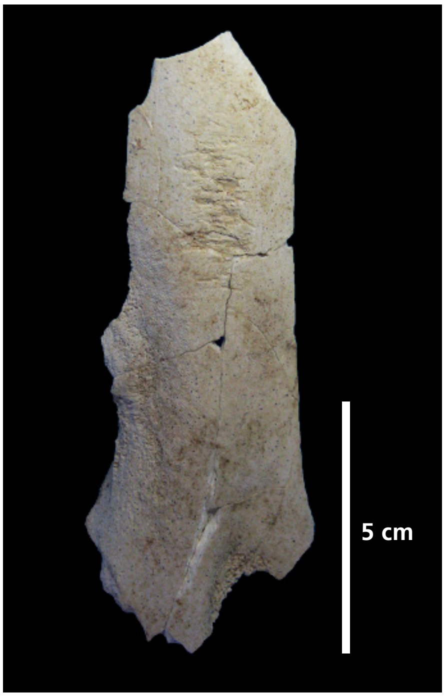

Figure 28 Le Rozel. Red deer right femur (LR 2012, n°175) with a helical fracture, cut marks and one use area; lateral view (photos by Noémie Sévêque).

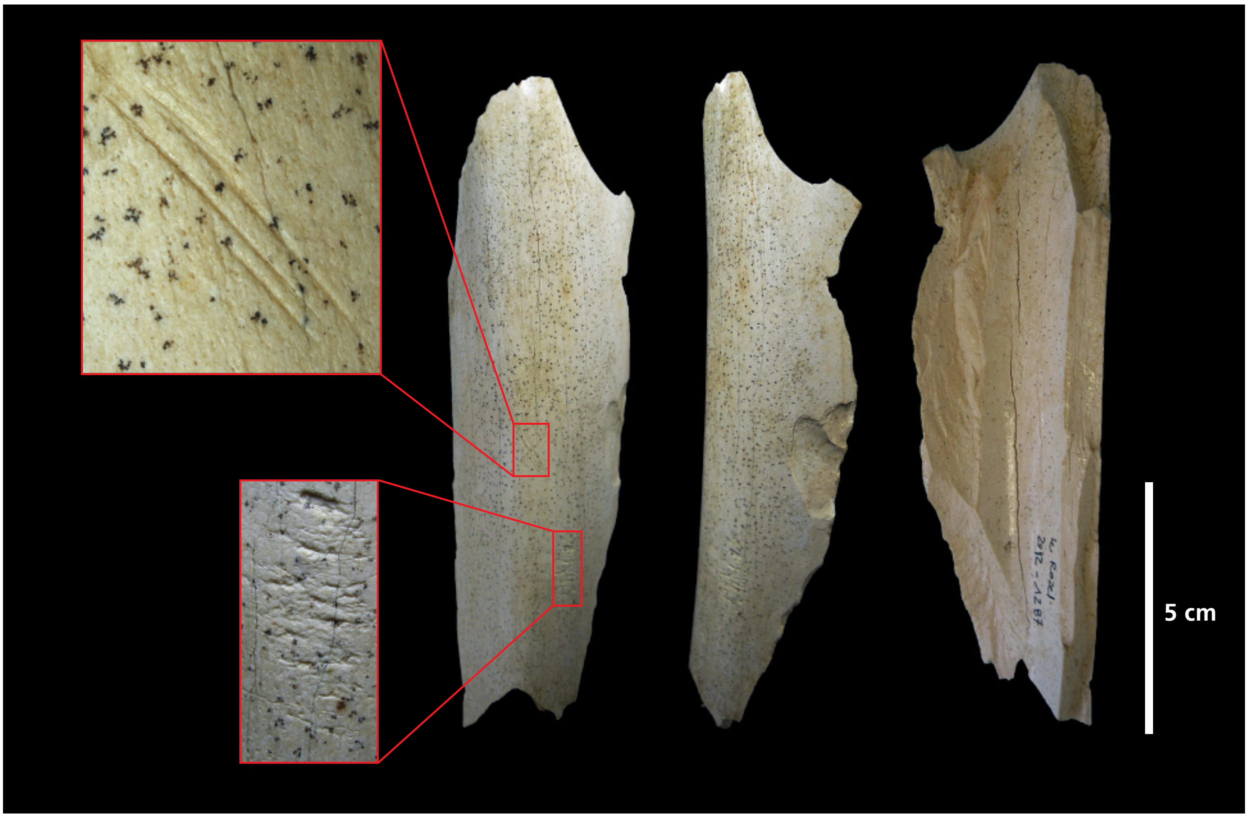

Figure 29 Le Rozel. Red deer tibia (LR 2012, n°1287) with a helical fracture, impact notch, negative flake scar, cut marks and a use area; cortical, lateral and medullary views (from left to right) (photos by Noémie Sévêque).

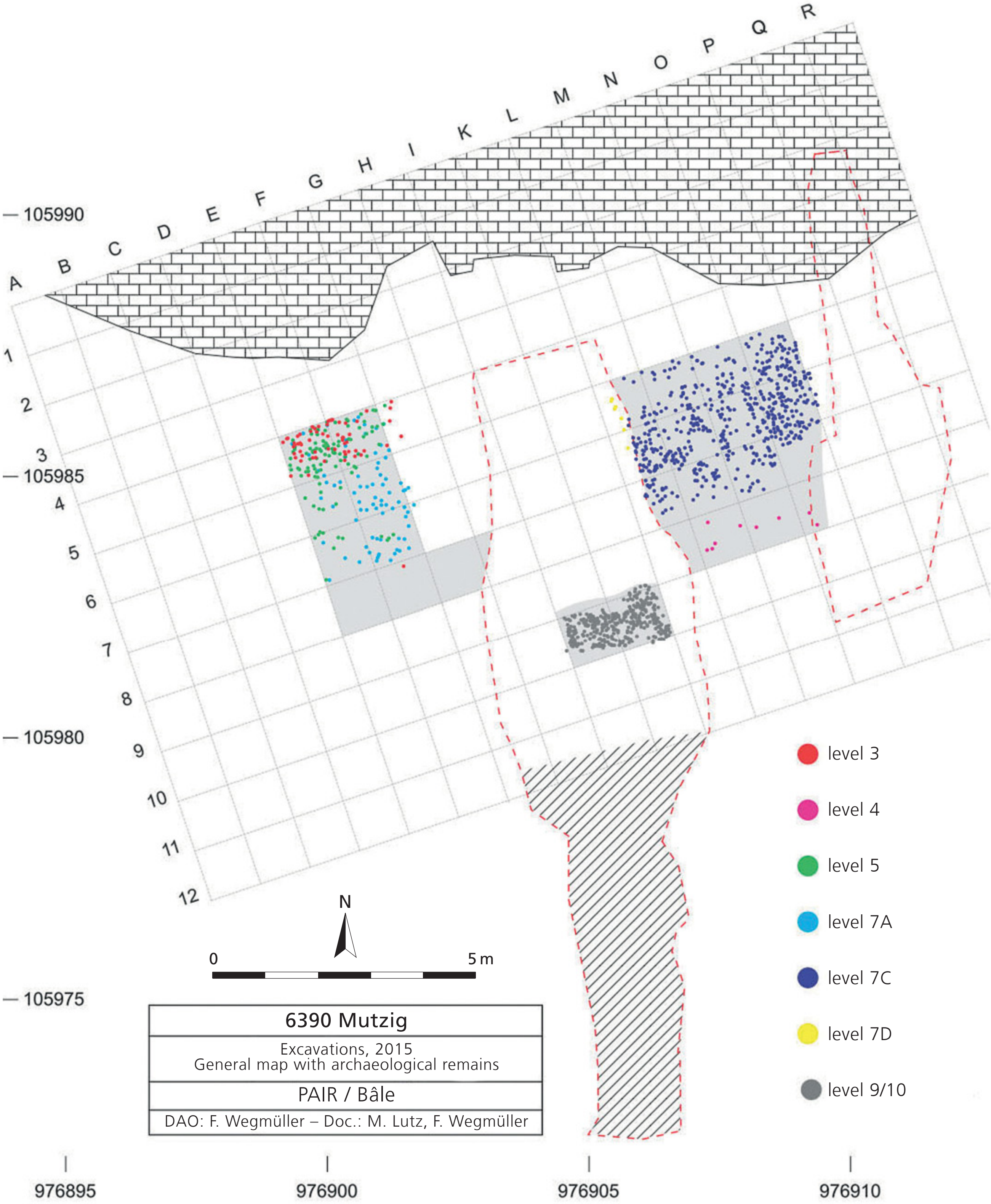

Figure 30 Mutzig. Map of the excavations with horizontal distribution of remains found in 2015 (after Koehler and Wegmüller, 2015).

Table 9 Large fauna species at Mutzig, with MNI (minimum number of individuals).

	Layer							
Taxon	5	7a	7c1	7c2	7d	8	9/10	Total
Rangifer tarandus	2	2	4	7	1	1	7	24
Equus sp.	2	3	4	1		1	1	12
Mammuthus primigenius	1	2	2	1	1	1	1	9
cf. *Bison priscus*	1	1	1	1			1	5
Coelodonta antiquitatis	1	1						2
small bovid			1					1
Canis lupus	2							2
cf. *Alopex lagopus*			1					1
Castor fiber							1	1

Table 10 Seasonality data from each archaeological level at Mutzig.

Level	Age of fawn/foal	Antlers	Months of Occupation	Season of Occupation
5	-	-	-	-
7a	<10 months <20 months	-	Before February	Winter
7c1	12-15 months	-	June - September	Summer
7c2	8-10 months 8-10 months 12-15 months 29-30 months	June – February	February - April February - April June - September November - December	All year
7d	-	-	-	-
8	-	-	-	-
9/10	8-10 months ± 10 months 12-15 months ± 20 months	-	February - April April June - September February	End of Winter - End of Summer

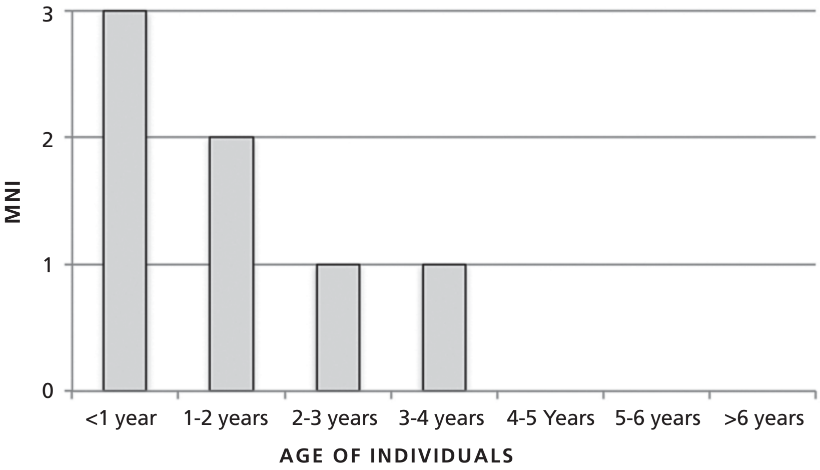

Figure 31 Mutzig. Mortality profile of reindeer in level 9/10.

Figure 32 Mutzig. Reindeer right tibia (MII 93, n°11o) with a helical fracture and two use areas; laterocranial, cranial, medullary, caudal-medullary and caudal views (from left to right) (photos by Noémie Sévêque).

The second retoucher was made on the bone of a horse (**Figure 33**), which is the second most represented species. The location of the use area is not clear, since the bone is freshly broken, but the missing portion suggests that the pits and scores were situated more toward the extremity than in the centre of the complete piece. The pits are numerous and rectilinear.

Finally, the third retoucher was made on a reindeer long bone (**Figure 34**). The use area is located in the centre of the artefact, but the bone is also broken so the original shape cannot be determined. The acidic sediment damaged the surfaces of the bone and prevented a detailed characterization of the pits and scores, but some are still visible at the periphery of the use area. The associated surface modifications are also remarkable, with numerous cut marks along one edge of the bone. In fact, this is the only bone from Mutzig that presents so many cut marks. Their location and abundance may suggest that they are not traditional cut marks from butchery activities, but linked to the retouching. Perhaps, Neanderthals tested the sharpness of the lithic tool on the edge of the bone during the retouching activity.

Discussion and conclusion

In northern France, retouchers are known from the end of the Lower Palaeolithic (Cagny-l'Épinette) and were used throughout the entire Middle Palaeolithic (Biache-Saint-Vaast, Le Rozel, Mutzig). Owing to the shape of the use areas and their locations on the bones, it is clear that there is a standardization of these retouchers, established since the beginning of the Middle Palaeolithic. The action of reshaping lithic tools was probably also standardized, whether it be with the large retouchers from Cagny-l'Épinette or the smaller examples from Mutzig. There is no evolution of the retouchers through time, in the same way we see that general patterns in lithic industries and subsistence behaviours did not change substantially during the Middle Palaeolithic. Neanderthals developed a specific tool-kit, and, since the very beginning, all the characteristics typical of Neanderthal culture were present and changed little through time. One problem with Cagny-l'Épinette is that we still do not know which hominin species was present in western Europe at that time *(Homo heidelbergensis* or *Homo neanderthalensis)*. Were the retouchers made by a species other that Neanderthals? If so, we contend that even with only six retouchers, there was already a standardization of these implements.

There is homogeneity in the source and shape of retouchers in northern France during the end of the Lower Palaeolithic and the Middle Palaeolithic. For the four sites presented here, most retouchers come from long bone diaphyses of herbivores and/or carnivores that were the most abundant species in the assemblages. In general, retoucher size was limited to bone fragments that were easily grasped in the hand.

But at the site level, differences can be seen within the bone tools. Indeed, there are huge differences in the number of retouchers from each site and within different levels of individual sites, from the 303 retouchers in level IIa of Biache-Saint-Vaast to the three retouchers from all levels at Mutzig.

Also, some retouchers show only one use area, while the others present two, three or sometimes four use areas on the same bone. Large concentrations of stigmata and a significant loss of cortical bone material are often described for some retouchers, but others present only a few scores and a very little loss of bone material.

Comparisons with experimental archaeology (Mallye et al., 2012) suggest that the retouchers described here were used in a fresh state, not dry. This corresponds to an *in situ* and *in tempore* use of bone as a raw material, where the elastic property of fresh bone is important.

Another noteworthy difference is the association with scraping marks, which may provide clues as to the timing of use. Experiments also show that scraping can be, if not should be, made on bones to remove the periosteum. This prepares the surface for percussion and then for the extraction of marrow or for use as a bone tool (Valensi, 2002). Some retouchers studied here present scraping marks on their surface, but others do not. Scraping seems to be habitual at Biache-Saint-Vaast and cleverly planned at Le Rozel, occurring only on retouchers with several use areas.

It is important to ask: what are the factors that can cause the differences mentioned above? First, the lithic raw material does not seem to have had much of an influence over the retouchers from northern France. Only flint was used at Cagny-l'Épinette and Biache-Saint-Vaast, yet the number of retouchers at

Figure 33 Mutzig. Horse long bone (MVIII 94, S8, n°2) with one use area; cortical (left) and medullary (right) views (photos by Noémie Sévêque).

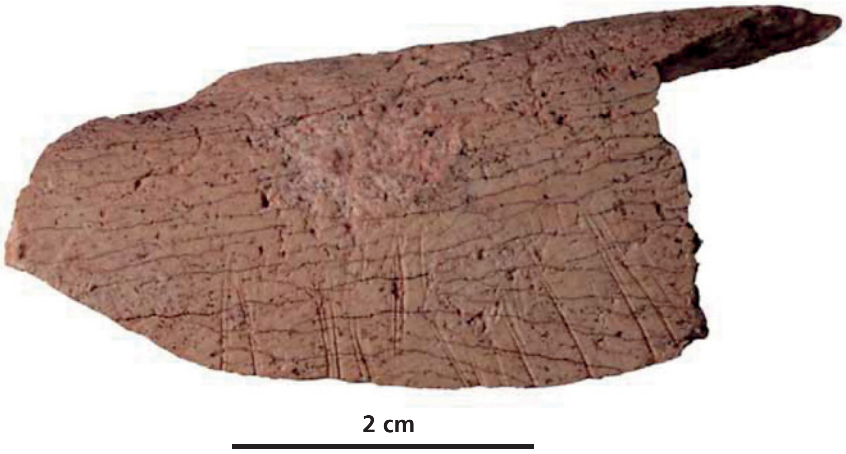

Figure 34 Mutzig. Reindeer long bone (M2 2013, c5, O6, n°171) with cut marks and one use area; cortical view (photo by I. Déchanez-Clerc).

these two sites is widely different. At Le Rozel, flint was used along with quartz and sandstone, and 38 retouchers have been identified in only four years of excavations. Finally, flint is rare in eastern France; at Mutzig, Neanderthals used at least 15 different lithic raw materials. Flint is absent in layers 7c1 and 9 at Mutzig and is most abundant in layer 7a, yet still accounts for only 18.2% of the material (Koehler and Wegmüller, 2015). Despite this, retouchers have been identified and were used regardless the lithic raw material.

The lithic tools associated with the retouchers are also an important consideration. The balance between the number of retouchers and flake tools is not the same across the four sites. Depending on the level, the flake tools of Cagny-l'Épinette represent 10-20% of the lithic assemblage (Moigne et al., 2016). This is quite a high for only six retouchers in the entire assemblage. On the contrary, Biache-Saint-Vaast level IIa yielded 303 retouchers and only 449 retouched artefacts (Auguste, 2002). In all levels combined, 483 flake-tools (1% of the lithic material) were discovered for 333 retouchers (Hérisson, 2012). The pattern at Le Rozel is the same as Biache-Saint-Vaast: 23 scrapers account for all of the flake tools (less than 1% of the lithic material), whereas 38 retouchers have been identified. Finally, the ratio of flake-tools from the new excavations at Mutzig is quite low: 28 retouched artefacts, representing only 6.9% of the lithic assemblage (Koehler et al., 2016), compared to only one retoucher (the two other retouchers came from the historic excavations). Overall, the ratios of retouchers to flake tools is quite variable – there are actually more bone retouchers than flake tools at Le Rozel. The types of tools also do not seem to be a factor, since several different tools were produced at the sites: three tool types at Cagny-l'Épinette, seven types at Biache-Saint-Vaast and four at Mutzig. The exception is Le Rozel, where only scrapers are present.

Site function may play a role in the identification of bone retouchers, since different types of sites preserve the remains of different activities. Cagny-l'Épinette and Biache-Saint-Vaast were both likely kill and butchery sites. The site functions were the same, but the number of retouchers is very different. Biache-Saint-Vaast is a large site with many occupations and the remains of a total of 626 individual animals. Cagny-l'Épinette preserves the remains of 123 animal individuals but only three retouchers. Between these two sites, the numbers of retouchers is not proportional to the number of animals killed. Le Rozel and Mutzig are butchery locations and communal habitation places. At Le Rozel, the 38 retouchers exceed the 21 animal individuals counted. But for Mutzig, there is a noteworthy discrepancy between the 30 animal individuals and the single retoucher found during the modern excavation. For now, we do not ascribe any connection between the function of the site and the number of retouchers, since for these four sites, the ratios between the number of animals killed and the number of retouchers is completely random.

In some cases, spatial distributions can provide evidence of activity areas with clearly delineated concentrations of butchery and/or knapping debris. In the future, it would be worthwhile to visualise the spatial arrangements of these retouchers in order to determine if they are clearly related to activity areas or randomly distributed across the sites.

A number of studies about bone tools from northern France are still in progress. We hope that future excavations at Le Rozel and Mutzig will provide more retouchers to further examine the use of these tools at the site level and across the broader region of northern France.

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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); Schöningen (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;

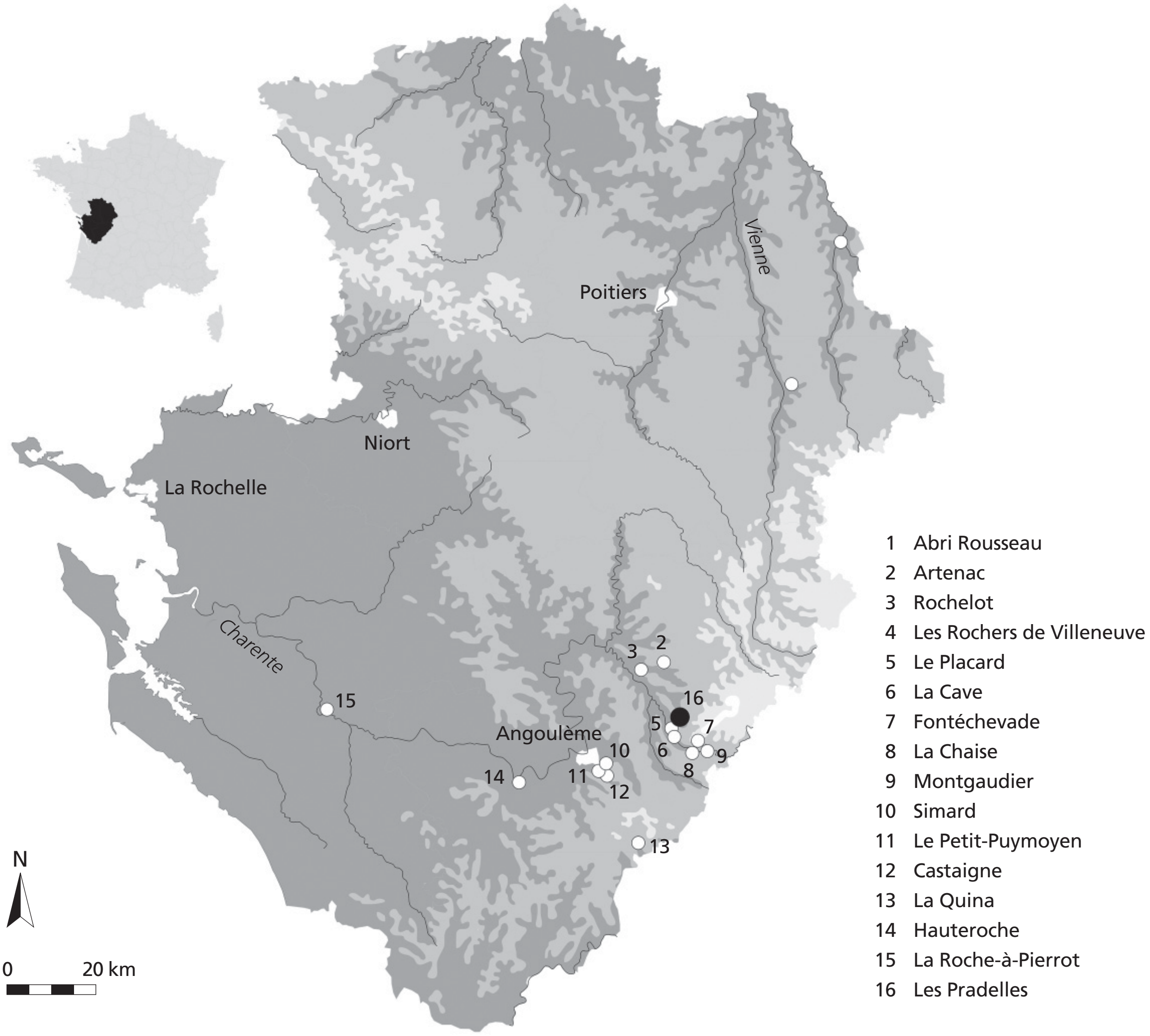

Figure 1 Location of Les Pradelles and other Mousterian sites in the Charente region (image by Lacrampe-Cuyaubère).

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

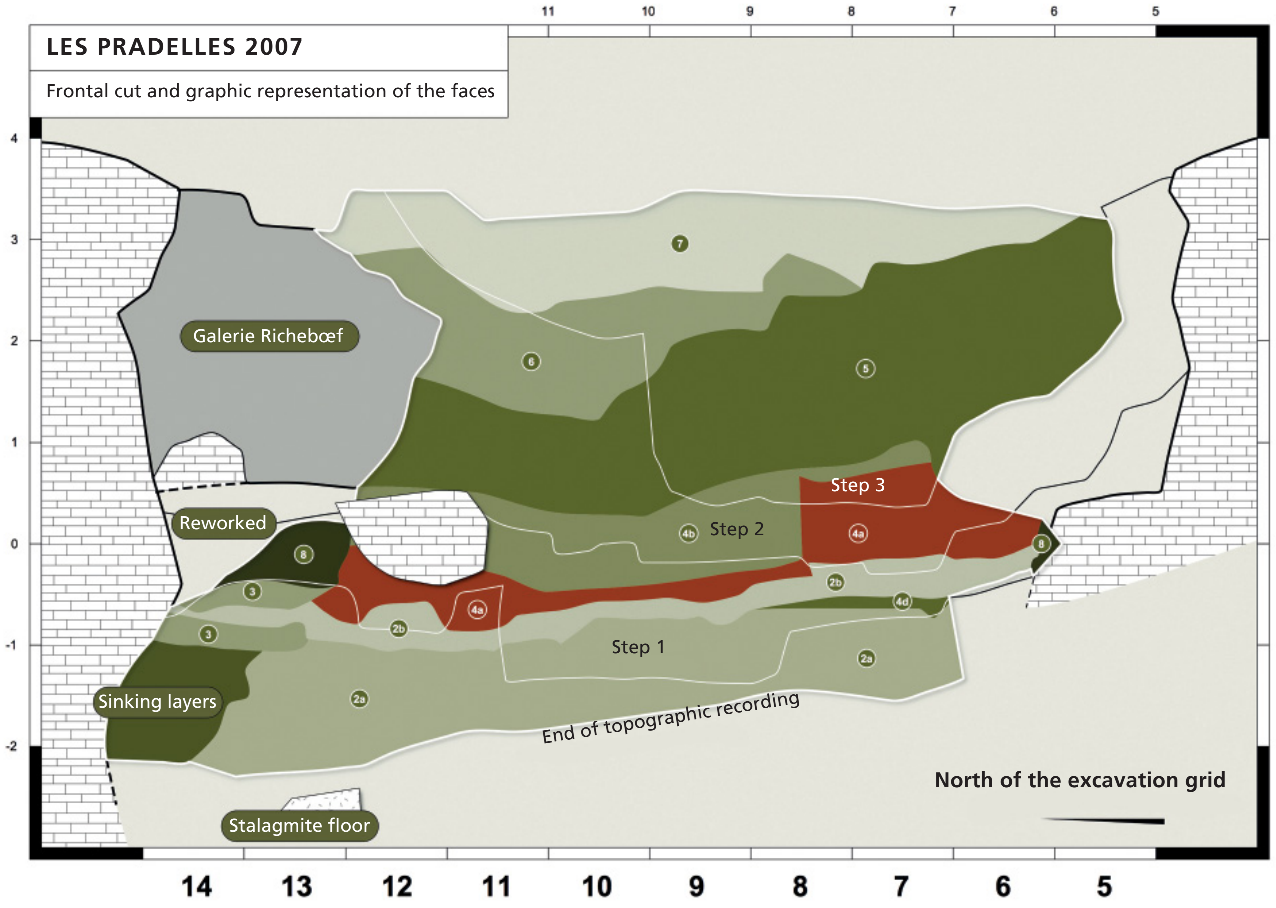

Figure 2 Lithostratigraphy of Les Pradelles (after Maureille et al., 2010; image by Lacrampe-Cuyaubère).

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 NISP$_O$); 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	MNE	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	-	-	-
Humerus	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	-	-	

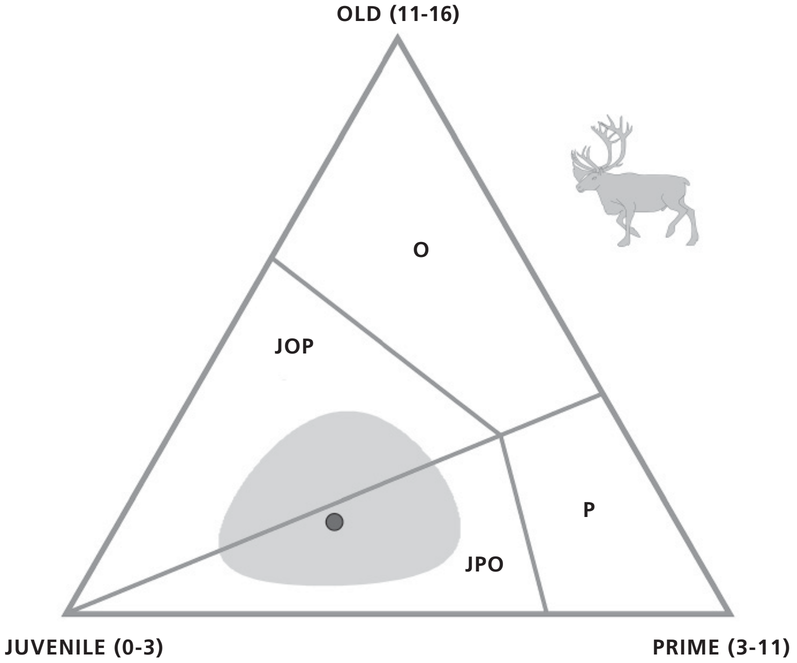

Figure 3 Mortality profile for Les Pradelles reindeer using a ternary diagram modified after Discamps and Costamagno (2015).

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).

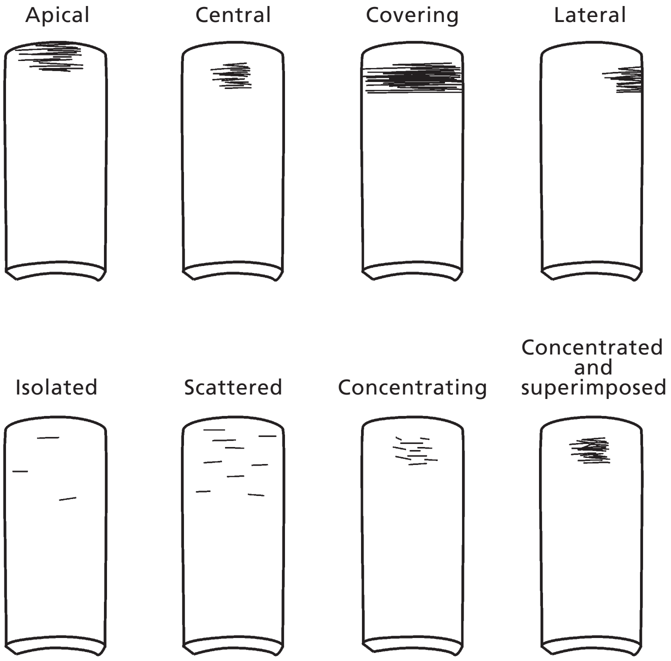

Figure 4 Nomenclature used for the Active Percussion Zone (APZ) description (after Mallye et al., 2012).

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).

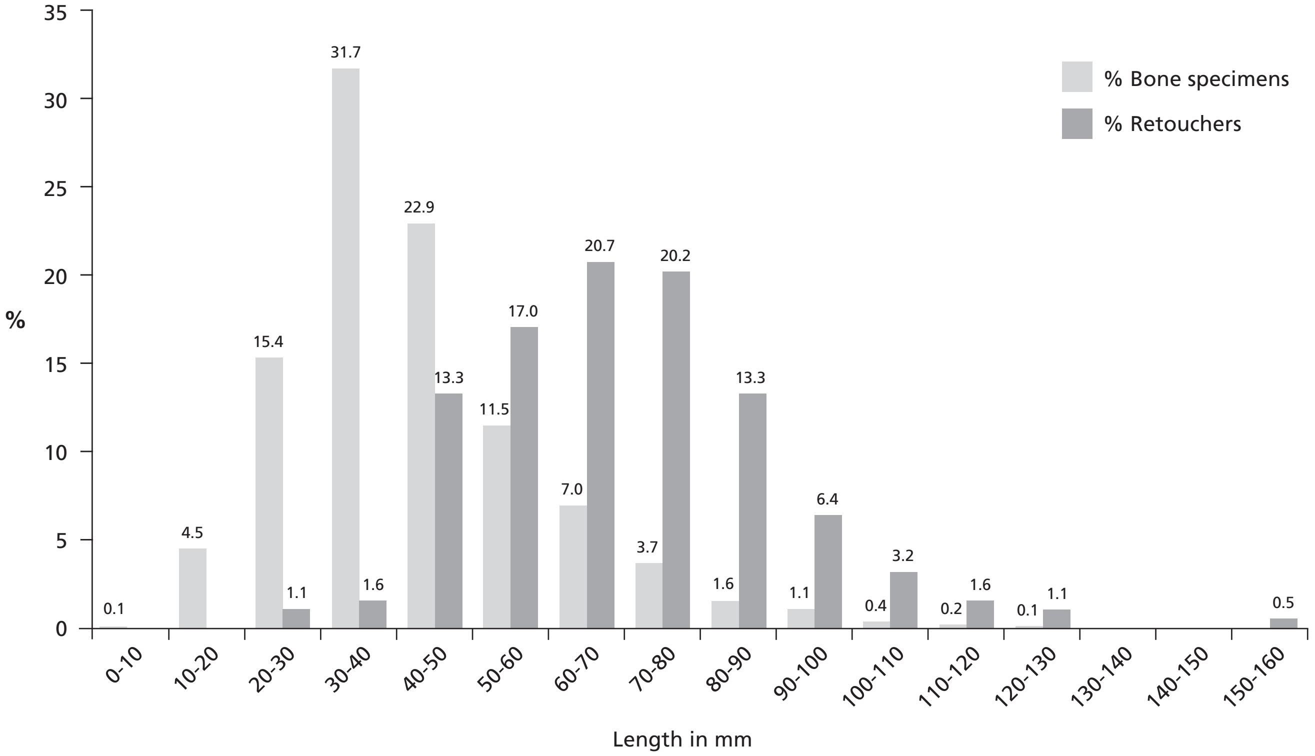

Figure 6 Proportion of bone retouchers and all bone specimens by size classes. Only complete fragments are taken into account.

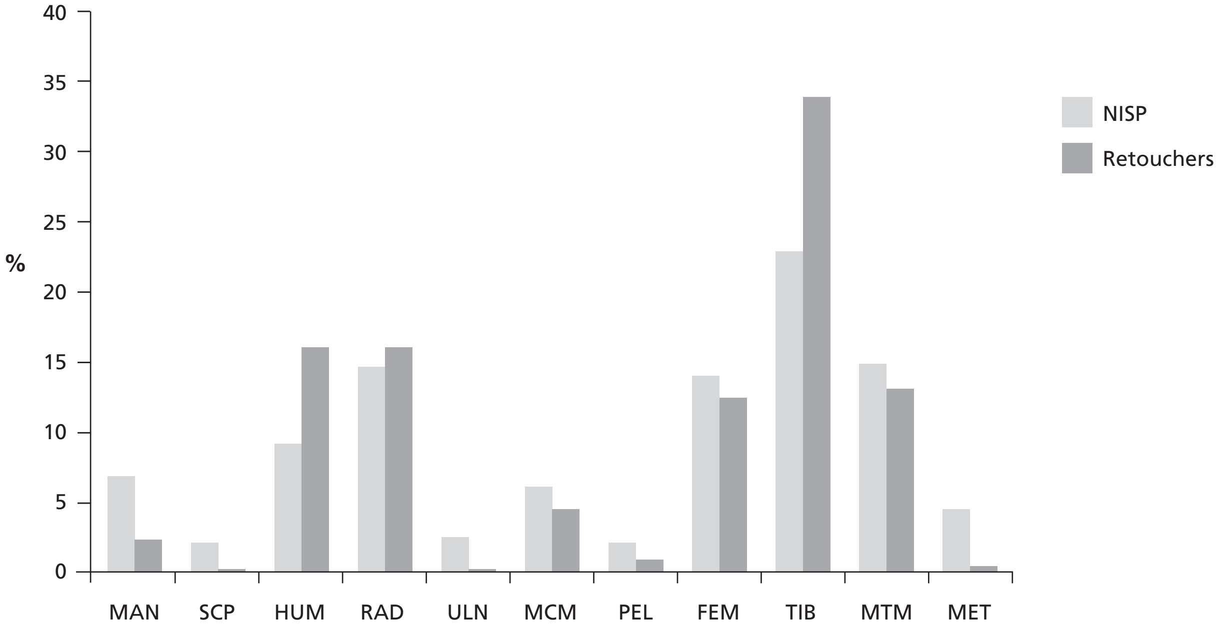

Figure 7 Proportion of bone retouchers and of bone specimens by skeletal parts for the reindeer (NISP = 2919; N retouchers = 473). MAN = mandible; SCP = scapula; HUM = humerus; RAD = radius; ULN = ulna; MCM = metacarpal; PEL = pelvis; FEM = femur; TIB = tibia; MTM = Metatarsal; MET = metapodial.

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

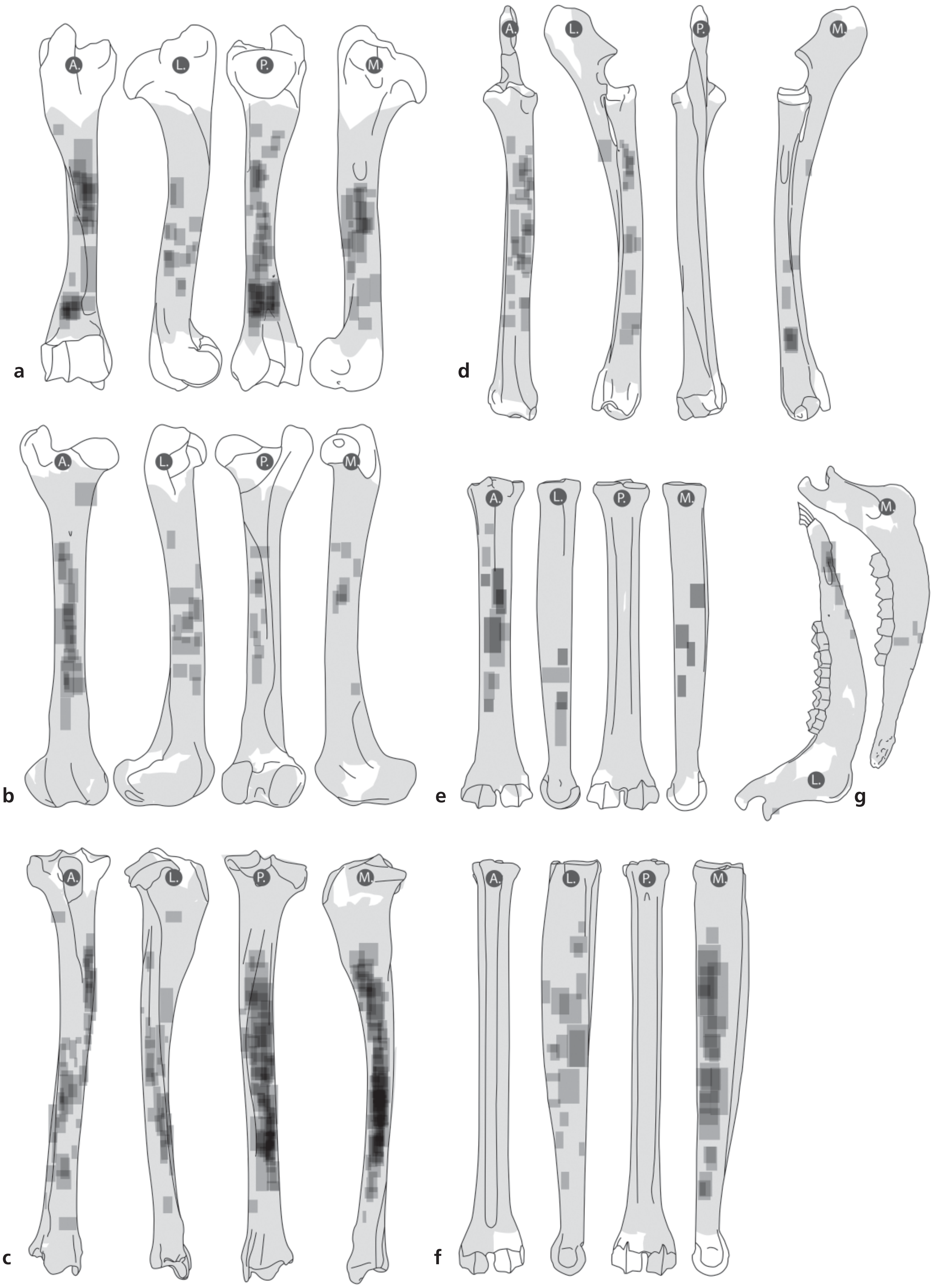

Figure 8 Location of the use areas on reindeer skeletal parts: a. humerus; b. femur; c. tibia; d. radio-ulna; e. metacarpal; f. metatarsal; g. mandible. A. = anterior face; L. = lateral; P. = posterior; M. = medial.

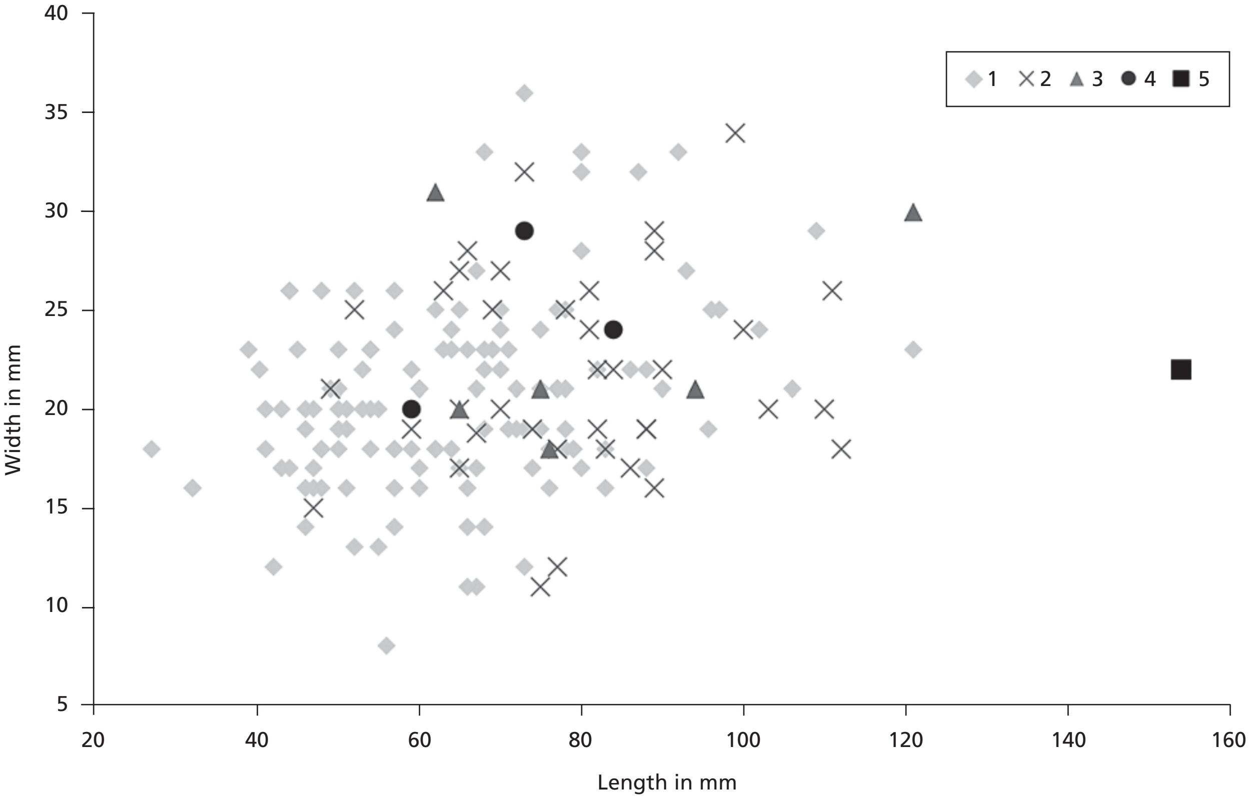

Figure 9 Number of use areas per blank relative to length and width dimensions.

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

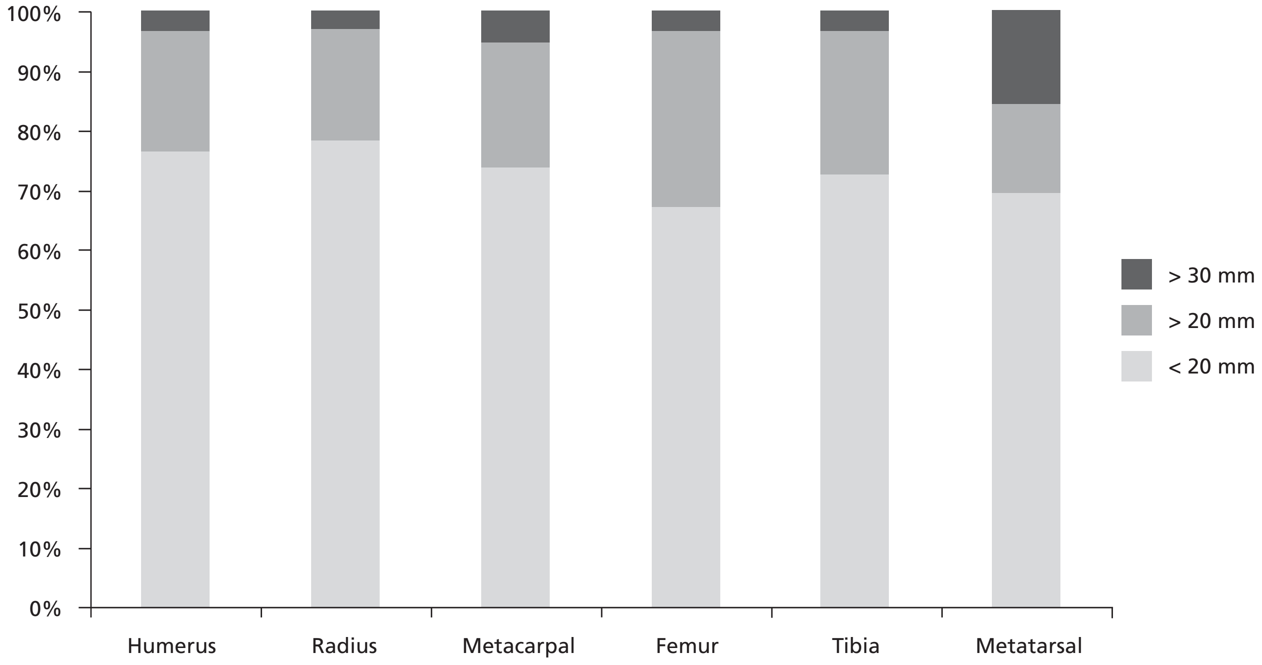

Figure 10 Length of the use areas by skeletal part.

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

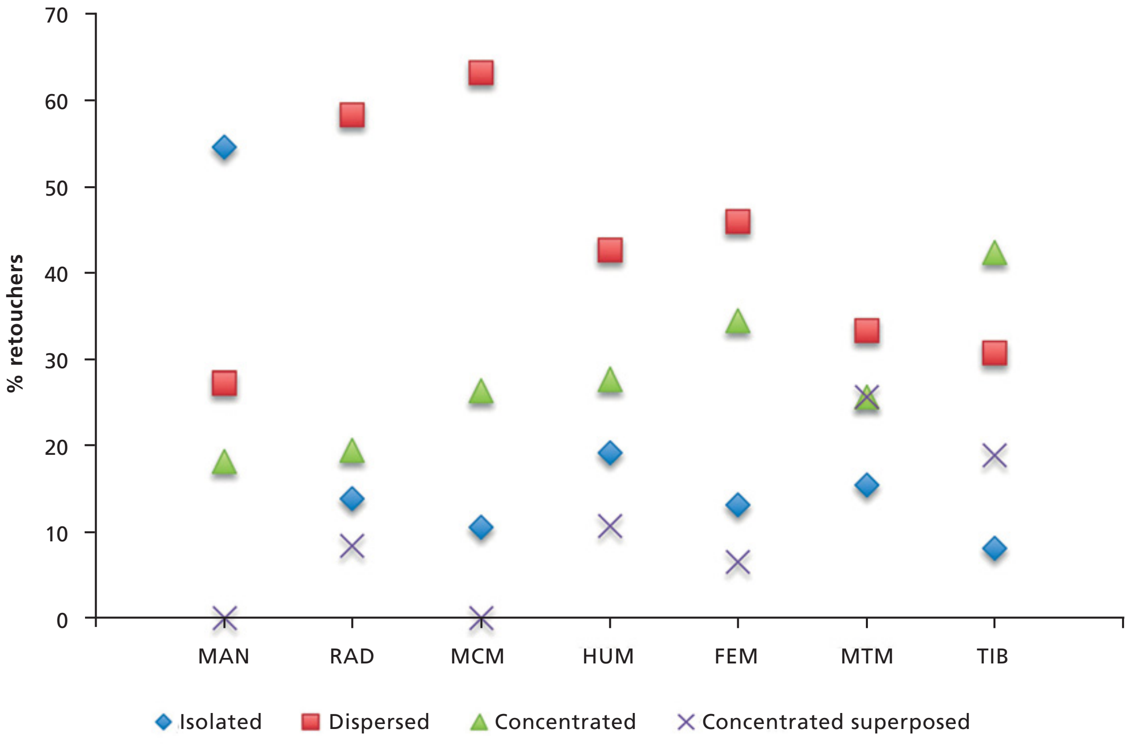

Figure 11 Trace distribution types by skeletal part. MAN = mandible; RAD = radius; MCM = metacarpal; HUM = humerus; FEM = femur; MTM = metatarsal; TIB = tibia.

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?

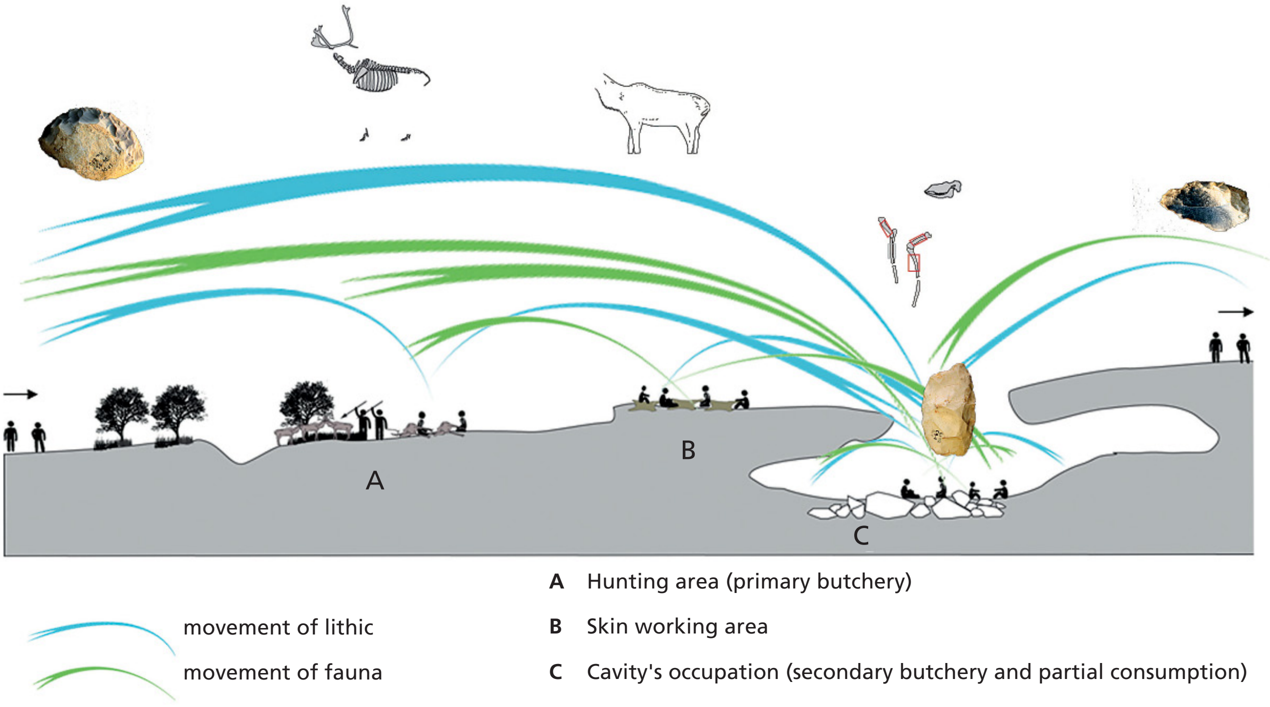

Figure 13 Synthetic techno-economic interpretation of Quina type Mousterian from Les Pradelles (image by Bourguignon).

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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GRÉGORY ABRAMS

PALAEOLITHIC BONE RETOUCHERS FROM BELGIUM: A PRELIMINARY OVERVIEW OF THE RECENT RESEARCH THROUGH HISTORIC AND RECENTLY EXCAVATED BONE COLLECTIONS

Abstract

Since the first half of the 19th century, Belgium has provided a multitude of sites dating back to the Palaeolithic. These discoveries have contributed to the definition of the Palaeolithic and to the understanding of prehistoric people. This long tradition of research has resulted in the collection of thousands of bones that are increasingly the subject of extensive analysis, including the study of bone retouchers. At present, this research has identified 535 retouchers in various Belgian repositories. The tools come from different sites with highly variable and incomplete contextual information depending on their excavation history (e.g., Trou du Diable and the Caves of Goyet). In contrast, unit 5 of Scladina Cave constitutes a well-defined assemblage. Bones with fresh fracture patterns provide interesting technological data, such as a refitted cave bear femoral shaft that includes four retouchers. The use of cave bear bones for producing tools at Scladina Cave as well as retouchers made from Neanderthal remains from the 3rd Cave of Goyet gives rise to questions about the possible symbolic meanings attributed to particular species.

Keywords

Belgium; Middle Palaeolithic; Retouchers; Neanderthals; Cave bear; Refitting

Introduction

Belgian Palaeolithic research has its roots deep in the first half of the 19th century with the work of Philippe-Charles Schmerling, who found the first Neanderthal remains in Engis Cave in the early 1830s. This discovery was followed by the fieldwork of Édouard Dupont, who excavated dozens of caves between the 1860s and 1870s, and the investigations of Spy Cave between 1885 and 1886 by Marcel de Puydt and Max Lohest (Toussaint and Pirson, 2006; Toussaint et al., 2011). The attractiveness of cave sites was such that most were explored during the 19th century.

Since the beginning of research into Belgian prehistory, archaeologists have focused their attention on the lithic artefacts. They used typological and technological analyses to balance the lack of contextual information, sorting the material based on their cultural attributions (Ulrix-Closset, 1975). While chrono-cultural attributions of lithic artefacts is facilitated by this techno-typological approach,

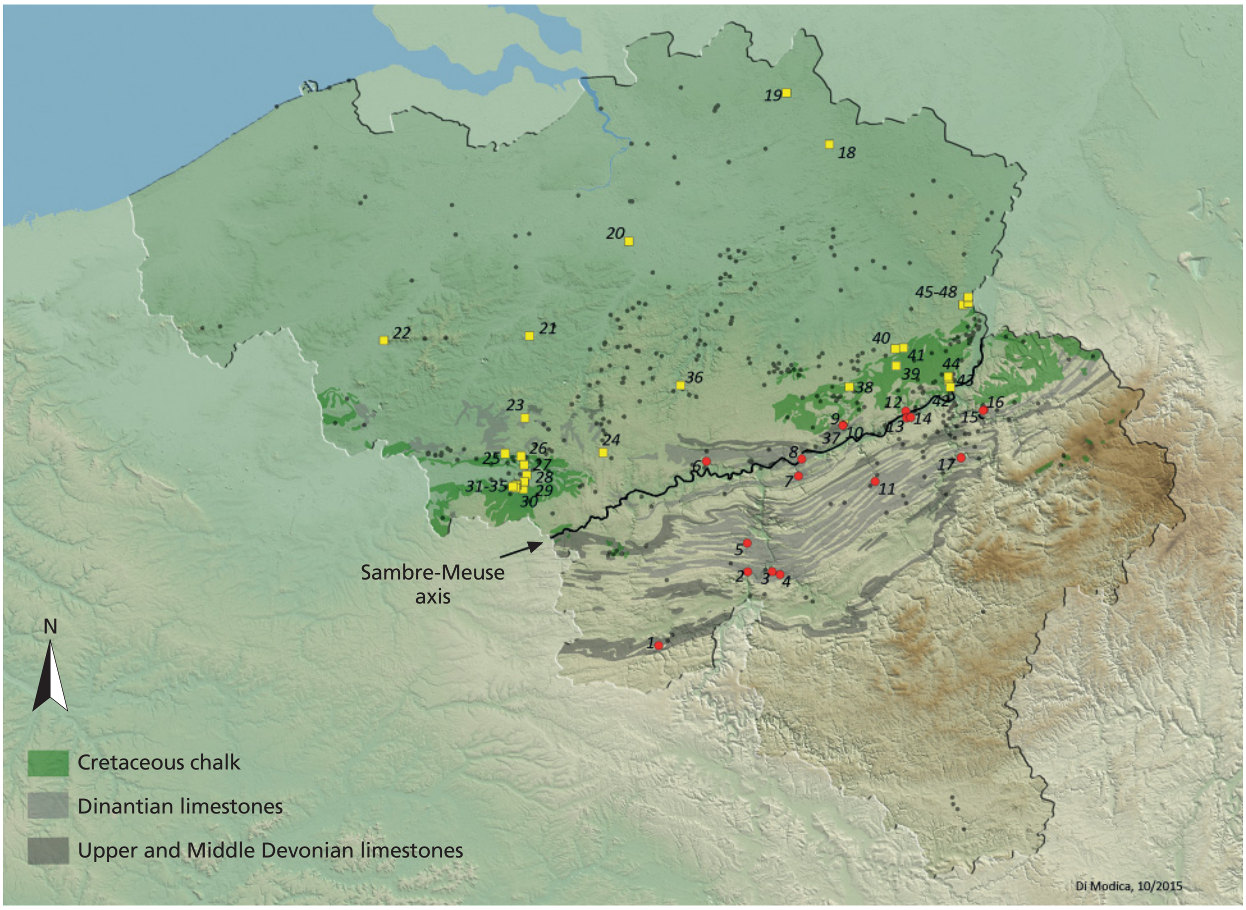

Figure 1 Distribution map of the Lower and Middle Palaeolithic locations in Belgium. Red circles are major cave sites; yellow squares are major open-air sites. Cretaceous chalk outcrops and Palaeozoic limestones outcrops redrawn after de Béthune (1954) (from Di Modica et al., 2016).

the absence of reliable contextual information makes the study of faunal remains much more difficult because no substantial distinction in the processing of animal carcasses can be established for the entire Palaeolithic timeframe.

It is for this reason that bone material from historic excavations has often been neglected. To date, there is no zooarchaeological synthesis across Belgian Palaeolithic sites, nor has there been a study of the bone retouchers. However, the existence of these tools has been known for over a century, since the beginning of Belgian Palaeolithic archaeology. In the late 19th century, Dupont (1871) described some bone fragments from Trou Magrite as intentionally broken with artificial blow marks and grooves. Even if they were not specifically called "retouchers", these characteristics fit with the modern descriptions of these types of tools (e.g., Patou-Mathis and Schwab, 2002; Mallye et al., 2012; Daujeard et al., 2014). The name "bone retoucher" does not appear until later; the first mention, so far established, comes from the catalogue of the International Exhibition of Paris edited by the Société d'Anthropologie de Paris (1889).

Unfortunately, early excavations were not conducted with the methods we aspire to now. Stratigraphic records, if they exist, are only schematic and often appear to be inaccurate, especially when considering the stratigraphic complexity documented recently in other cave sites, for example the Scladina Cave and Walou Cave sequences (Pirson, 2007; Pirson et al., 2008; Pirson et al., 2011; Pirson et al., 2012). For historic collections, original interpretations regarding the division of the deposits into different layers and their cultural attribution must be considered with caution. For example, a refitting was made on bones from the terrace of the 3rd Cave of Goyet, which included fragments coming from three different ossiferous levels observed during the excavation (Rougier et al., 2016). Another example comes from Spy Cave, where the 2nd and the 3rd ossiferous levels with "mammoth age-like faunas" are associated with Neolithic ceramic fragments (Fraipont, 1887).

On the basis of current knowledge, Belgium is scattered with at least 443 Middle Palaeolithic sites that are unequally distributed throughout the whole territory (**Figure 1**) and cover a long timeframe, from the early Middle Palaeolithic to the Middle/Upper Palaeolithic transition (**Figure 2**). The sites are of variable importance due to the quantity of the recovered artefacts and the quality of the asso-

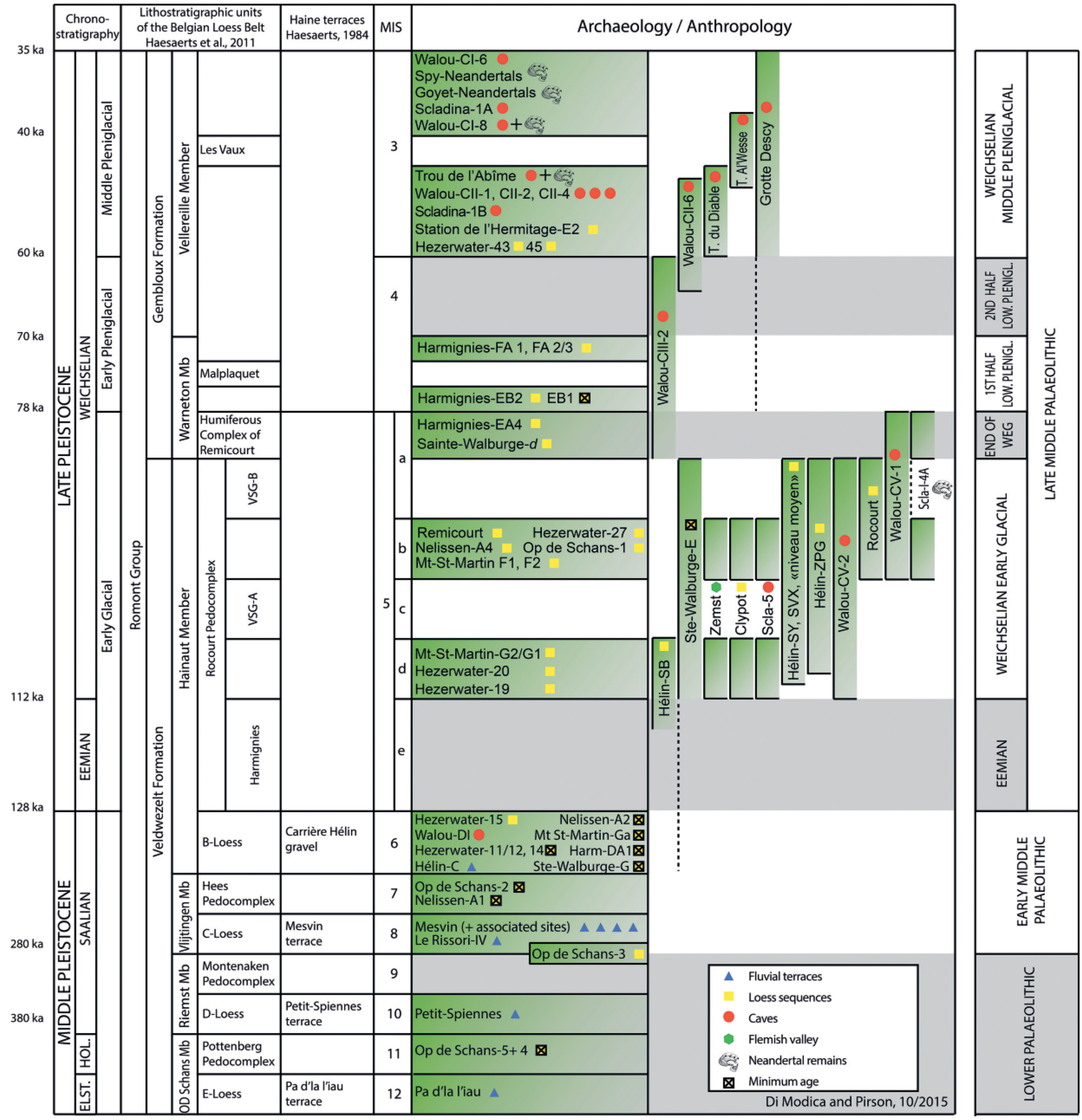

Figure 2 Chronostratigraphic distribution of the Middle Palaeolithic sites from Belgium (from Di Modica et al. 2016).

ciated contextual information (Di Modica et al., 2016). Almost 90% of the known sites are open air, but the vast majority of bone tools are found in cave deposits. The lack of bone tools discovered in Belgian open air sites is most likely related to the preservation conditions, as bones unearthed in such depositional environments are often very poorly preserved (Bosquet et al., 2009). Nevertheless, bone retouchers have been recovered in open air settings dating back at least to the early Middle Pleistocene in sites such as Boxgrove (UK; Roberts and Parfitt, 1999), Cagny-l'Epinette (France; Moigne et al., 2016) or Schöningen (Germany; van Kolfschoten et al., 2015).

Most of the studied faunal remains from the Belgian Palaeolithic were unearthed from cave deposits, which results in a better preservation of the faunal remains. To date, 46 caves have yielded Middle Palaeolithic artefacts, of which eight have delivered Neanderthal remains (Toussaint et al., 2011). All cave sites are located in the Devono-Carboniferous limestone of the Meuse Basin in southern Belgium.

The aim of the current project was to study the faunal remains collections from southern Belgium, first to identify and re-examine the bone retouchers described in the 19th century within the current methodological framework. Furthermore, species preference and the *chaîne opératoire* of retoucher production were investigated in order to shed light on patterns of Neanderthal behaviour.

Materials and methods

Twenty historical and recently excavated faunal collections were inspected in the course of this analysis

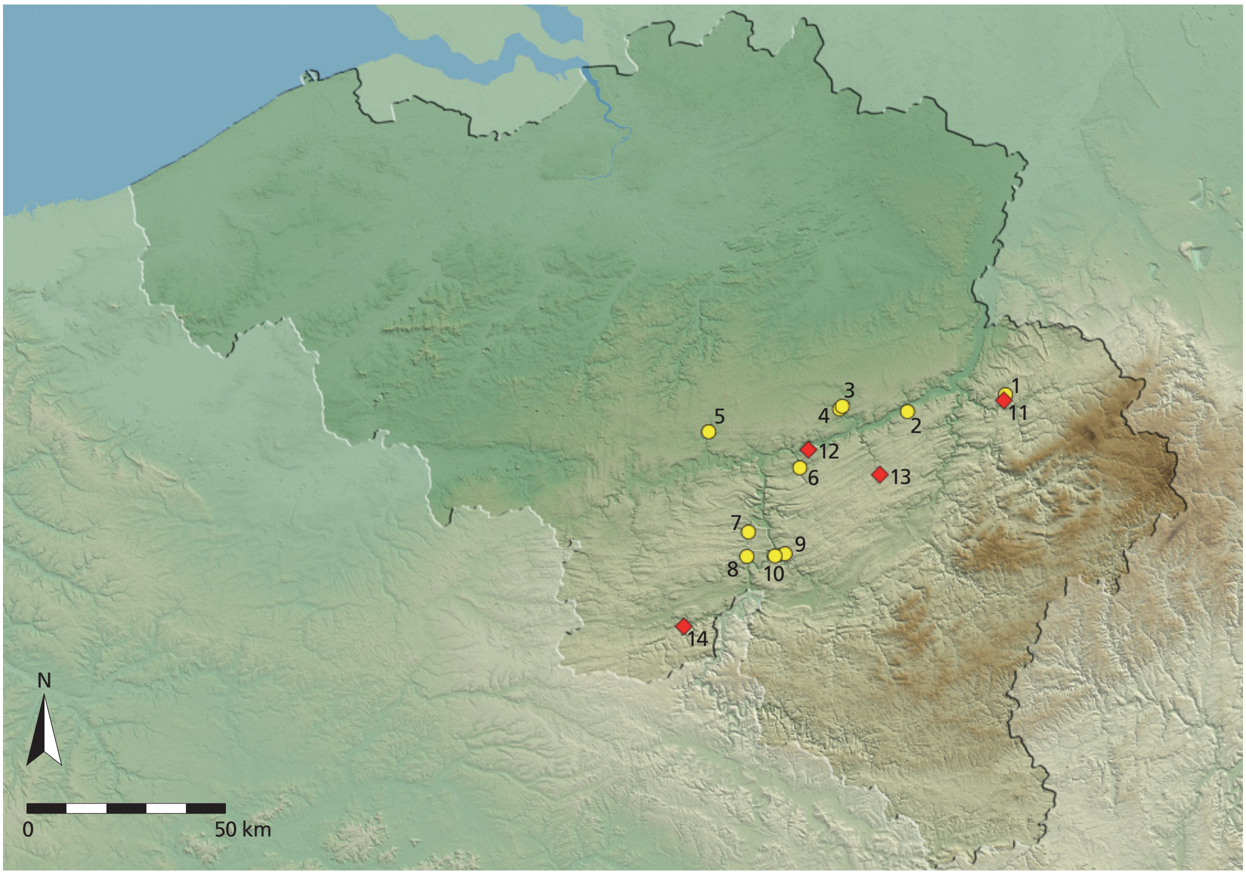

Figure 3 Location of the sites that have yielded bone retouchers. Historic collections are shown as yellow circles: 1. Bay Bonnet Cave (Fond-de-Forêt); 2. Palaeolithic site of Engihoul; 3. Hermitage Cave; 4. Docteur Cave; 5. Spy Cave (Bêtche Al Rotche); 6. Goyet Caves ; 7. Trou du Sureau ; 8. Trou du Diable ; 9. Trou du Renard ; 10. Trou Magrite. Modern collections are shown as red diamonds: 11. Walou Cave; 12. Scladina Cave; 13. Trou Al'Wesse; 14. Trou de l'Abîme.

Table 1 Chronological data available for Belgian sites with bone retouchers.

Site	Units	MIS	Sample-ID[1]	Uncal date	$+\sigma$	$-\sigma$	References
Spy Cave (Betche-aux-Rotches)	1st-3rd Ossiferous Levels	3	**GrA-32617**	30170	160	150	Semal et al., 2013
Trou Magrite	1st-4th Ossiferous Levels	3	**Beta-419008**	39080	280	280	Smolderen, 2016
			Beta-419007	39690	320	320	
Trou du Renard	E	3	**OxA-26773**	40800	1300	1300	Dinnis and Flas, 2016
	B?		**OxA-26311**	>48400			
Scladina Cave	T-RO	3	GrA-48408	34000	2050	2760	Bonjean et al, 2013
			GrA-47939	38470	350	310	
			OxA-23790	40800	1300	1300	
Goyet, 3rd Cave	1st-3rd Ossiferous Levels	3	GrA-54024	36590	300	270	Rougier et al., 2016
			GrA-60018	37250	320	280	
			GrA-54257	37860	350	310	
			GrA-60019	38260	350	310	
			GrA-46170	38440	340	300	
			GrA-46178	39140	390	340	
			GrA-54022	39870	400	350	
			GrA-46176	40690	480	400	
			GrA-46173	41200	500	410	
Trou Al'Wesse	16-17	3	OxA-7497	41100	2300	2300	Otte et al., 1998
Trou de l'Abîme	II	3	GrA-40444	44500	1100	800	Toussaint et al., 2010
Trou du Diable	1st-3rd Ossiferous Levels	3	-	-	-	-	Di Modica et al., 2016
Engihoul, Palaeolithic site	Typical Mousterian	3	-	-	-	-	Di Modica et al., 2016
Walou Cave	CV-2	5d-5a	-	90300	4600	4600	Debenham, 2011
Scladina Cave	5	5d or 5b	-	-	-	-	Di Modica et al., 2016
Goyet, Salle du Mouton	Mousterian	-	-	-	-	-	
Trou du Sureau	3st-4th Ossiferous Levels	-	-	-	-	-	
Docteur Cave	-	-	-	-	-	-	
Hermitage Cave	-	-	-	-	-	-	
Bay Bonnet Cave	(2nd Level)	-	-	-	-	-	

[1] bold identification numbers denote samples taken directly from bone retouchers

(**Table 1; Figure 3**). From thousands of bone fragments originating from extensive prehistoric excavations conducted during the 19th century, bone tools were extracted and examined for their use as retouchers.

In order to overcome uncertainties related to the methodology of historical excavations, specifically the lack of chronostratigraphic context, several radiocarbon dates have been carried out directly on bone retouchers from Spy Cave (Semal et al., 2013), Trou Magrite (Smolderen, 2016) and Trou du Renard (Dinis and Flas, 2016) (see **Table 1)**. As part of our NERC research project, an extensive sampling programme has been undertaken to date bone retouchers, but the results are not yet available.

For the recently excavated collections, stratigraphic observations were more accurate and gave precise information regarding chrono-cultural attributions. With the exception of sedimentary units DII and DI of Walou Cave, dated to at least MIS 6 (see **Figure 2**; Draily, 2011; Di Modica et al., 2016), and the lithic industry recovered in the deposits of la Belle Roche, dating from at least 500 ka (Cordy, 2011), none of the sedimentary cave deposits in southern Belgium have yielded conclusive evidence of a hominin occupation before MIS 5d. Considering this, it is likely that most of the faunal material studied can be attributed to deposits ranging between MIS 5d and MIS 3.

The identification of bone retouchers was first based on macroscopic observations followed by comparisons with experimental material and an extensive literature on Middle and Upper Palaeolithic tools (Patou-Mathis and Schwab, 2002; Mallye et al., 2012; Abrams et al., 2014b; Daujeard et al., 2014). All bone fragment surfaces were analysed under a Leica S6D stereomicroscope with magnification ranging between 6.3x and 40x. This allowed for preliminary identifications of anthropogenic modifications, such as grooves and pits associated with a knapping activities. Finer details, such as the shape of the use marks and the presence of lithic chips embedded within the bone matrix, were analysed using a LEO1455VP Scanning Electron Microscope (SEM). Images were captured at high lateral resolution (3 nm) with a magnification ranging from 40x to 600x.

Energy-dispersive X-ray (EDX) spectroscopy was used to identify the nature of the lithic fragments embedded in the scores. This technique can distinguish siliceous material from concretions, adhering sediment and bone splinters on the basis of their chemical compositions and fracture characteristics (Bello et al., 2013). The EDX microanalysis determined the elemental composition of surface inclusions using an Oxford Instrument X-Max 80 Silicon Drift Detector and INCA software.

Figure 4 Significant loss of bone material on the use surface causes by an intense use of a retoucher from Scladina Cave (Sc84-E16-48). Picture A. Mathys; © RBINS.

Site	N RETOUCHERS	%
MODERN COLLECTIONS		
Scladina Cave, Unit 5	27	5.0
Scladina Cave, Unit T	1	0.2
Trou Al'Wesse, Layers 16/17	11	2.1
Trou de l'Abîme, Unit II	3	0.6
Walou Cave, Layer CV-2	1	0.2
HISTORIC COLLECTIONS		
Bay Bonnet Cave	13	2.4
Betche-aux-Rotches (Spy Cave)	5	0.9
Docteur Cave	1	0.2
Engihoul, Palaeolithic Site	48	8.9
Goyet, 3rd Cave	30	5.6
Goyet, Salle du Mouton	59	11.0
Hermitage Cave	1	0.2
Trou du Diable	295	55.1
Trou du Renard	3	0.6
Trou du Sureau	3	0.6
Trou du Magrite	34	6.4
TOTAL	535	100

Table 2 Total bone retouchers for each site. An additional 400 bone tools from the Trou Magrite historical collection have been identified by E.-L. Jimenez and A. Smolderen but are not yet analysed in detail.

Figure 5 (A) Retoucher made from a horse tooth (Trou du Diable © RBINS). (B) from a limb shaft fragment (Scladina Cave, unit 5).

The retoucher use areas provide information related to the intensity of use based on the concentration of marks: isolated, dispersed, concentrated or concentrated and superposed (Mallye et al., 2012). In some cases, prolonged use of the tools has generated deep alterations and a significant loss of bone material from the cortical surface (**Figure 4**). The retoucher use area locations on the bone fragment were described using the categories and nomenclature proposed by Mallye et al. (2012): apical, centered, covering or lateral.

Other anthropogenic modifications were documented, including cut marks, scraping marks and bone breakage patterns. Characterization of cut marks was based on several features, such as v-shape, internal microstriations, shoulder effects and hertzian cones (Shipman and Rose, 1983; Andrews and Cook, 1985; Behrensmeyer et al., 1986; Greenfield, 1999; Bello and Soligo, 2008; Bello, 2011; Bello et al., 2011). Patterns of bone fracture were characterized using several frameworks to identify the agents responsible for breakage (Binford, 1981; Blumenschine and Selvaggio, 1988; Chase, 1990; Villa and Mahieu, 1991; Lyman, 1994). Bone freshness was assessed based on fracture shape (Lyman, 1994).

Results and discussion

Detailed analysis of the collections led to the discovery of 535 retouchers originating from 14 cave sites (**Table 2**). Preservation quality varied between sites, but overall preservation was excellent. Regardless of the preservation conditions, the number of retouchers is highly variable from one cave site to another, ranging from one to nearly 300 pieces.

So far, the faunal collection of Trou Magrite has not been subjected to detailed study by the author, but about 400 additional tools been recovered from the material collected by Dupont (E.-L. Jimenez, personal communication). If further analysis can confirm these identifications, it would increase the corpus of bone retouchers in Belgian collections to almost 900.

Figure 6 The proximal end of this retoucher was intentionally reshaped (Scladina Cave, Unit 5).

Figure 7 The distal end of this small retoucher features a bend-breaking pattern, suggesting breakage during use (Scladina Cave, Unit 5).

Blanks

Horse upper molars or premolars are documented as retoucher blanks in a few sites, such as Trou Magrite, Trou du Diable and Trou de l'Abîme (**Figure 5A**). The use marks are concentrated on the proximate surfaces, where one tooth contacts a neighbouring tooth. The only site that has yielded these peculiar blanks within a reliable chrono-cultural attribution is Trou de l'Abîme (see **Table 2**; Toussaint et al., 2010; Abrams and Cattelain, 2014). At present, in Belgian sites there is no further evidence of retouchers made from other herbivore or carnivore teeth, such as those from La Ferrassie, France (Castel et al., 2003), or in the Swabian Jura (Conard and Bolus, 2006).

Most often limb bone shaft fragments were used as tool blanks, selected for their thickness, length, mass, shape and raw material (bone versus tooth). The length ranges from 3.5 cm to 15 cm; 70% fall between 8 cm and 12 cm, with a mean of 9.5 cm for the whole sample. The thickness measured at the use area fluctuates between 0.4 cm and 2.4 cm (mean = 1.05 cm).

All retouchers bear fractures and evidence of percussion notches and flaking. Helical and spiral fractures are abundant. These patterns reinforce assumptions about the systematic use of fresh bone fragments. It also appears that bones were fractured prior to their use as retouchers (see refitting section below). Nevertheless, surface damage on dry bones has also been observed, but likely relates to the use of picks during excavation or damage from storage and handling.

In some cases (e.g., Scladina Cave and Trou du Diable), blanks show evidence for having been reshaped (**Figure 6**). The presence of very small retouchers, where the distal part was broken by bending, suggests that some tools may have been broken during use (**Figure 7**).

Unlike older sites, such as Schöningen where a complete bison radius and complete horse metacarpals were used as tools (van Kolfschoten et al., 2015), there was no evidence for the use of complete bones at the Belgian sites. This difference is probably related to the technological process. Com-

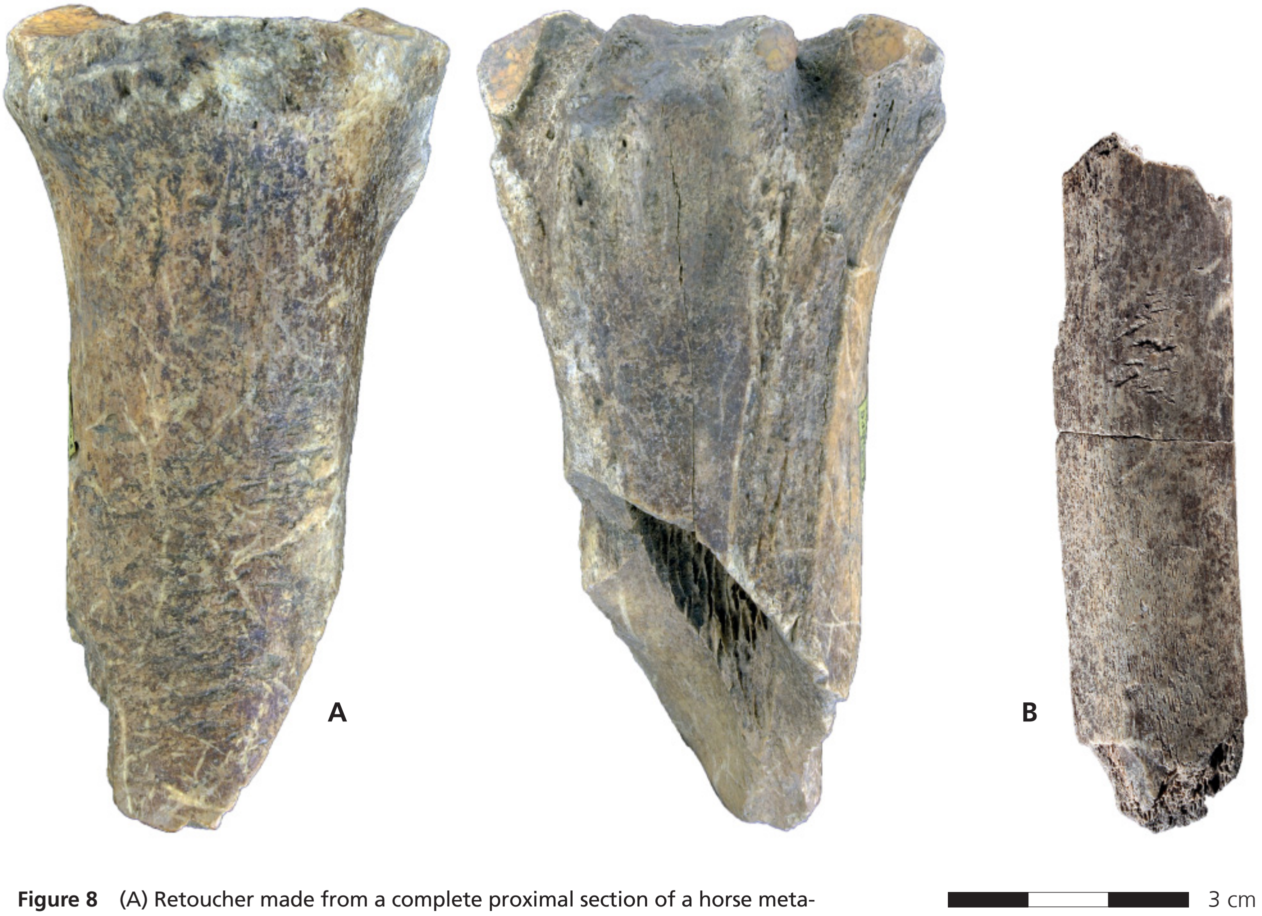

Figure 8 (A) Retoucher made from a complete proximal section of a horse metatarsal (Trou du Diable © RBINS). (B) From a rib fragment (Scladina Cave, unit 5).

plete bones seem to provide increased accuracy as anvils or soft hammers, while shaft fragments seem to be more efficient for shaping lithic edges. Moreover, limb bone fragments with the entire original circumference preserved were rarely used (Figure 8A). The use of flat bones, such as ribs, was even more rare (Figure 8B).

Use Marks

The various use marks are the result of contact between bone (or other osseous material) and the hard edges of a stone tool. Scores (elongated grooves) and pits (small depressions) are the most common damage and are often concentrated in the same area. The pits are evidence of punctiform penetration into the bone matrix. The scores feature two opposing sides: one side is characterised by micro-cracks and a crushing pattern generated by the penetration of the stony edge into the cortical bone; the opposite side presents internally perpendicular micro-striations resulting from the sliding of the lithic edge on the bone surface (Figure 9A). Together, both sides of the score form a mouth-like shape.

Scores are oriented transversely relative to the long axis of the bone blank, but sometimes perpendicular. Longitudinal scores have been documented to appear during the Aurignacian with the development of tools made from laminar blanks (Schwab, 2002; Tartar, 2012). The orientation of the scores may be an indication of lithic technology; the dominance of transverse scores indicates that many of the retouchers described here were used on flakes rather than on blades. This is an interesting possibility, but may not be conclusive because the transverse orientation of scores persists throughout the Upper Palaeolithic.

The accumulation of use marks on a surface creates a so-called "use area". Most often, this area is located near the edge of the bone fragment (see

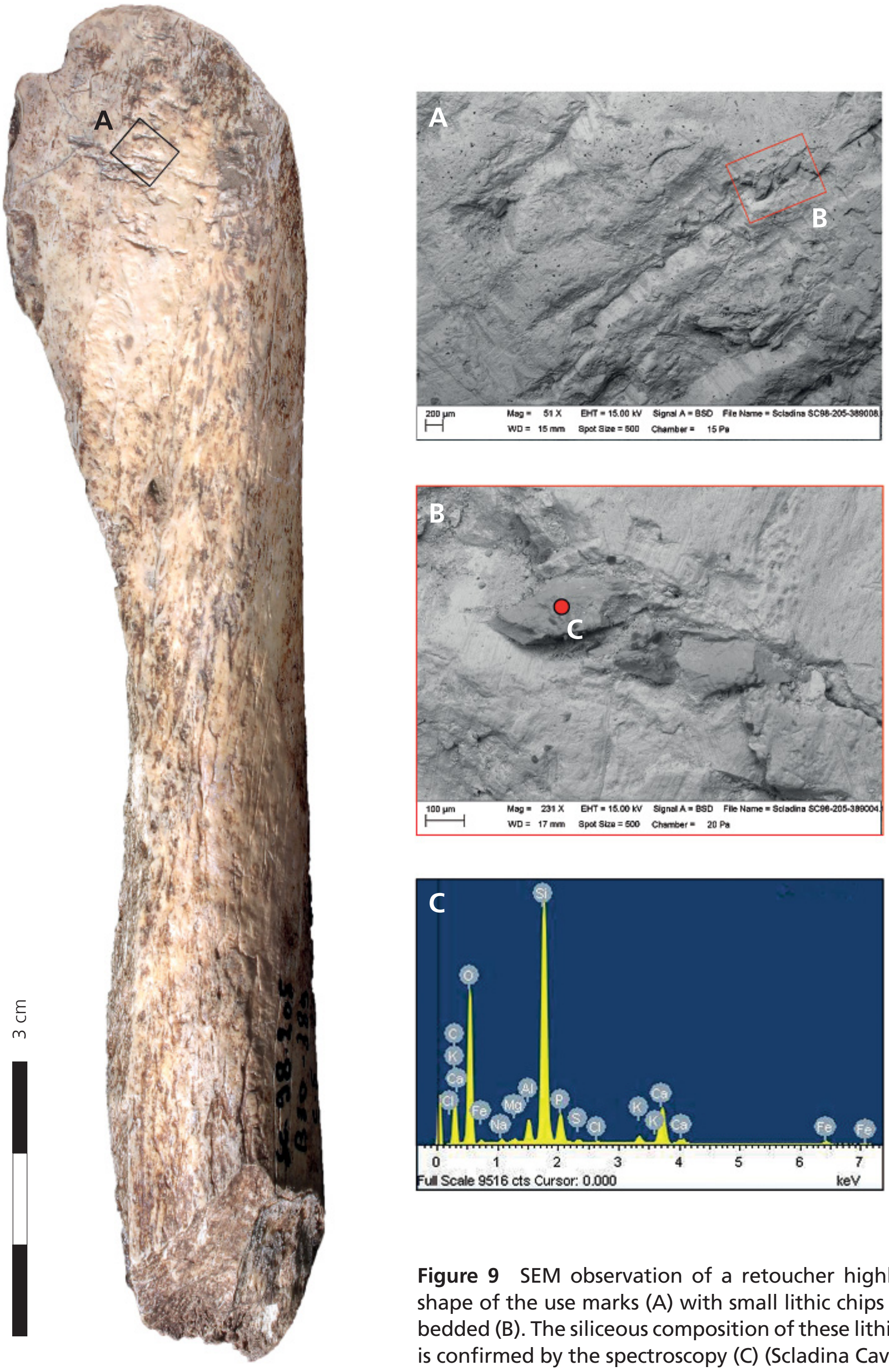

Figure 9 SEM observation of a retoucher highlighting the shape of the use marks (A) with small lithic chips are still embedded (B). The siliceous composition of these lithic fragments is confirmed by the spectroscopy (C) (Scladina Cave, unit 5).

Figure 5). According to Mallye et al. (2012), bone retoucher use areas are generally centred or laterally oriented and occur on convex or plano-convex surfaces. On horse teeth, use marks tend to be located on the contact facets with adjacent teeth (mesially and distally).

The extent of use areas observed here are highly variable, ranging from 0.56 cm² to 19 cm² (mean = 4.8 cm²). Usually, bone retouchers present one or two use areas, in rare cases three or four. The retoucher with the largest use area includes marks covering nearly its entire surface (**Figure 10**; Trou du Diable: TDD-1365-CO1-Ret03).

Use marks are frequently concentrated and superposed (following Mallye et al., 2012). Repeated blows on the surface may have caused partial flaking and loss of cortical bone surface. When comparing sites, the retouchers from Trou du Diable present the most damage from use. The use intensity of the bone tools is likely related to the high number of stone tools recovered at Trou du Diable, as well as the extensive and repetitive sharpening observed on the lithic material (Di Modica, 2005). Nevertheless, interpreting these observations in light of cultural patterns must be made with caution, as the Trou du Diable faunal assemblage and those from the other historical collections is probably the result of the unfortunate mixing of Mousterian and Aurignacian materials during the excavations.

Stereomicroscopic examination of the surface of the retouchers resulted in the identification of several putative lithic chips embedded in some of the retouchers (**Figure 9B**). The EDX spectra of these lithic chips exhibit silicon peaks (**Figure 9C**). Unfortunately, this technique does not distinguish between different siliceous raw materials frequently used by prehistoric people (e.g., flint, quartz, quartzite, chert, phtanite). Other analyses are currently ongoing to further define the raw materials embedded within the bone in order to establish a closer link between the lithic industry and the bone tools.

Associated anthropogenic marks

Retouching marks are often associated with other anthropogenic modifications that occurred prior to the use of retouchers as tools. All breakage patterns on bone retouchers suggest fractures made on fresh bone (Chase, 1990; Villa and Mahieu, 1991; Lyman, 1994).

Scraping and cut marks related to butchery testify to the freshness of the bone fragments used as retouchers. The presence of cut marks on some retouchers suggests that prehistoric people removed meat, tendons and other tissues still attached to the bones prior its use as a retoucher. Sub-parallel striations have been observed in close association with the use areas. Identified as scraping marks, these striations were probably the result of periosteum removal to prepare the surface prior to use of the bones as retouchers (Verna and d'Errico, 2011; Manzon et al., 2012). This is demonstrated by the use marks overlapping the striations and cut marks. Taken together, the cut and scraping marks are evidence of the bone's freshness and the need for the periosteum to be removed prior to its use as a retoucher. None of the retouchers present scraping marks on the entire cortical surface, which indicates that the bone surface was cleaned only on the intended use area. However, the functional benefit of this surface cleaning is still unclear, especially since the retouchers were not all cleaned in the same way. In one case, refitted retouchers (see below), of which contemporaneity is certain, exhibit different surface treatments in two of the four retouchers (**Figure 11**; Abrams et al., 2014a; Abrams et al., 2014b).

Figure 10 The retoucher with the largest use area from Trou du Diable (TDD-1365-CO1-Ret03), with marks covering almost the entire surface © RBINS.

Figure 11 Refitting including four bone retouchers (represented in red, yellow, blue and orange) and two unused fragments (shown in green and purple). All belong to a shaft fragment of a right cave bear femur (Scladina Cave, unit 5).

Except in one example recovered at Trou du Diable, where carnivore tooth marks cross tool use marks, none of the retouchers exhibit clear evidence of animal modifications.

Species

High levels of fragmentation impeded many species identifications. However, the identifiable fragments belong to the same animals found elsewhere in Palaeolithic sites. Dominant species include horses and cervids *(Cervus elaphus* and *Rangifer tarandus)*, followed by aurochs/bison and mammoth/rhinoceros. Aside from these common species, two other taxa stand as unique: cave bear *(Ursus spelaeus)* and Neanderthal.

So far, seven retouchers made from cave bear remains have been recovered from Scladina unit 5 (Abrams et al., 2014a; Abrams et al. 2014b), of which four are associated within a single refitting (see **Figure 11**). While cave bears are often well represented within cave site faunal assemblages, it is still difficult to explain why prehistoric people used so few of their remains. The bones used as tools from Scladina point to the recovery of a relatively fresh carcass. Their acquisition could be the result of either hunting or scavenging. So far, there is no convincing evidence that leads us to favour one hypothesis over the other, except maybe the differential treatment of the tools, highlighted by presence of underlying scraping marks on two of the four retouchers. This could be evidence for a different preparation of the blanks or for an advanced state of decomposition of the cave bear carcass.

The study of the Belgian Paleolithic collections also resulted in the discovery of another infrequently used species. Neanderthal remains have been identified among several thousands of bone fragments collected on the terrace and within the 3rd Cave of Goyet (Wißing et al., 2016). These remains were unearthed during the excavations of Dupont in the late 1860s and were only recently recognised. Marks characteristics of use as tools were observed on several shaft fragments of Neanderthal hindlimbs (Rougier et al., 2016): one femur (Femur III; **Figure 12**) and three tibiae (Tibia III, IV, V).

Figure 12 General view (A) and detail (B) of the functional surface of a retoucher made from a Neanderthal bone (Femur III, 3rd Cave of Goyet; E. Dewamme © RBINS).

The examples of cave bear from Scladina and Neanderthal from the 3rd Cave of Goyet are particularly enlightening when considering the processing of these species is similar to the other anthropogenically modified species *(Rupicapra rupicapra, Equus sp., Cervus elaphus, Rangifer tarandus)* in the assemblages. These discoveries seem to show that even if they are very rare, there is no species avoided by Neanderthals when looking for suitable bones to use as retouchers. The use of bear remains *(Ursus arctos* and *Ursus deningeri)* is documented in the Biache-Saint-Vaast deposits (Auguste, 2002) and other Neanderthal bone fragments were used as retouchers at La Quina (Verna and d'Errico, 2011) and Les Pradelles (Mussini, 2011).

Approaching the chaîne opératoire-refitting

Refitting fragments of retouchers makes possible an understanding of the *chaîne opératoire* and the creative thoughts of (stone) tool producers. A few refittings were possible on the Belgian collections studied here. The example from unit 5 of Scladina Cave is currently the most complete. It incorporates a cave bear femur where use marks were observed in combination with several breaks, cut marks and scraping marks. With the presence of these different anthropogenic modifications, it is possible to reconstruct the complete *chaîne opératoire* for this artefact, from the acquisition of the cave bear femur to the abandonment of the tools after use. The refitting associates four bone retouchers and two unretouched fragments. One unretouched fragment in the refit series is likely related to the reshaping of one of the bone retouchers (shaded purple in **Figure 11**).

In reconstructing the *chaîne opératoire*, we consider the cave bear femur as raw material modified through a number of processes. First, several cut marks attest to the cleaning of the bone through the removal of meaty tissues. After this cleaning process, the debitage took place: the two epiphyses were removed followed by the reduction of the shaft with the aim of producing the bone blanks. Once separated from the others, a blank was reshaped through a reduction of the length, which is suggested by the breakage pattern visible on the internal surface. Finally, scraping marks present on the use surfaces of two of the four retouchers suggest the subsequent removal of the periosteum prior to the use of the bone fragment as a retoucher.

The similarity in the size of the blanks, the observation of similar reshaping and cleaning traces and their association with the same portion of the bone used in the retouchers from other sites leads us to suggest that the *chaîne opératoire* observed in the cave bear femur from Scladina Cave involves the possible existence of a pre-conceptualization of the tool.

Conclusion and prospects for future research

The aim of this study was to better understand the role of bone tools, specifically bone retouchers, during the Middle Palaeolithic in Belgium. The study of animal bone collections from more than 20 archaeological sites led to the identification of at least 535 bone retouchers. The patterns in species preference and the *chaîne opératoire* of retoucher production were investigated. The bone retouchers made from a cave bear femur at Scladina Cave suggest predetermination in the production of these bone tools.

To date, none of the open air site assemblages that were studied yielded bone tools. Reasons for this absence are more likely related to poor preservation of organic materials at open air sites. In order to verify this, a review of additional collections from open air sites should be conducted (e.g., Godarville, Le Clypot, Saint-Symphorien quarries).

Limb bone shaft fragments were preferred over complete sections of bone shafts or complete bones. At present, the reason for this preference is unclear. Was it related to a better grip of the tool, to a technically added value of the tool or the function of the bone tool (retoucher, soft hammer, anvil)? To shed light on this question, an experimental study will be conducted in collaboration with the Natural History Museum of London, the Préhistomuseum and the *Centre d'Étude des Techniques et de Recherche Expérimentale en Préhistoire* (CETREP).

The use bones from rare species, such as cave bear and Neanderthal, appears to be similar to commonly hunted species like cervids and horses, suggesting that there is no particular distinction between them. Therefore, currently it is of little value to consider the symbolic treatment of some species in the context of bone retoucher use.

The lack of reliable stratigraphic contexts for most of the series (e.g., Trou Magrite and Trou du Diable) makes the cultural attribution of bone retouchers difficult. In order to further refine the chronological context, a new radiocarbon dating campaign is in progress, which includes several modified bones from Scladina, Trou du Diable, Trou Al'Wesse, Trou de l'Abîme and Engihoul. Nevertheless, in the current stage of knowledge, most of the bone retouchers seem to be associated with the Mousterian. Notwithstanding a direct date on a retoucher from Spy Cave, there is no obvious evidence for specialised Aurignacian bone retouchers, such as those with longitudinal scores or those made from carnivore teeth.

This study of Belgian Palaeolithic bone retouchers is still in progress, so the results presented here are only preliminary and will be further refined by a continued review of other collections. Nevertheless, some interesting patterns already seem to be emerging and add valuable information on the role of retouchers in the lives of prehistoric people.

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RETOUCHERS FROM MAMMOTH TUSKS IN THE MIDDLE PALAEOLITHIC: A CASE STUDY FROM KŮLNA CAVE LAYER 7a1 (CZECH REPUBLIC)

Abstract

The existence of retouchers made from hard animal tissues in the Middle Palaeolithic was first identified in the early 20th century, but only in recent years have researchers been paying more attention to this phenomenon. The overwhelming majority of retouchers are fragments of bones without modifications to the shape of the objects. In the collection of these *ad hoc* tools from the Micoquian layer 7a1 in Kůlna Cave (Czech Republic) we also identified two retouchers of mammoth ivory. So far, the use of this material for retouchers at Kůlna Cave remains unique in the Middle Palaeolithic of Europe. A diachronic comparison of Taubachian and Micoquian assemblages of hard animal tissues with anthropic impact suggests that the utilisation of mammoth ivory in the Micoquian was not just a random phenomenon, but it was probably related with the overall change in Neanderthal behaviour towards mammoths as a source of raw materials.

Keywords

Micoquian; Taubachian; Mammoth tusk; Retoucher

Introduction

Increasingly detailed analyses of archaeological and osteological materials from the European Middle Palaeolithic continue to bring evidence of premeditated manipulations of hard animal tissues, many of which are not directly linked with subsistence practices. Quite often, we encounter fragments of bones and teeth, and sometimes whole bones, bearing scratches on their surfaces resulting from use in lithic tool production. For the Middle Palaeolithic, this type of object was first described in the works by Henri-Martin (1906, 1907, 1907-1910), who identified retouchers at the well-known site of La Quina in France. A comprehensive overview by Taute (1965) and experimental analyses by Feustel (1973) and Chase (1990) are counted among the major contributions towards the identification and functional understanding of these items. A significant move towards the codification of retouchers was made in 2002, when the Commission de Nomenclature sur l'Industrie de l'os Préhistorique (Société Préhistorique Française) published an influential volume entitled *Retouchoirs, Compresseurs, Percuteurs… Os à Impressions et Éraillures*, which standardised the definitions and descriptions of these artefacts

Table 1 Contextual data for retouchers of mammoth ivory from Kůlna Cave.

Inventory number	Field ID	Layer	Sector	Unit	Depth from recent surface	Cultural classification
106743	K-5698/66	7a1	G2	S/29-30	240-270 cm	Micoquian
107432	K-5261/66	7a1	G3	R/33-38	240-290 cm	Micoquian

(several authors in Patou-Mathis, 2002). Over the last few years, the issues of identifying these objects at Middle Palaeolithic sites and applying suitable documentary techniques have received considerable attention (e.g., Jaubert et al., 2008; Jéquier et al., 2012; Mallye et al., 2012; Khlopachev, 2013; Abrams et al., 2014; Daujeard et al., 2014; Mozota, 2015; van Kolfschoten et al., 2015; Moigne et al., 2016).

An important collection of retouchers made on hard animal tissues comes from the Middle Palaeolithic layers in Kůlna Cave (Moravian Karst, Czech Republic). The complex stratigraphy allows a diachronic study of how these *ad hoc* tools were used within two techno-complexes: Taubachian and Micoquan. Early on, Valoch (1988b) highlighted the existence of retouchers at Kůlna Cave, and he also correctly discriminated two items of mammoth ivory in layer 7a1 bearing scars resulting from retouching lithic tools (**Table 1**). Both items were mentioned in synthetic works on the use of bones in the Middle Palaeolithic (Vincent, 1993) and mammoth ivory in the Palaeolithic of Czechoslovakia (Oliva, 1995). In a detailed analysis of retouchers from the sites of Biache-Saint-Vaast (Pas-de-Calais, France) and Kůlna Cave, Auguste (2002) only referred to one mammoth ivory retoucher without a more detailed description. Likewise, later works only mention the objects (e.g., Tartar, 2004). Within the project "Neanderthals and modification of bones – interdisciplinary analyses and cultural implications", which primarily focused on identification of non-utilitarian uses of hard animal tissues (Neruda et al., 2011), a new analysis of retouchers was performed on individual stratigraphic layers 11, 11c, 7c, 7a and 6a at Kůlna Cave, with due regard to both retouchers of mammoth ivory (see **Table 1**). The aim of the present study is to highlight anew the existence of these unique objects, and put them in a broader context of the other retouchers and hard animal materials with anthropic impacts at Kůlna Cave.

Kůlna Cave state of research

Kůlna Cave is located in the northern part of the Moravian Karst approximately 30 km from Brno, in the municipality of Sloup (**Figures 1A, 1B**). The vast, tunnel-shaped cavern has a large southwest-oriented portal and a smaller northern entrance (**Figures 1C, 1D**). The length of the cave is approximately 87-91 m; its maximum width is 25 m, and the maximum height is 8 m.

Extensive and systematic investigations at Kůlna Cave were undertaken in 1961-1976 by Valoch (1988b), who collected a considerable number of artefacts and established a chronostratigraphic division of the sedimentary record. A small part of the cave filling in sectors B and C was excavated in 1995-1997 (Valoch, 2002). The total explored area amounted to 900 m^2 (Valoch et al., 2011). Archaeological items were discovered mainly in the entrance (sectors A-D2, L and K) and central part of the cave (sectors E-G3; **Figure 1D**), whereas the area adjacent to the northern entrance (sectors H1-3) is archaeologically rather sterile, and was also greatly damaged during World War II (Břečka, 2011; Neruda, 2013).

In the course of his excavation, Valoch (1988b) differentiated a very complex stratigraphy; sector D comprised 14 geological layers with numerous sublayers (**Figure 1F**). The inner part of the cave contained only part of the stratigraphic sequence (from layers 8/7c to 5), probably due to the morphology of the cave bedrock that indicates the rock step stretching across the space ca. 20 m from the en-

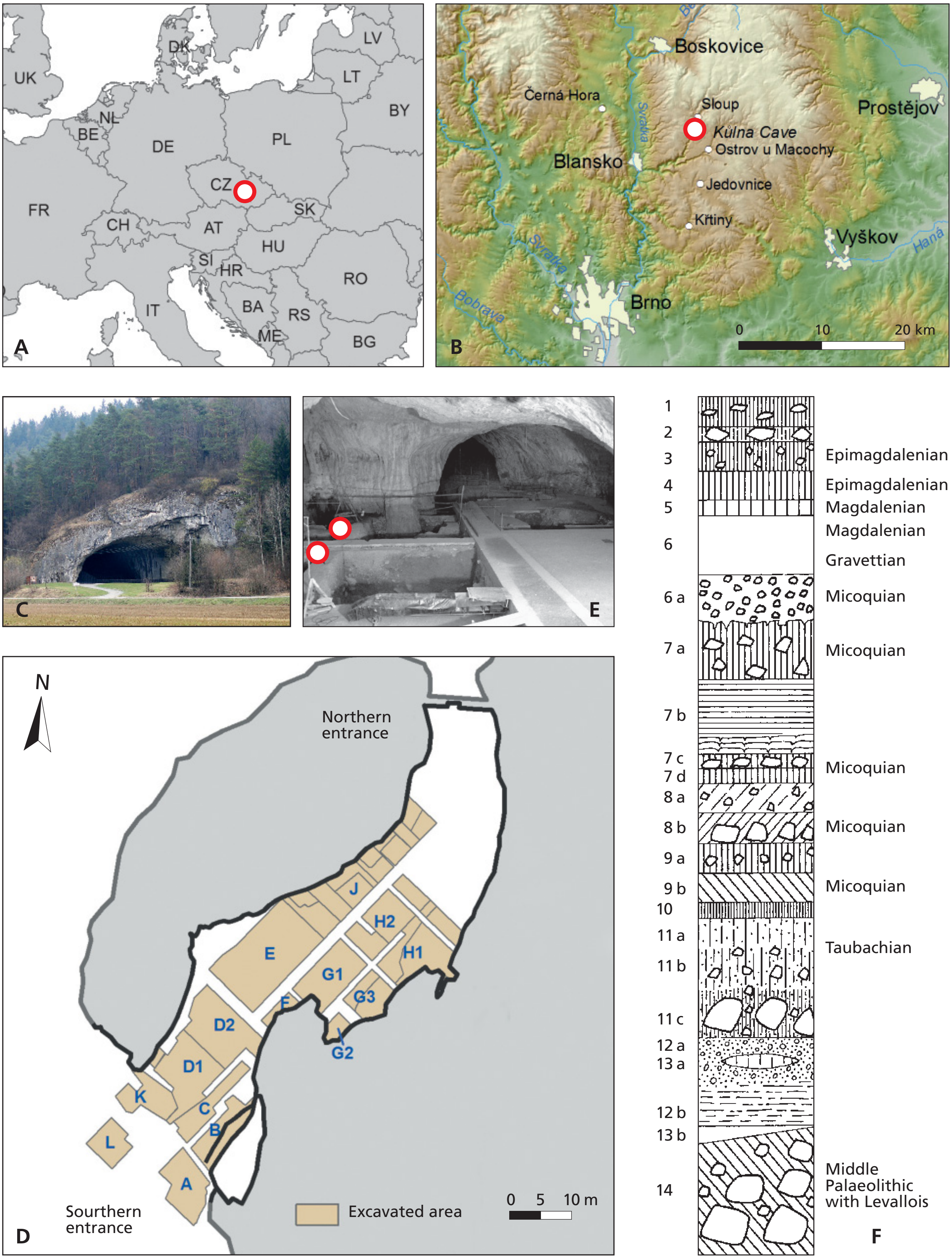


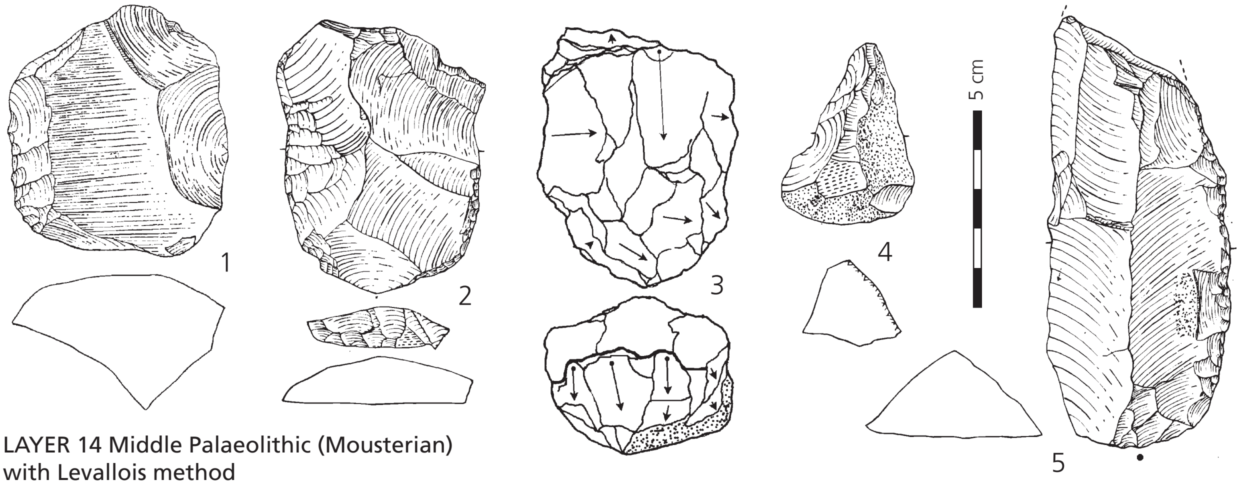
Figure 1 Location of Kůlna Cave (circles) in Europe (A) and DEM of Moravian Karst (B) with the position of Kůlna Cave (created by P. Neruda); (C) view of the southern entrance of the cave (photo P. Neruda); (D) ground plan of the cave (created by P. Neruda); (E) view from the inner part of the cave to the southern entrance (photo K. Valoch) – circles indicate approximate position of retouchers; (F) ideal stratigraphic sequence of Kůlna Cave (modified from Valoch 1989, fig. 1).

trance. Due to heavily damaged stratigraphy during World War II it was impossible to follow distinct layers continuously from the southern entrance to the inner part of the cave. In such cases, Valoch (1988b) correlated layers according to their stratigraphical position in profiles and distinguished them using a denomination of sub-layers (e.g., 6a in the entrance and 6b inside to cave). The Middle Palaeolithic is recorded in the lower and middle part of the idealised sequence (**Figure 1F**), from layer 14 (probably end of MIS 6) to layer 6a (MIS 3), where we are able to distinguish three main techno-complexes.

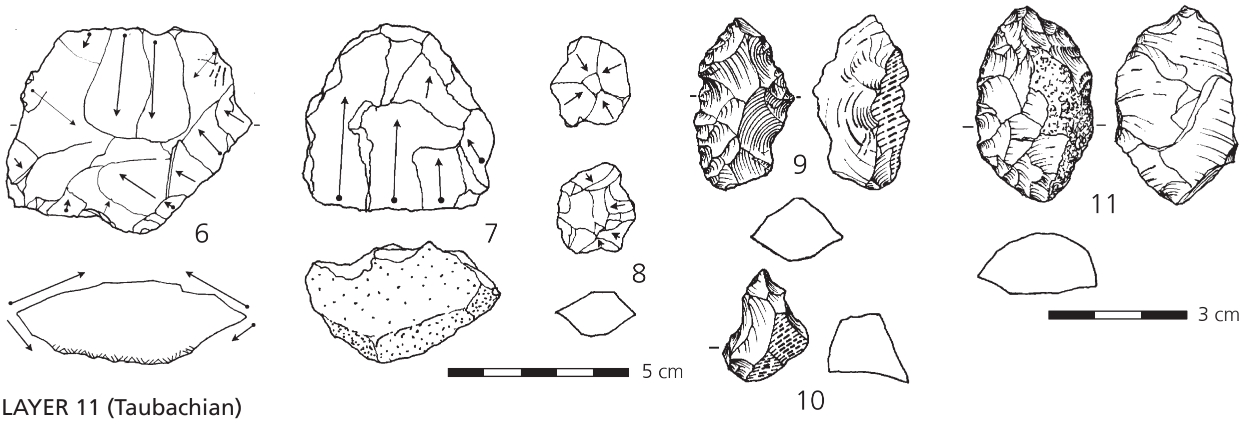
The lowermost layer 14 yielded a small lithic assemblage (100 pieces) classified as Middle Palaeolithic (Mousterian) with Levallois method. Besides Levallois cores and flakes (**Figure 2: 1-3, 5**), simple prismatic cores and archaic points (**Figure 2: 4**) were uncovered. Neanderthals used mostly local raw materials. Valoch (1988b, 1989) correlated this horizon with the end of the penultimate glacial. This layer was not included into the analysis due to the very limited area that was excavated.

The second techno-complex is represented by a Taubachian occupation of the cave (layers 13a-10). The largest archaeological assemblage was obtained from layer 11 and sub-layer 11c and encompassed lithic artefacts and faunal remains, including hard animal tissues with anthropic impacts (Valoch, 1984, 1988a, 1988b). The lithic artefacts (**Figure 2: 6-11**) are characteristically small in dimension, and the majority were made from quartz, quartzite, and spongolite originating from sources up to 15 km away. On the other hand, we noted raw materials from more distant sources (50-100 km; Neruda, 2001). In the manufacture of stone tools, Neanderthals used mainly the volumetric method for core reduction, specifically the discoid method (Boëda, 1993) in several variants (**Figure 2: 6, 8**; Moncel and Neruda, 2000; Neruda, 2011). Besides discoid cores *sensu lato*, simple prismatic-like cores were noted (**Figure 2: 7**). Cores are preserved in all stages of reduction (compare **Figures 2: 6, 8**). Among the tools, simple side scrapers (**Figure 2: 11**), notches and denticulates, and archaic points (**Figure 2: 9-10**) predominate (Valoch, 1984, 1988a, 1988b). The assemblage of hard animal tissues contains more than 60 retouchers made mostly from bones of large-bodied mammals (Auguste, 2002; Neruda et al., 2011). The cave probably served as a base camp. Based on malacological analysis and higher humus content in sediment layer 11 (Valoch et al., 1969), the Taubachian techno-complex (layers 13-10) dates to the end of the last interglacial or to the beginning of the last glacial (Valoch, 1989, 2002).

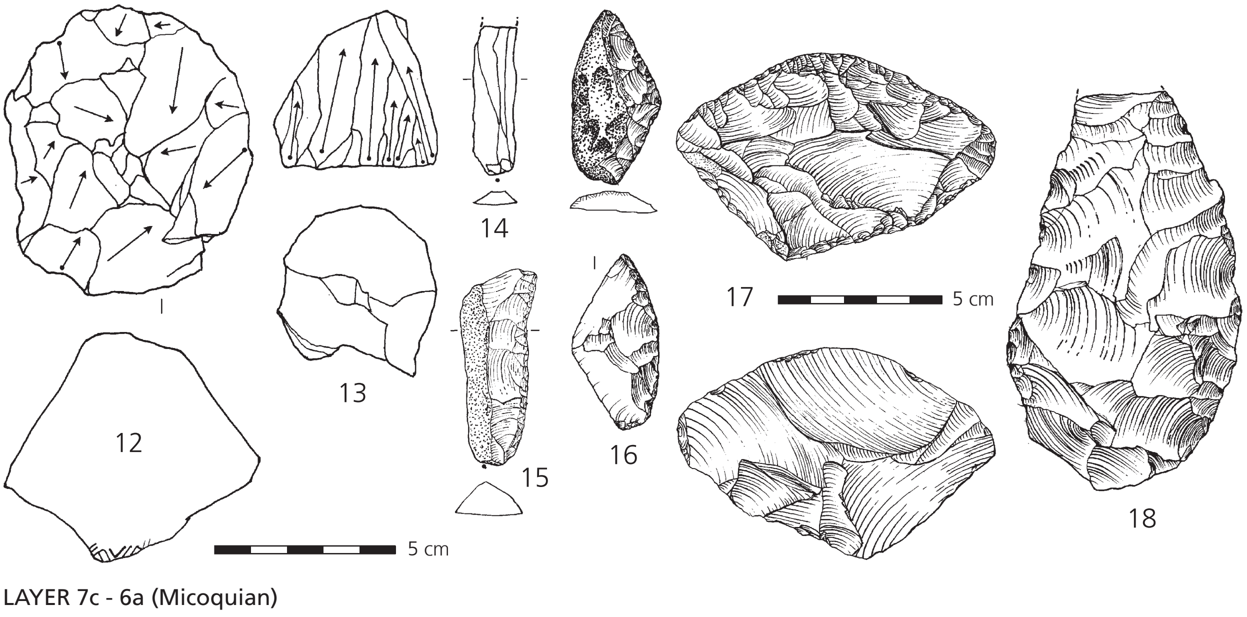
The third Middle Palaeolithic unit is the Micoquian occupation, recognised in layers 9b, 8a 7d, 7c, 7a and 6a. All layers contain typical Micoquian industries based on the reduction of volumetric discoid cores (mostly two types, **Figure 2: 12**), indicating the production of large flakes. Such blanks were modified into complex side scrapers (**Figure 2: 17**), often resembling bifacial knives (**Figure 2: 16**). Another *debitage* method is represented by blade production from Upper Palaeolithic-like cores (Neruda, 2010). The second important method of tool production is bifacial shaping: *façonnage* (Boëda, 1995) of bifacial side scrapers, hand-axes (**Figure 2: 18**) and especially bifacial backed knives in different stages of reduction, which can be considered as the *fossile directeur.* Raw material economy (Féblot-Augustin, 1993, 1997) was based on the exploitation of quality sources from minimal distances of about 10 km. We noted the decreasing number of raw materials from distant sources, indicating a different mode of mobility and economy, which, unlike the Taubachian, was more tied to the region of South Moravia (Neruda, 2010, 2011). In the Micoquian layers, bone tools are represented by retouchers from hard animal tissues (Auguste, 2002; Neruda et al., 2011). Layer 7a represents a base camp settled during the winter and early spring (Nerudová et al., 2014). Comparing all available data, we can codify two chronological markers within the Micoquian horizons in Kůlna Cave. Layer 9b is dated to 69 cal ka BP (ESR; Rink et al., 1996), and layer 7a was deposited around 50 cal ka BP (ESR and ^{14}C; Mook, 1988; Rink et al., 1996; Neruda and Nerudová, 2014).



LAYER 14 Middle Palaeolithic (Mousterian)
with Levallois method



LAYER 11 (Taubachian)



LAYER 7c - 6a (Micoquian)

Figure 2 Lithic artefacts from Mousterian with Levallois method (1-5), Taubachian (6-11) and Micoquian (12-18) layers.

Materials and methods

For the analysis of the Middle Palaeolithic collections, we primarily utilised the well-stratified finds from Taubachian layer 11 and Micoquian layers 7c, 7a, and 6a. The processing of hard animal tissues was aimed to review the circumstances of recovery for all finds, using original field notebooks and drawings, in order to facilitate an analysis of the spatial distribution of the studied objects. The locations of all hard animal tissue finds with anthropic impacts and retouchers were compared with other groups of archaeological remains to evaluate the functions of find concentrations (Neruda, 2017). Taking into account that in the course of Valoch's excavations finds were localised into areas of varying sizes defined by the square metre grid it was not possible to precisely visualise the positions of most unearthed artefacts. In most cases, find places were defined by an area of several square metres. However, by means of randomised coordinates, we generated kernel density maps for various find groups, thereby defining the functions of the individual concentrations with greater accuracy; and, in the case of the two mammoth ivory retouchers, we were able to assess their positions within the spatial divisions of the cave.

Osteological analysis focused on taxonomic designations of the individual items of hard animal tissues. Because of a high degree of fragmentation of the material, in most cases it was only possible to determinate animal size groups. At the same time, we selected pieces eligible for bearing the designation of retouchers. Into this group, we included artefacts on which it was possible to observe a concentration of impacts (retouch scratches or *stigmata*), most often grouped into scar fields (use areas or *plages*) with varying sizes and shapes.

These pieces were verified and described using various methods of microscopic analysis. In the course of the analysis we concentrated on the objects in three stages: the physical properties of the hard animal tissue fragments, the morphology and morphometry of the areas of retouch damage, and the individual traces of retouching (Neruda et al., 2011). All pieces were examined using a Nikon SMZ645 stereo zoom microscope. We applied both laser scanning electron microscope (LEXT) and scanning electron microscopy (SEM) for selected pieces of hard animal tissues with anthropic impacts. The ivory retouchers were documented by CT scans performed in the X-ray micro CT and nano CT research laboratory of the Central European Institute of Technology (CEITEC) in Brno. Both pieces were scanned using 120 kV voltage, 350 µA current, and 85 µm resolution.

To calculate the diameters and radii of curved parts of the retouchers we applied the circular arc method. Radius (r) was calculated using the formula $h/2+c2/8h$, where c stands for width of the arc and h is its height measured at the midpoint along the base of the arc. These results must be taken as approximate values, since the amount of post-depositional changes cannot be determined with certainty. One of the retouchers had been glued together from four parts, and as the contact areas are very thin, we cannot exclude a minor deflection in the arc radius. Simultaneously, it is possible that the arc radius might have been altered because of the pressure exerted by the sediment in which it was deposited. Deviations linked with both post-depositional deformations and the precision of the measurements are quite standard for this type of calculation, since a deviation of arc height on the order of 0.5 mm will result in up to a 2 cm difference in the radius of the measured arc.

Results

Description of retouchers from mammoth ivory

ID 106743

The retoucher ID 106743 (**Table 1; Figure 3**) is a fragment of a thin, convex-concave layer of ivory glued together from four parts. The maximum preserved length and width are 125.3 mm and 44.2 mm, respectively. The thickness of the layer varies from 1.71 to 3.35 mm. The convex side of the artefact bears two types of stigmata indicative of scra-

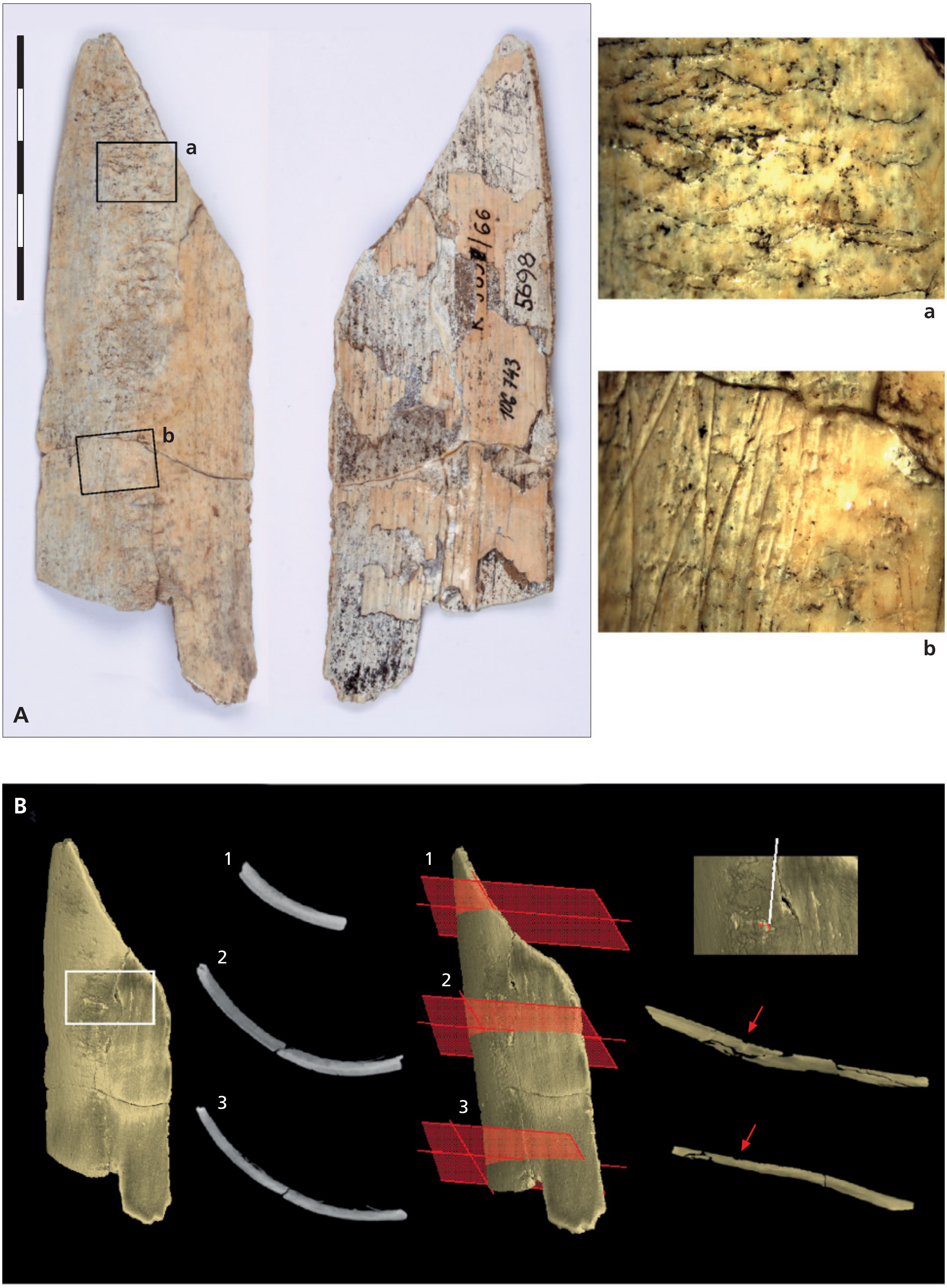


Figure 3 Retoucher 106743 from a mammoth tusk: (A) inverse and reverse of the retoucher *(photo K. Jursa)*, (a) detail of a scar field (8x), (b) scraping (8x); (B) CT scan.

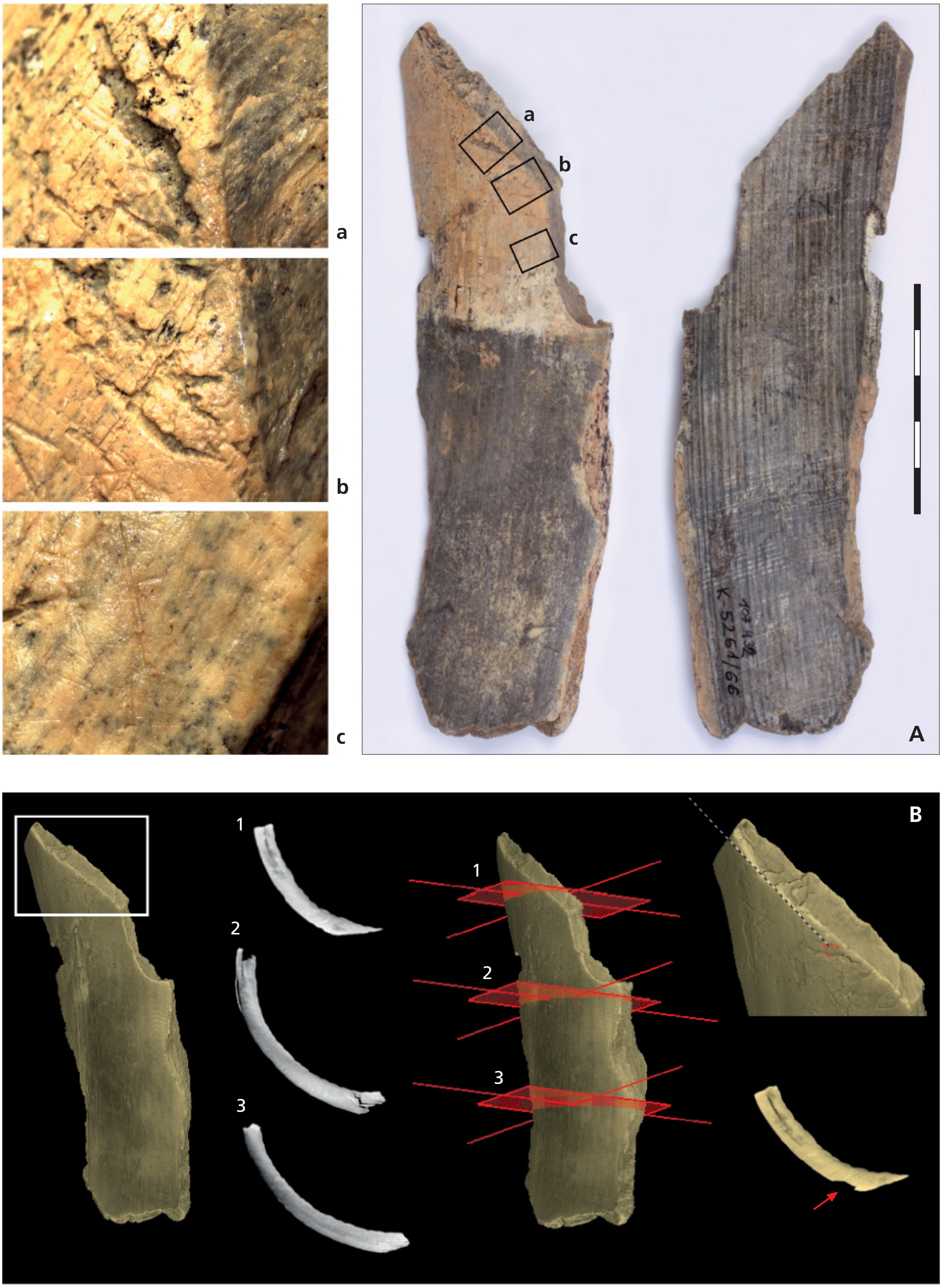


Figure 4 Retoucher 107432 from a mammoth tusk: (A) inverse and reverse of the retoucher *(photo K. Jursa)*, (a-b) detail of a scar fields (8x), (c) preservation of the artefact surface (8x); (B) CT scan.

ping, and a grouping of use-wear scars perpendicular to the long axis of the artefact. The concave side is without traces of anthropic impact.

The state of artefact surface preservation is poor and repair of the object is not precise. Both glue and a thick layer of protective finish, which permeates the ivory and partly fills out grooves and retouch scars, impede more detailed observation. The finish peels off on the concave side. The artefact also suffered a recent fracture on its proximal end.

Reconstructed diameter of the original tusk amounted to 65-70 mm in the middle part of the retoucher. On its longitudinal axis, the retoucher is concave, with a curvature diameter of ca. 660 mm. This calculation may be slightly distorted because of inaccurate joining of the object from several parts.

Fracture edges are markedly smoothed in its distal (convergent) part and on both edges. At the proximal end, the thinnest part of the retoucher, fractures are due to post-depositional damage. A recent fracture is apparent in the lower left portion of the object as shown in **Figure 3**.

One edge of the object on the convex side bears traces of scraping in the form of long grooves on the surface. We also observe a continuous scar field related to retouching lithic tools situated along the entire longitudinal axis, slightly offset from the apical extremity. On the opposite extremity (proximal), the scar field is damaged by the previously mentioned fractures.

The entire scar field is indicative of intense use, since the individual scars overlap. The scar field can be divided into two zones with the highest concentration of marks: the upper third of the object and its apical convergence.

ID 107432

The artefact ID 107432 (**Table 1; Figure 4**) is preserved in the form of a fragment, one layer of mammoth ivory, with a maximum length of 157 mm and 52.8 mm width. The thickness of the layer varies between 4.1 mm and 4.7 mm.

Retouch scratches resulting from use are concentrated in the scar fields near the fracture edge on the convex side of the artefact altered by dry transport (*charriage-à-sec*; d'Errico and Giacobini, 1988); the concave side bears no use traces.

The diameter of the tusk from which the artefact originates measured 48-58 mm at a minimum. In its longitudinal axis, the retoucher is concave, with a curvature diameter amounting to ca. 680 mm.

A preservative substance peels off only in the upper third of the item on the convex side, close to the left edge near the recent fracturing, as shown in **Figure 4**, which was probably caused during excavation. Except for this area, the edges are slightly smoothed. In the distal part of the object the edges are convergent, and the apex is shifted off-centre towards the left side. In the central part of the right edge, and in its lower third, the original surface of the convex area of the object has been broken off. In this case, the breakage surface is coarse and exposes the laminated ivory structure.

The surface on the outer, convex side of ivory is preserved in two hues: light ochre in the distal part of the object and grey-brown in the remaining two thirds. These dissimilar colours may correspond with different sediment chemistry during various stages of exfoliation. The part of the tusk that escaped decomposition was “protected” against the sediments and its colour remained unaltered (C. Heckel, personal communication). Chemical alteration of hard animal tissues was likewise observed during the previous excavations in Kůlna Cave (Patou-Mathis et al., 2005; Michel et al., 2006a; Michel et al., 2006b).

Contrary to the first artefact (ID 106743), retouch scratches do not form a continuous scar field; instead, they are scattered over the surface. We can identify a single concentration near the margin of the sloping edge in the distal part of the piece.

Archaeological context

Both objects can be incorporated into the spatial analysis of find distributions in layer 7a, or 7a1 (Valoch, 1988b; Neruda, 2017). According to field notebooks, retoucher number 106743 was situated within the area of squares S/29-30 in sector G2

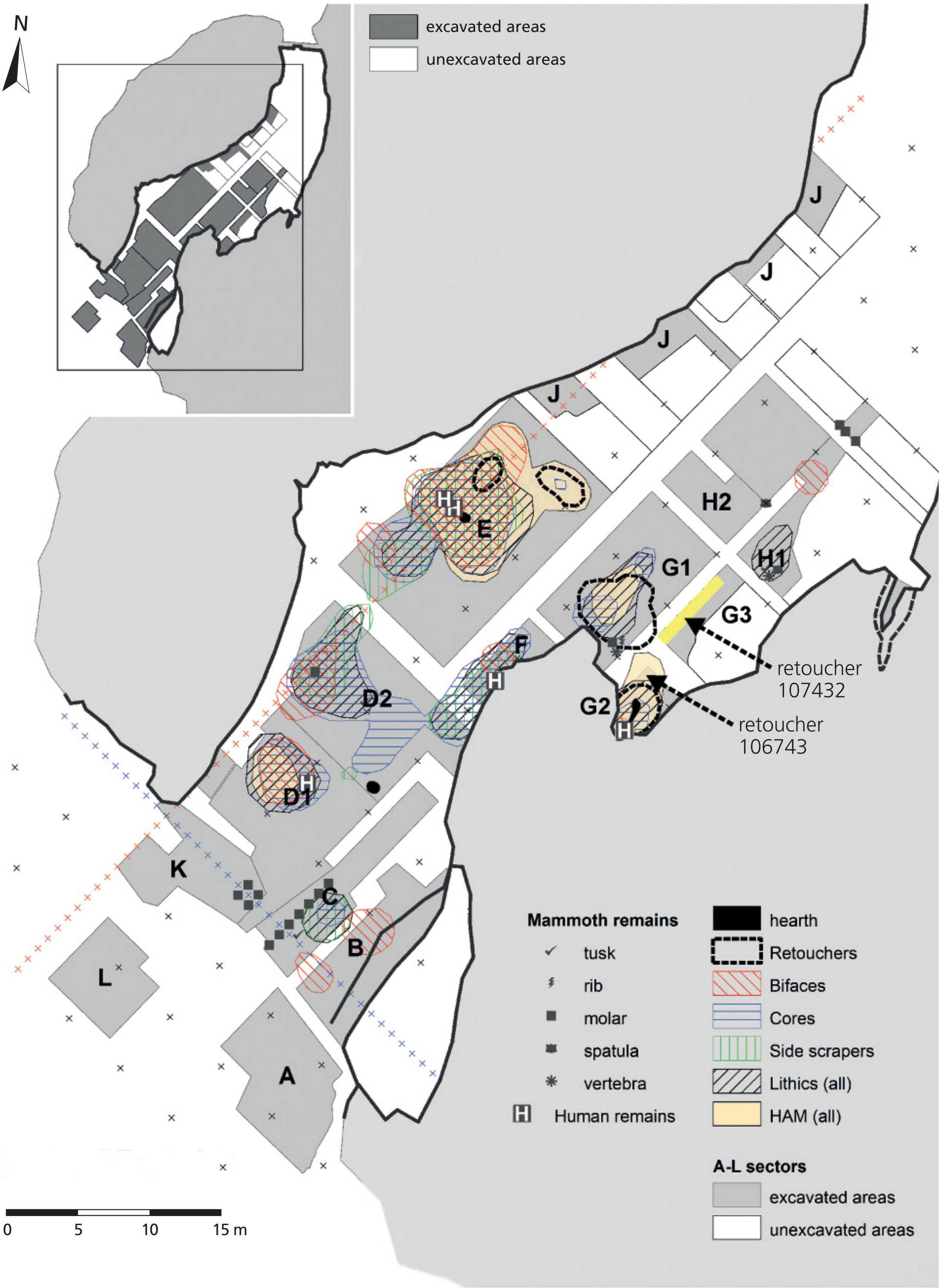


Figure 5 Spatial distribution of distinct groups of finds in layer 7a (7a1). Arrows and the yellow strip indicate the area where retouchers were found.

and retoucher 107432 within area R/33-38 in sector G3 (**Figure 5**). If we look into the composition of artefacts in the nearest accumulations, it becomes evident that a number of activities took place in this part of the cave (including sector G1), many of which were linked with the production of lithic tools.

In sector G2, a concentration of hard animal tissues with anthropic impacts was noticed, which also included a marked presence of bone retouchers and one ivory retoucher (ID 106743). Their application might relate to the production of bifacial artefacts, which are relatively abundant in this sector (Neruda, 2017). The production of tools and/or their reutilization was carried out around the elongated combustion zone in this area of the cave.

The location of the second ivory retoucher (ID 107432) is less precise, falling within an area of 6 x 1 m in sector G3, as the finds from this area were merged together by Valoch. The closest accumulation of retouchers of hard animal tissues was found in sector G1, where mainly lithic flakes and cores occurred. However, a more significant representation of side scrapers and bifacial artefacts that were produced using retouchers of hard animal tissues was found missing in the area. Consequently, this could be the location where the entire process of tool manufacture, from exploitation of blanks through retouching, took place, but the tools were used and deposited at another place within the cave (Neruda, 2017).

Discussion

Problem of a contamination

First we must ask whether the unearthed retouchers from mammoth ivory are indeed linked with Neanderthal activities in the Middle Palaeolithic. Kříž (1903) found a small ivory cylinder ornamented with tiny indentations in trench VI, which was situated in what is now sector G2. Therefore, we come to a possibility that the ivory retouchers in the Middle Palaeolithic layers may represent a more recent contamination.

Currently we are no longer able to correlate Kříž's trenches with the stratigraphy defined by Valoch, mainly because the original ground level in the G sectors had been removed prior to the construction of a factory during World War II (Břečka, 2011). However, analysis of remnant sediments on the cave walls (Neruda, 2013) revealed that the original surface was situated 1 m above the factory floor, i.e., more than 1 m above the upper level of the original, intact sediments studied by Valoch. Kříž's discovery was reported to have come from a depth of 0.95 m. This would lie above the level of the uppermost layers under the concrete floor, from which Valoch measured find depths during his excavations. Both ivory retouchers were discovered at a depth exceeding 2.4 m (see **Table 1**), i.e., at least 3.4 m from the original Holocene surface of the cave. This clearly rules out any contamination from more recent layers excavated by Kříž.

The fact that layer 7a1 is separated from the uppermost Middle Palaeolithic layer 6a and from the lowermost Upper Palaeolithic layer 6 containing both Gravettian and Magdalenian finds, is also of importance. Although in some parts of the cave (e.g., the southern entrance) it is difficult to make a lithological differentiation of layer 6a from Upper Palaeolithic sedimentation (Lisá et al., 2013; Neruda and Nerudová, 2014), in the G sectors that yielded the retouchers, the Middle Palaeolithic layer 6a can be clearly differentiated from the Upper Palaeolithic sequence. Layer 7a, also comprising layer 7a1 inside of the cave, does not show any contaminations with more recent material in the outcomes of ^{14}C dating (Neruda and Nerudová, 2014). The technological and morphological character of the retouchers is also in correspondence with these conclusions, since we are not aware of this type of *ad hoc* tool in the Upper Palaeolithic material of Moravia. Perhaps the most similar artefact is a bone with impact scars from the Magdalenian sequence in Pekárna Cave, but the scars in this item are oriented more or less parallel to the longitudinal axis of the bone fragment; therefore, its function may have been different (Lázničková-Galetová, 2010). Yet, research focused directly on the identification of retouchers in

Upper Palaeolithic assemblages may reveal other examples. Such items from the sites of Geißenklösterle IIIa and Vogelherd in Germany, or Isturitz in France, stand as evidence (e.g. Taute, 1965; Leroy-Prost, 2002; Schwab, 2002; Conard et al., 2006; Wolf, 2015; Camarós et al., 2016).

Synchronic and diachronic comparison

The ivory retouchers bring about the issue of human and mammoth interactions at Kůlna Cave. The appearance of retouchers can be explained by random choice of this material from the remains of hard animal tissues found within the cave. Nevertheless, in Kůlna we have the option to study the utilization of hard animal tissues both from synchronic (comparing raw materials) and diachronic (Taubachien vs. Micoquian) perspectives, which can be helpful for interpreting these finds.

Interestingly, the assemblages of non-ivory retouchers from the Taubachian and the Micoquian are very similar, in that primarily fragments of long bones were used in both techno-complexes. On the surfaces of the retouchers, we can often observe sub-parallel grooves running along the longitudinal axis of the object (scraping). Auguste (2002) recognised differences in the use of blanks in the Taubachian, with a prevalence of metapodials, and the Micoquian, with tibias prevailing; however, these differences are only a matter of several per cent. Likewise, morphometric differences cannot be applied as distinctive features for classifying individual pieces to Taubachian or Micoquian assemblages (Neruda et al., 2011). Similarly, Auguste (in Patou-Mathis et al., 2005) observed the absence of significant differences between the Taubachian and Micoquian sequences in his summary of the Middle Palaeolithic layers from Kůlna Cave.

More essential differences are connected with taxonomic identification of hard animal tissue fragments used for retouching lithic tools. Auguste (2002) states that the use of bison (*Bison priscus*) bones is typical for the Taubachian, whereas mainly reindeer (*Rangifer tarandus*) were utilised in the Micoquian. In general, this corresponds to the comparison of size categories we carried out in relation to the great degree of fragmentation of the faunal remains in both techno-complexes (Neruda et al., 2011). For the Taubachian (**Figure 6A**), large animals such as bison (~70%) prevail, whereas medium-sized animals represent less than 30%. The use of very large animals, like mammoth or rhinoceros, was not recorded. In contrast to Auguste (2002), we hold the opinion that this comparison suggests a certain selection of blanks. In the collection of all hard animal tissues with anthropic impacts from the Taubachian sequence (**Figure 7A**), the ratio of medium (47%) to large animals (51%) is more or less balanced. At the same time, it is apparent that although the Taubachian sequence yielded remains of very large animals, evidence of their utilisation is missing. Moreover, the percentage in the graph is markedly lower, since in the entire osteological collection consisted mainly of mammoth molars, on which we are unable to detect intentional anthropic modifications. A conspicuous increase of large animals in the retoucher group and a total absence of very large animals indicates that Neanderthals indeed had certain preferences, perhaps related with compact bone thickness or total retoucher weight.

In the Micoquian we observe different strategies in the use of blanks, and the principal trends are the same in all studied layers 7c, 7a, and 6a (Neruda et al., 2011). Among retouchers, fragments of long bones from medium-sized animals prevail (**Figure 6B**), which is in conformity with Auguste's (2002) conclusions. The share of large animals is much smaller than in the Taubachian, but retouchers from bones of very large animals appear (Neruda et al., 2011). In this case, it is perhaps impossible to refer to a specific selection of blanks (cf. Auguste, 2002), since in the entire assemblage of hard animal tissues the trend is the same, the difference being the markedly higher prevalence of medium-sized animals (**Figure 7B**).

The relevant fact concerning the Micoquian collection is an increase in the proportion of very large animals, including mammoth, which is also manifested in the assemblage of retouchers. Importantly,

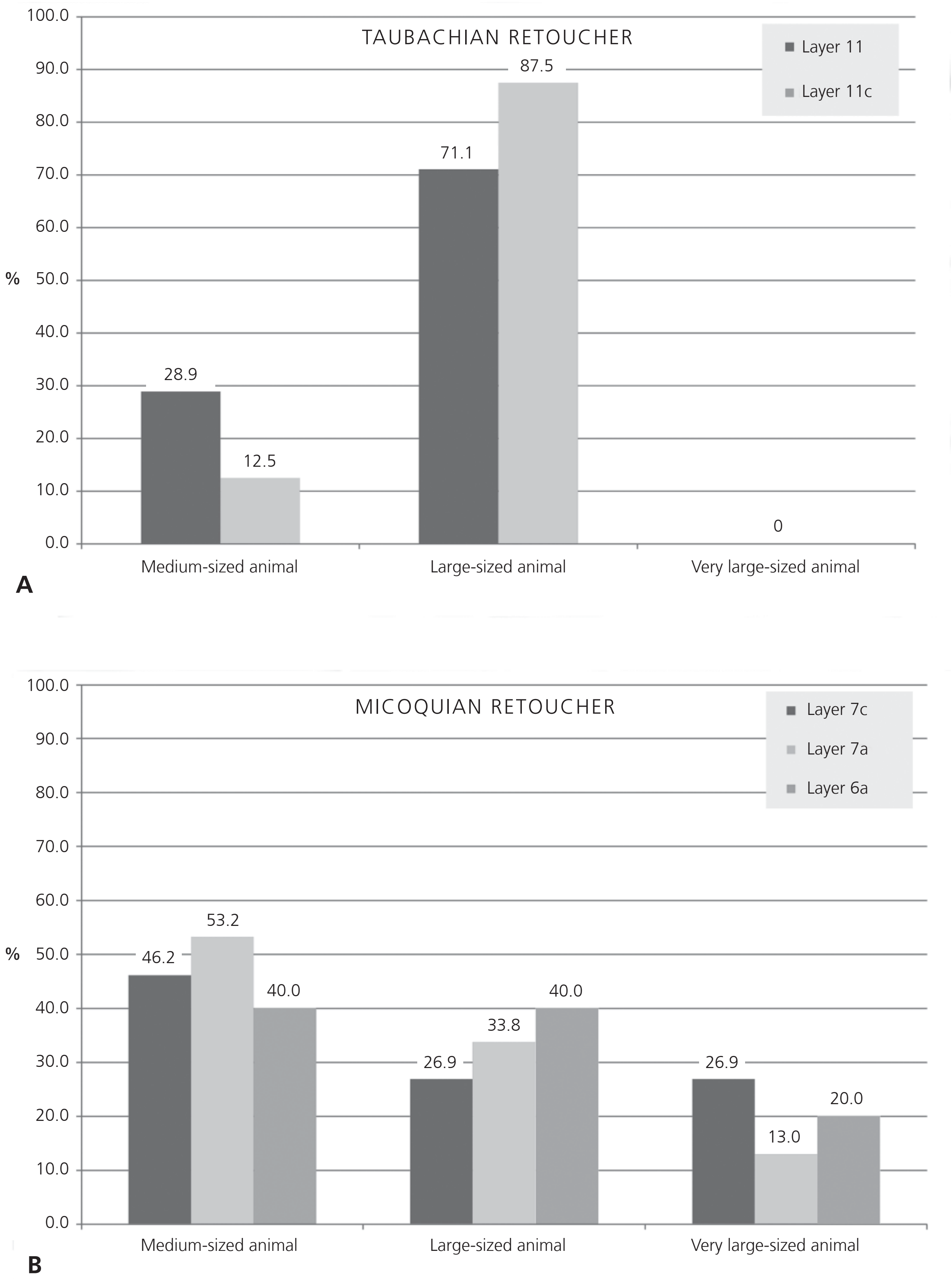


Figure 6 Percentage of animal size groups in assemblages of retouchers.

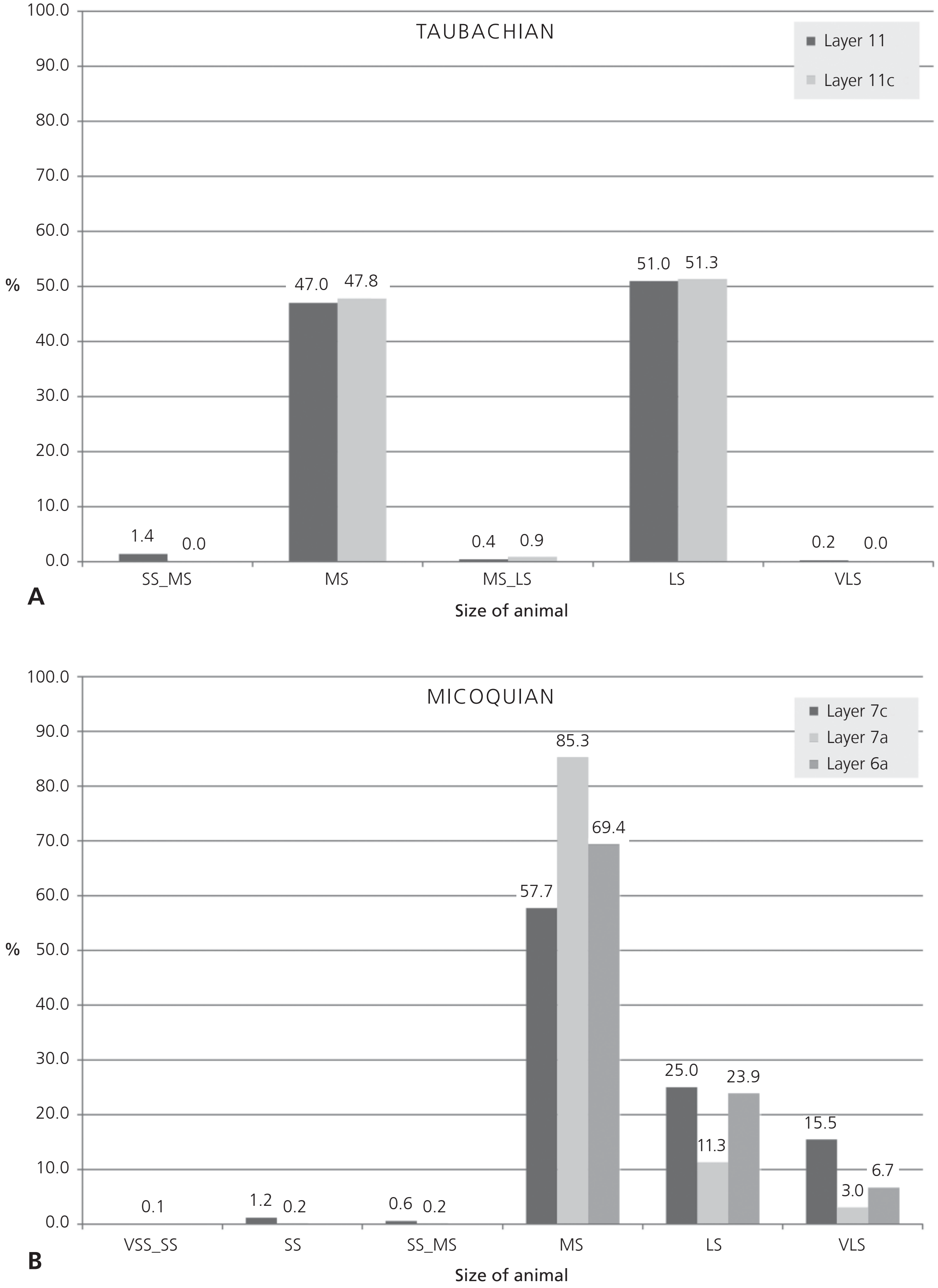


Figure 7 Percentage of animal size groups in assemblages of hard animal tissues. SS – small-sized, MS – medium-sized, LS – large-sized, and VLS – very large-sized animals.

these animals are not represented only by teeth that could have been sought by Neanderthals as curiosities, but long bones and ribs appear as well (Neruda et al., 2011). This could indicate a change in the interaction between humans and mammoths occurring in the Micoquian, not only at the technological level as a source of blanks for retouchers used in the manufacture of lithic tools, but also as a major constituent of subsistence strategies arising in the Late Middle Palaeolithic (e.g., Patou-Mathis et al., 2005; Bocherens, 2009). The high proportion of very large herbivores, such as woolly rhinoceros and woolly mammoth, in the Saint-Césaire I (France) Neanderthal diet, when viewed in comparison to that of the scavenging hyenas, suggests that Neanderthals could not acquire these animals entirely through scavenging; they probably had to hunt for proboscideans and rhinoceros (Bocherens et al., 2005). Due to the considerable fragmentation of mammoth bones in the Micoquian sequence in Kůlna, which can be related to acquiring highly nutritive tissues (e.g., Patou-Mathis, 1995; Bocherens et al., 2001; Sorensen and Leonard, 2001; Marean, 2005; Snodgrass and Leonard, 2009), it seems probable that mammoths constituted a valuable source of food at Kůlna Cave. Whether these very large animals were acquired through hunting or scavenging during the Micoquian at Kůlna Cave could not be determined (Patou-Mathis et al., 2005).

The approach of Neanderthals to these animals must have been different in the Taubachian. Theoretically, the absence of retouchers of hard tissues from very large animals, like mammoth and rhinoceros, could be explained by ecosystem requirements of these animals. The Taubachian sequence falls roughly into the terminal period of the last interglacial or to the beginning of the last glacial, with a rather forested environment related to a warmer climate. On the contrary, we generally associate mammoth and rhinoceros with cold steppes during cold phases of glacial periods. Had this been the case, the remnant tissues of these animals must have been manuports, collected as curiosities randomly found in the sediments of the Moravian Karst. Some studies show, however, that the behaviour we assume for Pleistocene animals could have undergone significant changes, and that mammoths might have occurred also in forested environments of the last interglacial (e.g., Bocherens, 2014). Consequently, the Taubachian hunters could have had opportunities to use relatively fresh tissues of these animals, acquired by scavenging at the very least, and made them part of the subsistence and technological chain similarly to the Micoquian hunters later on. But, for the time being this does not seem to have been the case.

A change of human behaviour towards mammoths or other very large herbivorous animals could have been expressed at the non-utilitarian level. It is interesting that in Kůlna Cave Micoquian layer 7α (equivalent of layer 7c in sector F) Valoch (1988b) discovered three mammoth tusks hidden in a vertical cavity. He excluded their natural deposition (K. Valoch, personal communication); thus, the only explanation is that for some reason the tusks were deposited into the cavity directly by Neanderthals. Regretfully, due to their poor preservation, the tusks were taken out incomplete (Valoch et al., 2011) and are not eligible for analysis to identify any intentional modifications. Nevertheless, it is important to point out that the share of mammoth remains with anthropic impact is the highest in layer 7α compared to other Micoquian layers.

The retouchers from layer 7a1 open up yet another important issue about whether Neanderthals developed some specific technology for processing mammoth ivory. Similar to bone material, scraping marks were found on the surface of the ivory retouchers. Grooves were also noted on the surfaces of other preserved tusk fragments from Kůlna (Vincent, 1993; Oliva, 1995). On the thin layers of ivory from which retouchers are produced, the modifications related to shaping are difficult to decipher. It seems that Neanderthals were able to produce fragments of ivory by means of dynamic fracture. Such modification is demonstrated from the Middle Palaeolithic horizon at Hohlenstein-Stadel, Germany (Kind et al., 2013), where two pieces of mammoth tusks about 17 cm long are altered to form a chisel-like shape on both ends.

On the other hand, it is obvious that processing of teeth for use as retouchers is more likely a phenomenon of the Upper Palaeolithic. Aurignacian horizons AH IV and AH V at Vogelherd (Germany) yielded retouchers of ivory that are similar to Middle Palaeolithic artefacts (Wolf, 2015). From the Aurignacian layers of other sites in the Swabian Jura, we have some evidence that modern humans also utilised canine teeth of carnivores as retouchers (e.g., Taute, 1965; Hahn, 1977; Leroy-Prost, 2002; Camarós et al., 2016).

Prior to comparing the Middle and Upper Palaeolithic treatment of ivory, it is necessary to comprehensively analyse individual pieces of ivory with the aim of determining how this material was modified and to define the possible technological *chaîne opératoire* as precisely as possible. Thereafter, it would be worthwhile to assess whether there were technological innovations exclusive to Neanderthals. Research on materials from the Micoquian horizons can be crucial in this respect. According to our findings so far, the Kůlna Cave ivory retouchers come from the period preceding the arrival of modern humans; therefore, the creation of these implements was not influenced by the process of acculturation (for discussions on the Middle/Upper Palaeolithic transition, see Conard, 2006a; Conard 2006b; Svoboda, 2006; Smith, 2008; Higham, 2011; Nigst, 2012; Neruda and Nerudová, 2013; Conard and Bolus, 2015; Davies et al., 2015).

Conclusion

Numerous retouchers come from both Taubachian and Micoquian layers in Kůlna Cave. In the Micoquian period, remains of hard tissues of mammoth or some other very large animal were also used for retouching. At present, the two retouchers of mammoth ivory are unique to the Middle Pleistocene at Kůlna Cave. Both objects were found in an area of the cave where retouchers of other hard animal tissues were recovered. These locations were areas of lithic tool production or reutilization, and both ivory retouchers played a role in those activities.

From the comparison of animal size categories in the assemblage of other hard animal tissues, a marked change in the relation of Neanderthals and mammoths occurred in the Micoquian, not only in terms of technology, but also on subsistence and symbolic levels. With regard to the age of the Kůlna Micoquian layers, these findings can contribute to future discussion on the mental capacities of Neanderthals and their interactions with anatomically modern humans.

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BONE RETOUCHERS FROM TWO NORTH ITALIAN MIDDLE PALAEOLITHIC SITES: RIPARO TAGLIENTE AND GROTTA DELLA GHIACCIAIA, VERONA

Abstract

The use of retouching tools made on hard animal materials has a broad chronological and geographical distribution throughout the European Palaeolithic. In Italy, analyses of retouchers are not particularly numerous. The current work presents the preliminary results obtained from the study of 79 retouchers recovered from two sites located in northern Italy: Riparo Tagliente and Grotta della Ghiacciaia, Verona. Results from Riparo Tagliente provide both qualitative and quantitative data, span several occupation levels, and the use traces on the cortical surfaces of these bone tools show great variability. Grotta della Ghiacciaia yields only qualitative data because of a restrictively small sample size. Overall, the retouchers analysed are mostly made on bone shafts of medium- to large-sized ungulates, especially red deer and other cervids, which were the most commonly hunted animals at the sites. Many examples were also made on the bones of small-sized mammals, such as roe deer. This variability can contribute to the identification of such tools at other sites and to better define a methodology for their analysis.

Keywords

Retouchers; Use areas; Middle Palaeolithic; Northern Italy

Introduction

One of the primary objectives of researchers in the field of prehistory is to understand the mechanisms involved in the behavioural evolution of ancient hominin groups. Even today, the degree of technological and cultural development of prehistoric hunter-gatherer groups is assessed mainly through stone tools (Blasco et al., 2013). The contribution of other disciplines, zooarchaeology in particular, has brought added value to the acquisition of information related to hominin behaviour. The analysis of faunal remains has not only aided the formulation of hypotheses regarding hominin prey spectra and the methods of animal carcass exploitation, but also the use of bones derived from butchery activities as raw materials.

The use of bone was not regularly included in the manufacture of stone tools until well into the Acheulean cultural complex, when various osseous materials were used both as raw material to be shaped and as tools for shaping lithic implements (Blasco et al., 2013). Retouchers on ungulate long bones were identified for the first time in the beginning of the 20th century (Daleau, 1884; Henri-Martin, 1906, 1907, 1907-1910) at the Middle Palaeolithic site of La Quina (Charente, France) and have since been recognized in numerous Middle Palaeolithic faunal assemblages from Europe.

Patou-Mathis and Schwab (2002) defined bone retouchers generically as fragments of large mammal remains, without modification of the original morphology, that present on their surfaces one or more impressed areas with various crushing marks, cupules and scores made by impact against a sharp edge of a stone flake, tool or handaxe. The absence of retouching tools in the archaeological record of many regions and chronological periods can be attributed to two principal factors: specific economic choices of the hunter-gatherers and the difficulty in recognizing these objects by archaeologists and faunal specialists.

In Italy, analyses of retouchers are not particularly numerous, beginning only in the second half of the 1990s with the recovery of such artefacts at Grotta di San Bernardino (Vicenza), Grotta di Fumane (Verona) and Riparo Tagliente (Verona) in northern Italy (Malerba and Giacobini, 1998). In a more recent study, 148 retouchers from the Mousterian and Uluzzian layers of Grotta di Fumane were analysed to assess the selection criteria of osseous blanks and their further patterns of retoucher use and discard by Middle Palaeolithic hominin populations in each of the stratigraphic units (Jéquier et al., 2012, 2013).

The current work presents the preliminary results obtained from the study of retouchers recovered from two other sites located in northern Italy: Riparo Tagliente and Grotta della Ghiacciaia, Verona. Our research is in progress, and this study represents the first step in the collection of basic descriptive data using current methodologies. This will provide a foundation for an interdisciplinary investigation devoted to a better understanding of Palaeolithic hominin behaviours in northern Italy related to bone retoucher use, including hunting strategies, bone blank selection, retouch typology and the relationship between the retouch type and bone blanks.

Background to the sites

Riparo Tagliente (Stallavena di Grezzana, Verona) is a key Mousterian site in northern Italy, located at the base of Monte Tregnago under a rockshelter formed by oolitic limestone. This strategic location features several karst cavities and an abundance of lithic and mineral resources, such as flint outcrops, which were heavily exploited by Palaeolithic groups, first by Neanderthals and later by anatomically modern humans. The rockshelter lies at 250 m a.s.l. on the eastern slope of Valpantena, one of the main valley bottoms of the pre-Alpine massif of the Lessini Mountains (**Figure 1**).

The discovery of the site is attributed to Francesco Tagliente in 1958. Initial investigations were conducted from 1962 to 1964 by the *Museo Civico di Storia Naturale* of Verona. In 1967, excavations were started once again by the University of Ferrara and are still ongoing. Cumulatively, these excavations have highlighted a long Upper Pleistocene stratigraphic series (over 4.5 m deep), comprising two main deposits separated by a fluvial erosion event: a lower deposit containing Mousterian (levels 52 to 31) and Aurignacian industries (level 25) and an upper deposit characterised by a Late Epigravettian materials (levels 18 to 4). Geological, bioarchaeological and lithic typological data suggest that the lowermost series corresponds to an entire glacial cycle dating to between about 60,000 and 30,000 years ago (Bartolomei et al., 1982, 1984; Guerreschi et al., 2002; Fontana et al., 2009).

Lithic assemblage analyses testify that raw material supply came from slope waste deposits in the vicinity of the site and coarse gravels were procured from the streambed opposite the rockshelter. However, from level 37 upwards, blade production was carried out using one specific kind of flint. Peresani (2009) observed that the Levallois method was still used even in the uppermost sequence, although uni- and bidirectional modalities were more frequent from level 37 upward. Centripetal reduction was featured in earlier levels. Discoid and unelaborated flaking methods may be attributed to specific reduction sequences or to discard of exploited

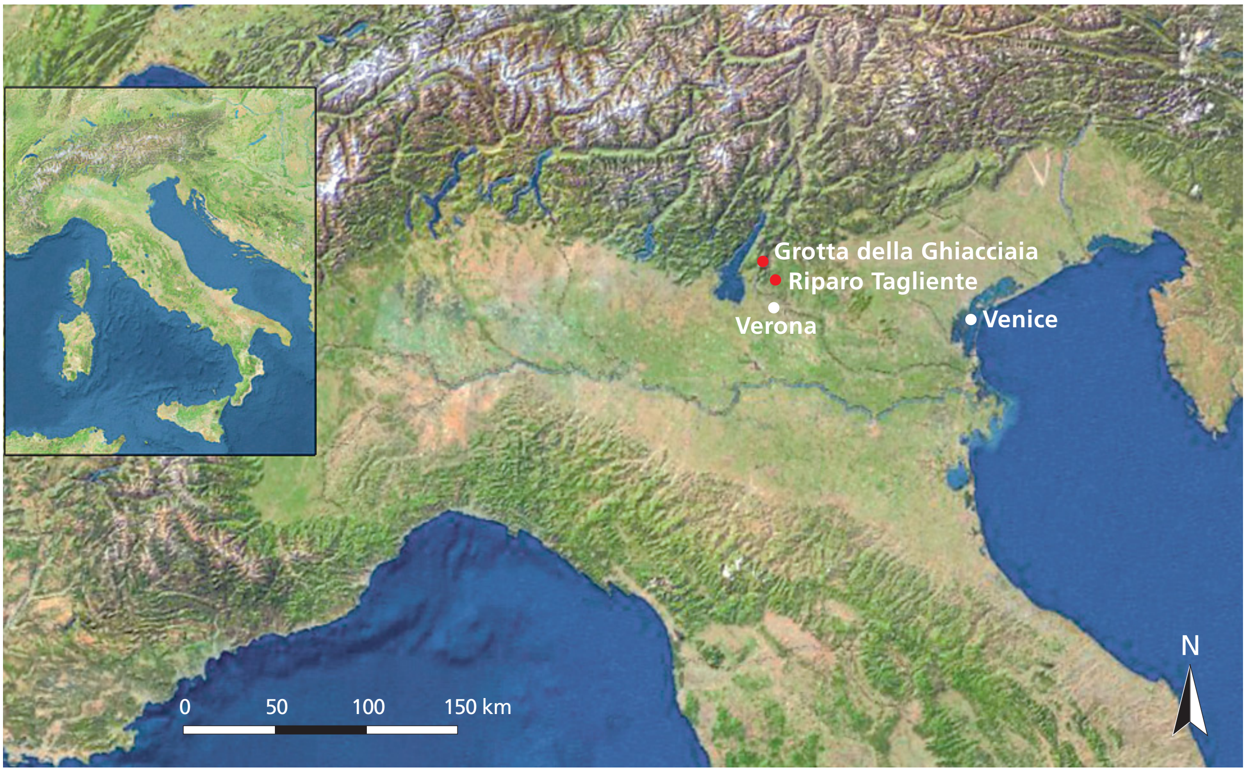

Figure 1 Map of Italy showing the locations of Riparo Tagliente and Grotta della Ghiacciaia, Verona.

Levallois cores (Arzarello and Peretto, 2005). The upper levels (37-34) show a greater diversity of retouched tools, likely a result of intense and long-term occupations of the site, as suggested by larger amounts of lithic and faunal remains relative to the lower levels.

Faunal analysis revealed an abundance of roe deer *(Capreolus capreolus)* and red deer *(Cervus elaphus)*, followed by chamois *(Rupicapra rupicapra)* and ibex *(Capra ibex)*, along with the presence of elk *(Alces alces)* and marmot *(Marmota marmota)* (**Table 1**). Palaeoenvironmentally, these species reflect a moderately humid, temperate-cold climate. A mixed biotope comprising forest, woodland areas and open steppe-grasslands marked the initial Mousterian phase. Increased aridity is indicted in levels 44-40, with a reduction in forest-dwelling species in favour of continental, Asian steppe fauna. In the upper part of the sequence, forest and woodland micromammals reappeared, but are less numerous than the open grassland or woody grassland forms (Fiore et al., 2004).

The frequency of anthropic modifications to ungulate remains indicates that Neanderthals played an important role in the accumulation of the faunal assemblage (Thun Hohenstein et al., 2001; Alhaique et al., 2004). Evidence of carnivores at the site is sparse, possibly due to the long duration of hominin occupation.

Grotta della Ghiacciaia is located at 250 m a.s.l. on the left side of Progni Valley, near Grotta di Fumane in the western Lessini Mountains (see **Figure 1**). Preliminary investigations were carried out in 1979-80 under the direction of Carlo Peretto in collaboration with the *Museo Civico di Storia Naturale* of Verona. The approximately 3.5 m thick deposit preserves an Upper Pleistocene series with three pedo-stratigraphic macro-units (Units 1, 2 and 3), which can be used to document palaeoenvironmental changes at the site. At the base is the sterile Unit 1 associated with the Last Interglacial, succeeded by short-term anthropic levels of Units 2 and 3 associated with the First Pleniglacial (beginning of MIS 4). This chronology is derived from sedimentologi-

Table 1 Number of identified specimens (NISP) and percentage contribution (%NISP) by taxa at Riparo Tagliente and Grotta della Ghiacciaia.

Taxa	Riparo Tagliente						Grotta della Ghiacciaia			
	Level 35		Level 36		Level 37		Unit 2		Unit 3	
	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP
Aves	3	2.6	6	2.2	2	1.1	-	-	-	-
Lepus sp.	-	-	1	0.4	1	0.5	-	-	-	-
Marmota marmota	4	3.5	15	5.4	24	12.8	-	-	-	-
Vulpes vulpes	-	-	3	1.1	-	-	1	11.1	1	8.4
Canis lupus	3	2.6	2	0.7	1	0.5	1	11.1	3	25
Ursus sp.	2	1.8	2	0.7	-	-	2	22.2	3	25
Carnivora	1	0.9	-	-	4	2.2	-	-	-	-
Sus scrofa	-	-	-	-	2	1.1	-	-	-	-
Equus sp.	1	0.9	-	-	-	-	-	-	-	-
Rupicapra rupicapra	5	4.4	31	11.2	2	1.1	-	-	-	-
Capra ibex	4	3.5	17	6.2	14	7.5	4	44.5	1	8.3
Capreolus capreolus	79	69.3	137	49.6	108	58.1	-	-	2	16.7
Cervus elaphus	8	7	38	13.8	14	7.5	-	-	-	-
Alces alces	-	-	4	1.4	2	1.1	-	-	-	-
Cervidae	4	3.5	2	0.7	5	2.7	-	-	-	-
Bison priscus	-	-	-	-	-	-	1	11.1	1	8.3
Bos sp.	-	-	-	-	7	3.8	-	-	1	8.3
Medium-sized ungulate	-	-	9	3.3	-	-	-	-	-	-
Large-sized ungulate	-	-	9	3.3	-	-	-	-	-	-
Total	114	100	276	100	186	100	9	100	12	100

cal and palaeobotanical evidence (Peretto and Thun Hohenstein, 2002).

The lithic assemblages discovered in Units 2 and 3 are techno-typologically variable. While the Levallois method was exclusively employed in the later units, mainly by means of unidirectional modality, Quina and semi-Quina scrapers are present among the few artefacts found in the earlier units. Moreover, throughout the series it is possible to recognise variation in the lithic assemblages, well evident in the frequency of retouched tools (Bertola et al., 1999).

Among the faunal remains (21 identified specimens), ibex *(Capra ibex)* is the most abundant species, followed by roe deer *(Capreolus capreolus)* and bison *(Bison priscus)* (see **Table 1**). Red deer *(Cervus elaphus)* is conspicuously absent. The predominant species in both units are characteristic of high altitude grassland and cold steppe, although species typical of open forest environments are present in Unit 2. Changes in the small faunal composition suggest a gradual drying of the climate, from cold and humid to cold and arid.

No traces of carnivore activity were identified, although the remains of bear (*Ursus* sp.), wolf *(Canis lupus)* and fox *(Vulpes vulpes)* are present (Peresani et al., 2001). In contrast, Neanderthal butchery and intentional bone breakage are well documented. Some bones were also used as retouchers for stone tools (Bertola et al., 1999; Thun Hohenstein, 2001).

Material and methods

The study material for the present research comprises 79 bone retouchers sourced from Riparo Tagliente and Grotta della Ghiacciaia. Both sites are characterised by the occurrence of the same lithic technologies: volumetric Levallois and laminar débitage that is correlated by some authors with an important climatic fluctuation, which may have caused a change in Neanderthal techno-economic behaviour (Ameloot-Van Der Heijden, 1993; Tuffreau, 1993; Révillion, 1995; Arzarello and Peretto, 2005).

The total number of bone retouchers from the upper part of the Mousterian series of Riparo Tagliente amounted to 75; however, 12 retouchers from this sample were not considered here, as their stratigraphical provenance was doubtful and their original morphology was not preserved. Therefore, only three levels (35, 36 and 37) with 63 bone retouchers were taken into consideration for our study: five (8.0%) from level 35, 22 (34.9%) from level 36, and 36 (57.1%) came from layer 37. Only four retouchers from the anthropic levels of Grotta della Ghiacciaia were examined. Since the Riparo Tagliente sample has a higher number of bone retouchers than at Grotta della Ghiacciaia, we ascribe to it greater significance. Accordingly, our preliminary results will focus more on Riparo Tagliente.

The corpus of bone retouchers from the present study has been identified in previous zooarchaeological analyses (Thun Hohenstein, 2001, 2006; Thun Hohenstein and Peretto, 2005). The methodological approaches for formulating our analysis are based mainly on individual works published in the edited volume, *Retouchoirs, compresseurs, percuteurs…Os à impressions et éraillures* (Patou-Mathis, 2002), particularly those by Giacobini and Patou-Mathis (2002) and Schwab (2002).

Our protocol commenced with taxonomic and anatomic identification of each bone retoucher. In a few cases, whenever precise taxonomic identification was not possible, the bone fragments were assigned to animal size class based on cortical thickness. In addition to identifying the skeletal element from which the bone retoucher was derived, further attempts were made to determine the portion of the element and its laterality. The primary dimensions of the retouchers (maximum length, width and thickness) were measured in millimetres using a digital calliper. The weight of each retoucher was recorded in grams using an electronic scale.

The second step was to carry out a taphonomic analysis of the surfaces and edges of the retouchers to determine the state of preservation, type of fracture and degree of fragmentation. Bone fractures were classified following Villa and Mahieu (1991). The taphonomic study was carried out using a Leica SD6 (6-40x) microscope. Fractures were either assigned to anthropic or post-depositional factors, or a combination of both, and the bone tools were assessed to be complete, partially complete or fragmented. Within these three categories, we documented the shape and morphology of the bone blanks and the locations of the use areas.

For the sake of consistency in our analysis of the use areas, the retouchers were oriented by always placing the use area on the cortical surface in the apical (top) position on the bone blank (Mallye et al., 2012). In relation to the long axis (i.e., maximum length), the opposite end of the "apical" edge is designated as the "basal" edge. Similarly, the remaining two sides lying on either side formed the "right" and "left" sides of the retoucher. When a retoucher preserved multiple use areas, the bone was reoriented to bring the use area to the apical position and the edges were re-designated.

To mark the exact location of the traces on the surface, we subdivided the surface of the tool into a grid, as proposed by Schwab (2002); rows were marked alphabetically and the columns numerically. For measurement of the use areas and their distances from the margins of the retoucher, the approach advocated by Giacobini and Patou-Mathis (2002) was implemented. This entailed measuring the distance from the tip of the apical edge of the retoucher to the tip of the top portion of the use area (Dp-e), the maximum length (Lpu) and width (lpu) of the use area, and computing the area (Spu = Lpu*lpu) of the used portion on the retoucher.

Table 2 Taxonomic identification of the bone blanks used as retouchers at Riparo Tagliente and Grotta della Ghiacciaia.

Taxa	Riparo Tagliente			Grotta della Ghiacciaia	
	Level 35	Level 36	Level 37	Unit 2	Unit 3
Rupicapra rupicapra	-	1	-	-	-
Capreolus capreolus	-	-	1	-	-
Cervus elaphus	2	3	2	1	1
Alces alces	-	2	1	-	-
Bos sp. / *Bison* sp.	-	-	3	1	-
Small-sized ungulate	-	2	-	-	-
Medium-sized ungulate	-	12	17	-	-
Large-sized ungulate	3	2	12	1	-
Total	5	22	36	3	1

With regards to codification of the morphology of the use areas, reference was made to the work of Mallye et al. (2012). The use area was assigned a nearest approximate shape: triangular, square, short or long rectangle, circular, semi-circular, ovoid or elliptical. Use areas were further categorised into the following three types based on superposition of traces: "hatched areas" characterized by the overlapping of numerous scores on the surface; "pitted areas" with overlapping pits; and, "scaled areas" created by the superficial detachment of small bone plaques. The intensive use of a retoucher leads to overlapping traces.

The next procedure was the description of individual traces within the use area. Nomenclature was again borrowed from Mallye et al. (2012). Pits are defined as triangular or ovoid depressions in the bone. Scores are shallow or deep incisions produced by the edge of a stone flake; score morphology can vary between rectilinear and sinuous, and the interior surfaces of scores can be smooth or rough. Individual traces orientations were recorded using the codification scheme of Schwab (2002), with angles ranging from 0° to 180°.

Our protocol also included revised identifications of bone surface modifications present on the retouchers, such as trampling marks and cut marks related to skinning and defleshing. The alphabetical and numerical grid used for pinpointing the exact location of use areas (Schwab, 2002) was once more adopted to locate the other traces. The methods adopted for orienting and describing the morphology of the other traces were the same as those adopted for use areas. For instance, linear surface modifications were described as oblique, longitudinal or transverse, while their arrangement with respect to each other was described as isolated, parallel, perpendicular, intersecting or chaotic. The retouchers were inspected for presence or absence of additional post-depositional traces such as weathering stages (Behrensmeyer, 1978), exfoliation, root etching, discolouration by oxides (manganese and iron), rounding, combustion and carnivore marks.

All retouchers were photographed at various magnifications. The traces were analysed and photographed using a Leica SD6 stereomicroscope with an integrated EC3 camera. The more interesting tools were subsequently examined under SEM.

Results

Riparo Tagliente

Retouchers from Riparo Tagliente demonstrate well-preserved bone surfaces. Weathering (medium to

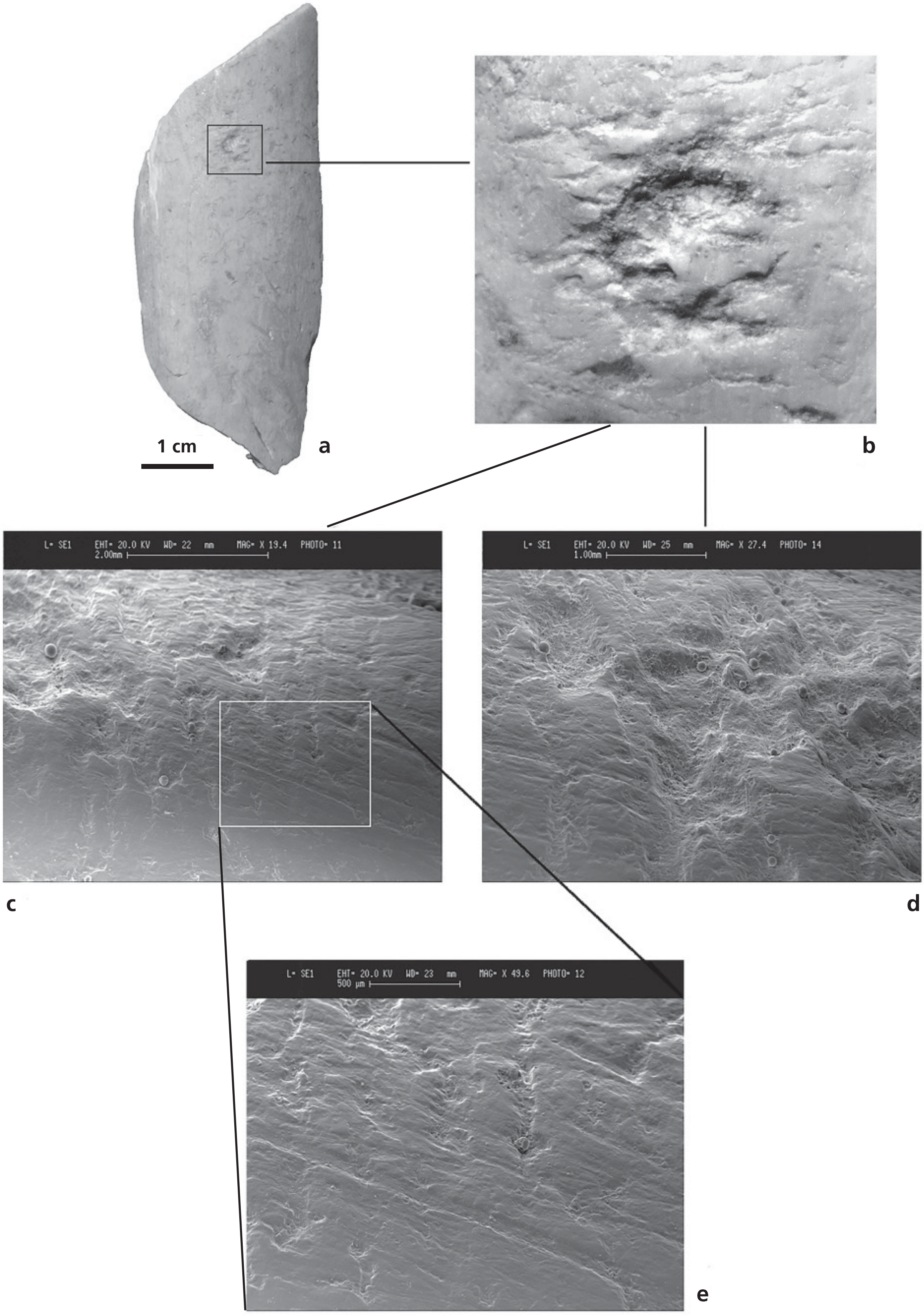

Figure 2 Diaphyseal fragment of a large-sized ungulate utilised as a retoucher from Riparo Tagliente.

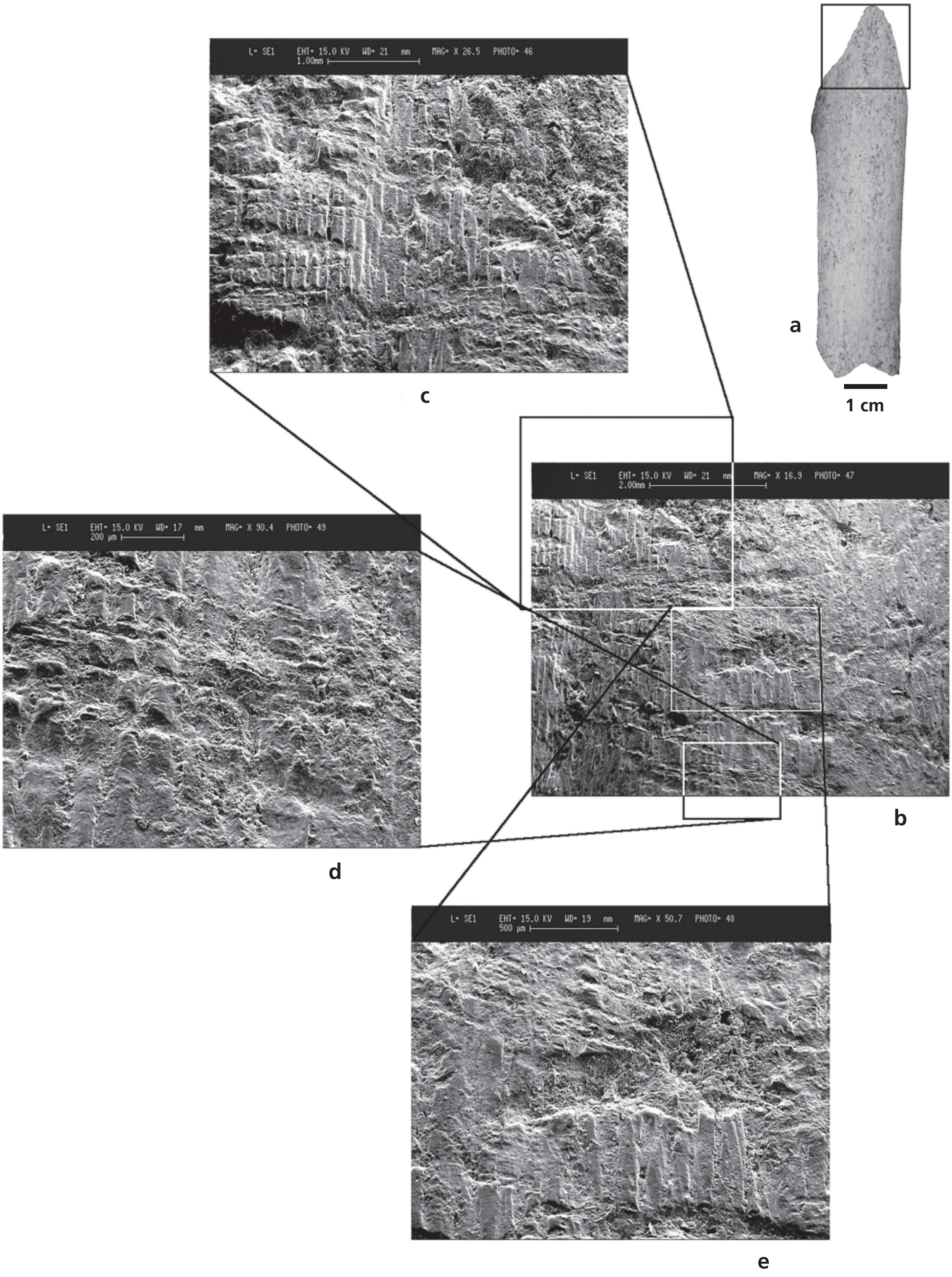

Figure 3 Retoucher on an indeterminate bone blank from Riparo Tagliente.

high degree) was one of the two chief alterations, observed on 44% of the retouchers. Weathering was associated with bones showing longitudinal fractures, which may have caused a general reduction in blank width. The second primary alteration was manganese oxide pigmentation, observed on 46% of retoucher surfaces. Exfoliation (5%) and root etching (5%) did not severely damage the bone surfaces.

The raw material for retouchers was obtained from red deer long bone diaphyses, followed in abundance by aurochs/bison and elk from layer 35 and 37 of Riparo Tagliente (**Figure 2**). Retouchers on chamois bones were present only in level 36. The use of small-sized animals such as roe deer and chamois was noticed in level 36 and 37 (**Table 2**).

In terms of anatomical part representation, long bones with flat surfaces, such as metapodial, tibia and numerous indeterminate limb shaft fragments (**Figure 3**), were preferred; less frequent were humerus, radius and femur (**Figure 4**). In level 37, two interesting exceptions were the exploitation of a first phalanx of roe deer (**Figure 5**) and rib of a large ungulate.

Analysis of diaphyseal fragments showed that complete and partially complete retouchers accounted for approximately 70-80% of the total, whereas the remaining 20-30% were fragmented and only preserved a fraction of their original morphology.

Roughly 70% of the bone retouchers have only one use area when all three levels are taken into consideration. Two use areas were documented on around 20% of retouchers, and only two examples from level 37 have three use areas. There is no association between the number of use areas and the length of the bone blanks. In fact, there are retouchers longer than 100 mm with just one use area. Many retouchers with two use areas are at least 50 mm long, but shorter than some retouchers with only one use area.

The ratio of length to width of the use area is homogenous in all the three levels of Riparo Tagliente. There is a clear increase in use area dimensions in levels 36 and 37 (**Figure 6**), which could be related to the débitage method utilized. This will be investigated in future studies.

There does seem to be a positive association between the use area dimensions and the length of

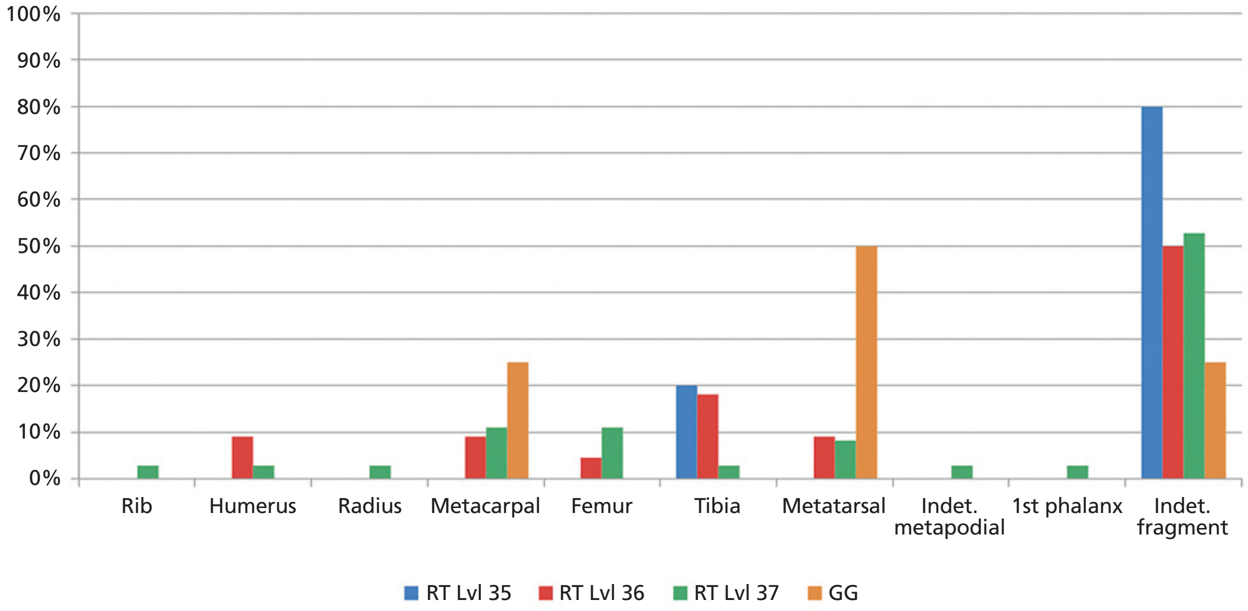

Figure 4 Percentage contribution of anatomical elements as raw material sources at Riparo Tagliente (RT) and Grotta della Ghiacciaia (GG).

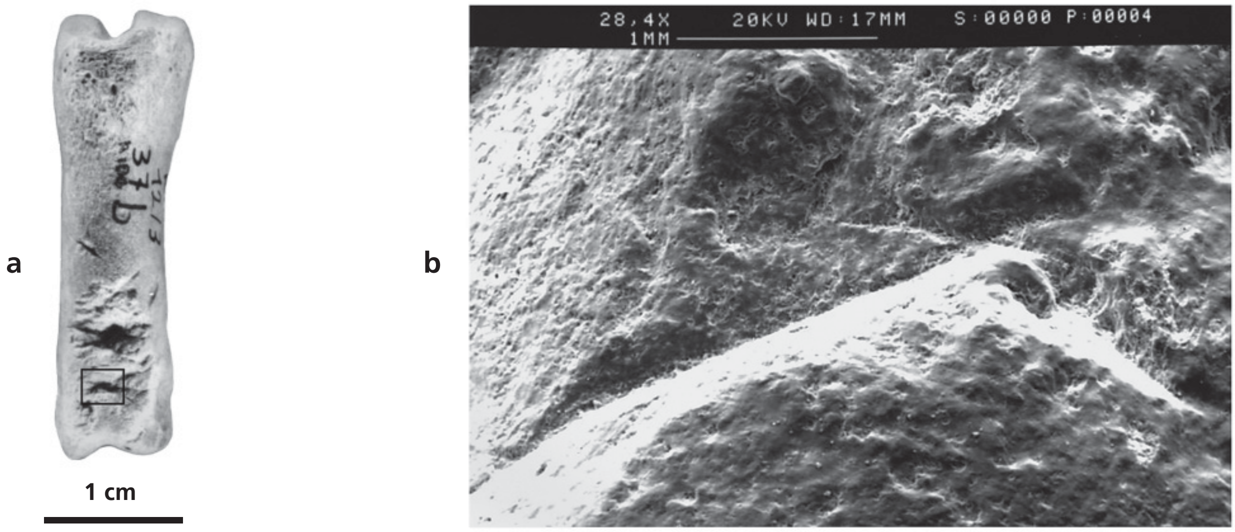

Figure 5 Retoucher on a roe deer *(Capreolus capreolus)* first phalanx from Riparo Tagliente.

the tool. This was observed mainly in level 37, due to the presence of long and intensively used retouchers from limb shafts of large-sized ungulate shafts, such as aurochs/bison and elk (**Figure 7**).

The Riparo Tagliente sample revealed diversity in use area shape. Morphologically, the most prevalent shape was rectangular, accounting for 44% and 54% in levels 36 and 37, respectively (**Figure 8**). In level 35, 40% of the use areas were circular; square, rectangular and oval/semi-circular contributed equally with 20% each. Trapezoidal use areas were recorded only in level 36 and accounted for only 4% of the use area shapes on retouchers in that level. Triangular use areas were absent in level 35, but made up roughly 15% of the total use areas in level 36 and 5% in level 37.

Linear scores associated with cupules were common, occurring together in 71% of retouchers in level 36 and in 61% in level 37. In level 35, 75% of the traces were linear scores with cupules, while the remaining 25% was a combination of linear scores, cupules and pits (**Figure 9**). This relationship may be explained by an intensive exploitation of the tools. Cases in which the traces were isolated or diffuse are rare.

Among retouchers, there were variations in the depths of the traces that could be associated with the state of the blanks, whether fresh or of intermediate freshness. Although it is difficult to quantify, Mallye et al. (2012) suggest that some traces are shallower on fresh bone than on bones of intermediate freshness. The traces observed on the retouchers from Riparo Tagliente were fairly deep, suggesting a preference for bones with an intermediary freshness for use as retouchers.

Linear scores were mostly oriented transversely (0°-30° and 150°-180°) with respect to the main axis of the tool, which indicates that there was a standard positioning of the bone retoucher with respect to the flint edge. This observation was better represented in retouchers from levels 35 and 37. Scores oriented parallel or sub-parallel (60°-90° and 90°-120°) to the main longitudinal axis of the tool were rare in all three levels (**Figure 10**).

To sum up, with respect to the characteristics of the use areas, the favoured blanks for retouchers at Riparo Tagliente were diaphysis fragments from medium- to large-sized ungulates of intermediate freshness.

Grotta della Ghiacciaia

The raw material for retouchers at Grotta della Ghiacciaia is similar to Riparo Tagliente: red deer and

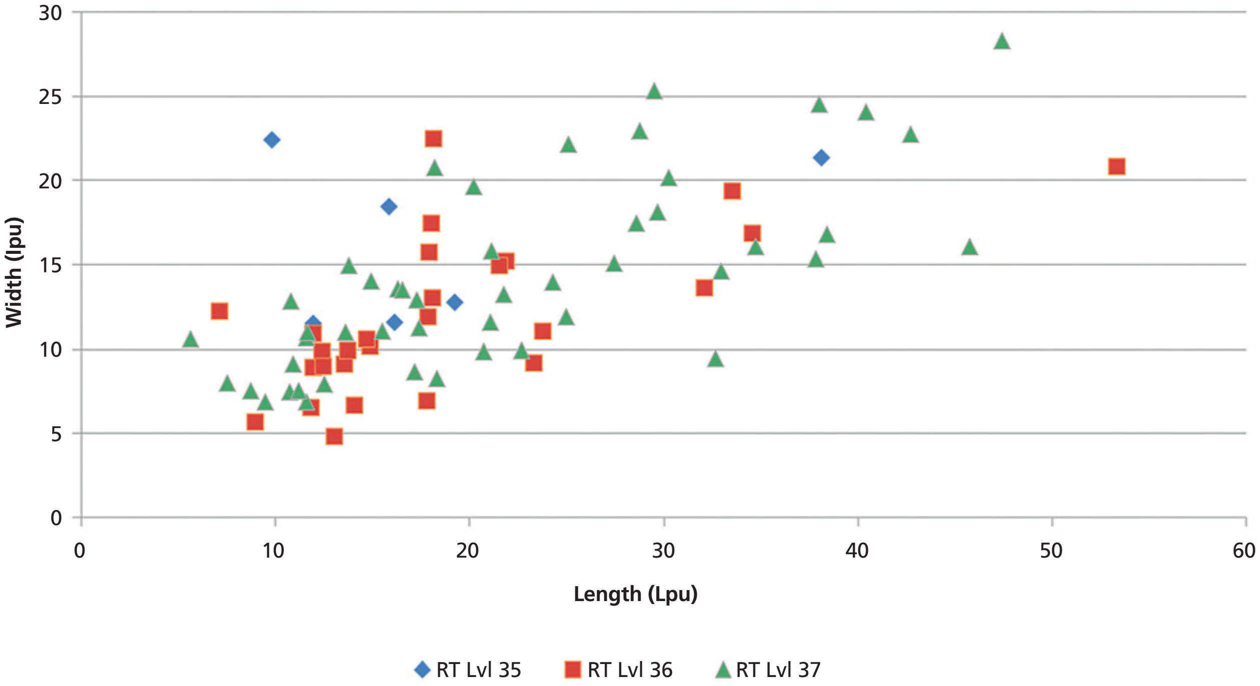

Figure 6 Ratio of length (Lpu) to width (lpu) of the use areas in the three levels at Riparo Tagliente (RT). Lpu and lpu are measured in mm.

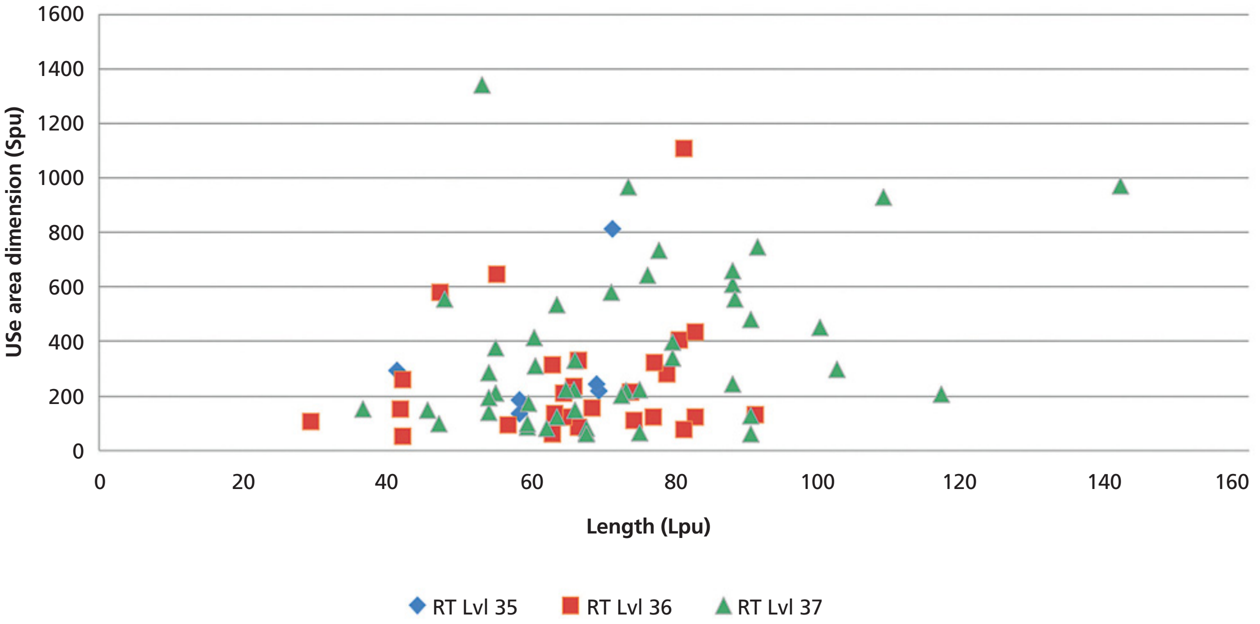

Figure 7 Ratio of the use areas dimensions (Spu) to length of the tool in the three levels at Riparo Tagliente (RT). Spu is measured in mm^2; length is measure in mm.

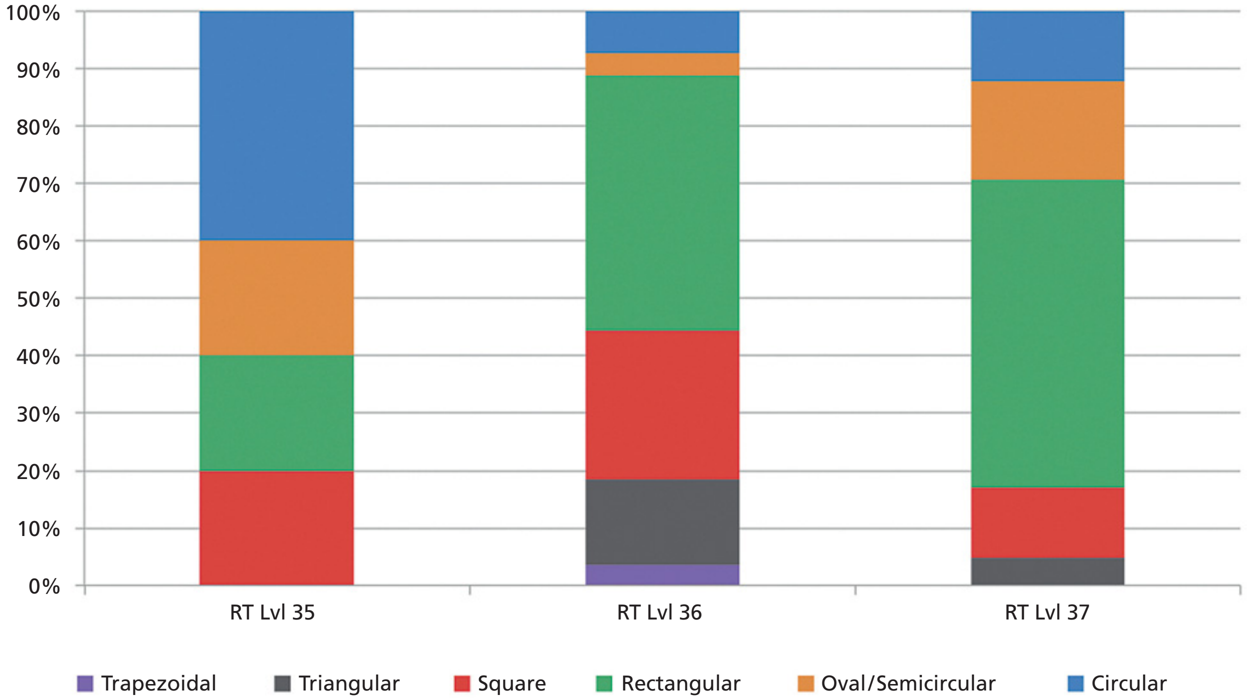

Figure 8 Percentage distribution of use area shapes on retouchers from Riparo Tagliente (RT). Total number of use areas = 74.

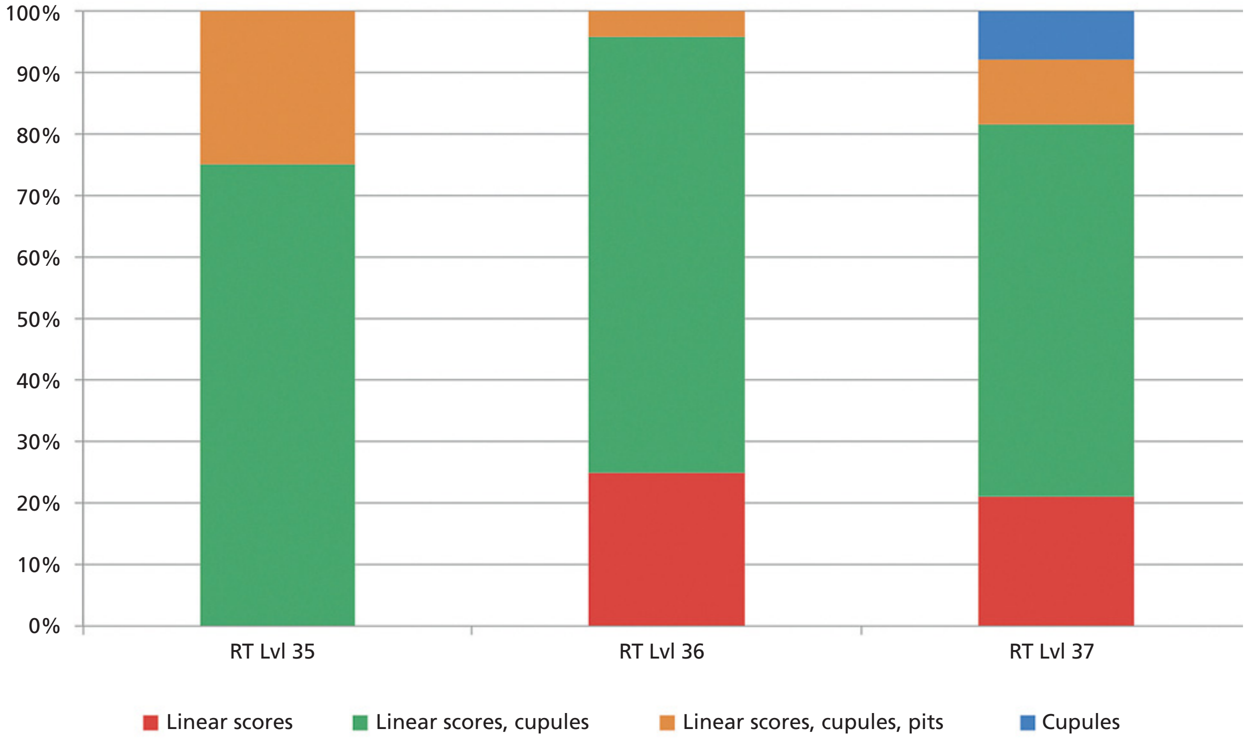

Figure 9 Percentage distribution of use trace types on retouchers from Riparo Tagliente (RT). Total number of use areas = 74.

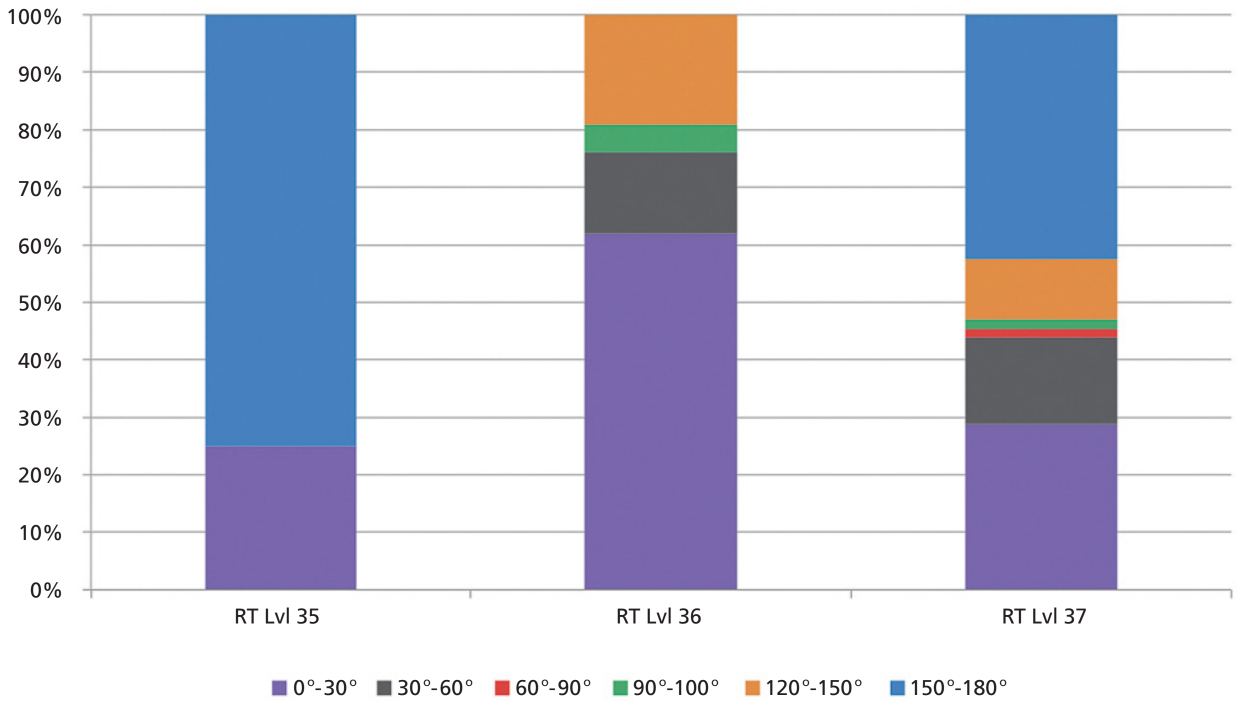

Figure 10 Percentage distribution of use trace orientations on retouchers from Riparo Tagliente (RT). Total number of use areas = 74.

aurochs/bison long bone diaphyses (**Table 2**). Two of the four retouchers were identified as red deer metapodia, the third is a metatarsal diaphysis of aurochs/bison, and the fourth is an unidentified diaphysis of large ungulate, likely aurochs or bison (see **Figure 4**; **Figure 11**).

All four retouchers were stained by manganese and iron oxides. The initial stages of weathering were seen on three of the four retouchers. The cortical surfaces on all four retouchers showed post-depositional trampling marks. These marks were mostly oriented obliquely to the main longitudinal axis of the bone and only a few were oriented transversely.

Out of the four retouchers, three had only one use area and the other had three use areas. Among the six total use areas, rectangular shapes were documented in two retouchers. Triangular, square, oval and circular use area shapes occurred only once each. Linear traces and cupules were observed together in two retouchers and separately in the other two retouchers. In three out of four retouchers, a majority of the linear traces were oriented transversely (0°-30° and 150°-180°) to the main longitudinal axis of the tool. On the contrary, cupules on one retoucher were found to be oriented parallel to the main longitudinal axis. Obliquely oriented traces were less common overall.

Conclusions

The analysis of retouchers from Grotta della Ghiacciaia provided only qualitative information whereas Riparo Tagliente yielded both qualitative and quantitative data. The heavily fragmented bone retouchers from Grotta della Ghiacciaia were found to be impacted by post-depositional processes. Bone blanks of intermediate freshness from large ungulates seem to have been the preferred raw material for utilisation as retouchers. Riparo Tagliente is the more significant sample analysed here. Blanks of intermediate freshness were most frequently utilised and the best-preserved specimens were also from large ungulates.

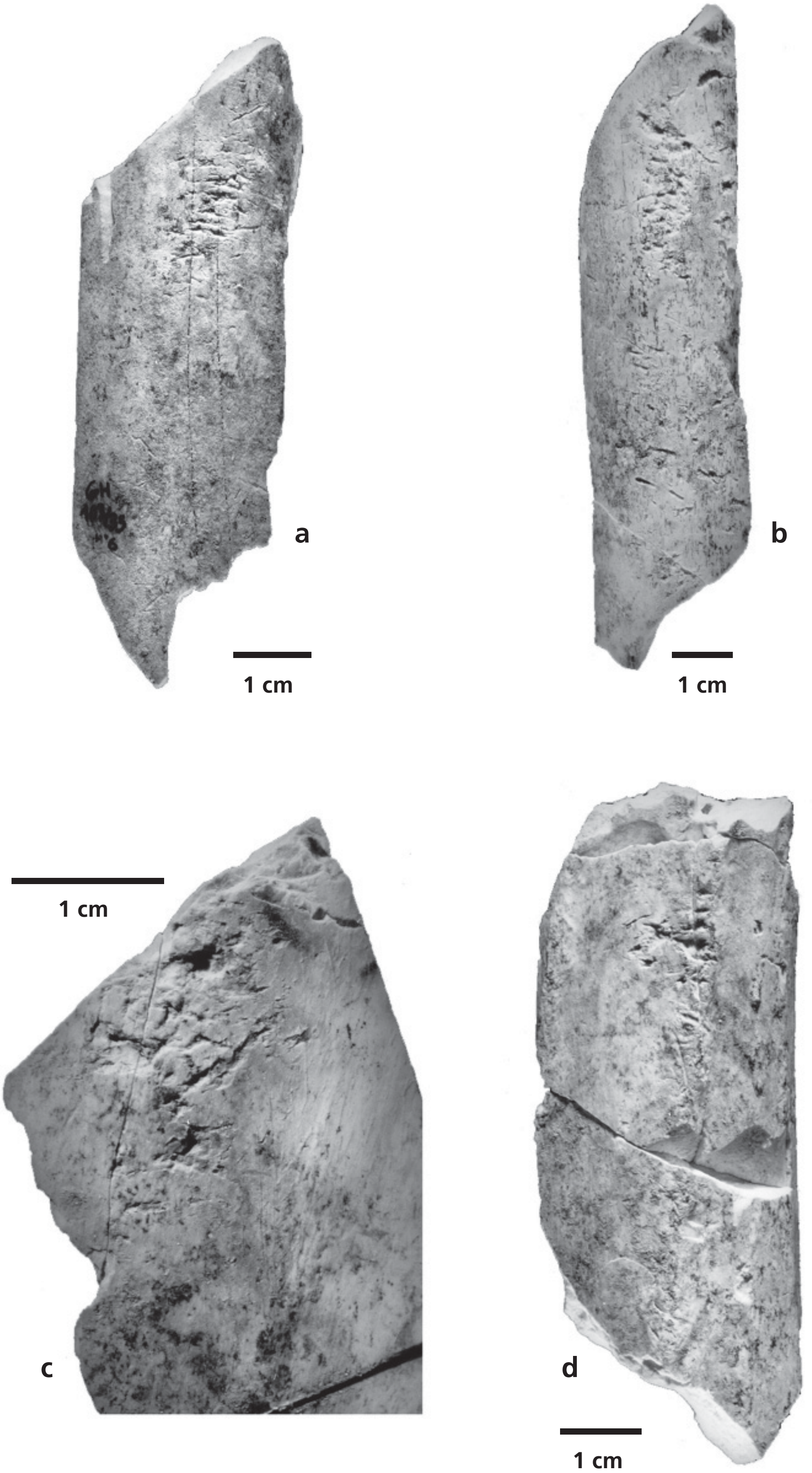

Figure 11 Retouchers on metapodial blanks (A, B), a large-sized ungulate diaphysis (C) and a tibia shaft (D) from Grotta della Ghiacciaia.

This was a preliminary study of retouchers from Riparo Tagliente and Grotta della Ghiacciaia. Future studies will address the completeness and original shape of the bone blanks, correlations between scraping marks and the use areas and the description of other traces and use areas in order to determine their relationship to knapping and/or butchery activities. These further studies, paired with an experimental programme, will clarify the association between bone retouchers and débitage methods at these sites and will aid in increasing our understanding of the use of bone retouchers in northern Italy during the Upper Pleistocene.

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MIDDLE AND UPPER PALAEOLITHIC BONE RETOUCHERS FROM THE SWABIAN JURA: RAW MATERIALS, CURATION AND USE

Abstract

The present paper examines Middle and Upper Palaeolithic retouchers recovered from various sites of the Swabian Jura located in the Ach, Lone and Lauchert river valleys of southwestern Germany. We provide an updated account of the available evidence including some of the finds retrieved over the last 50 years. Our study builds on the work of Wolfgang Taute, who in the 1960s compiled an extensive review on the retouchers of Central Europe from the Middle Palaeolithic to the Neolithic. Bone retouchers are the only organic tool that "survived" the transition from Neanderthals to modern humans in a nearly unchanged form. No other organic tool has had such a long tradition. The analysis of bone retouchers from Hohle Fels, Geißenklösterle, Sirgenstein, Vogelherd, and Schafstall I enables us to shed new light on raw material choices and on tool use across the Middle and Upper Palaeolithic.

Keywords

Organic retouchers; Middle and Upper Palaeolithic; Swabian Jura

Introduction

The Swabian Jura of southwestern Germany has a long tradition of archaeological research that extends back to the second half of the 19th century (Fraas, 1862, 1886). Many of the caves and rock shelters in Jurassic limestone that form the karstic landscape of the Swabian Jura contain evidence for human occupation during the Middle and Upper Palaeolithic. Among these, several sites located in two tributary valleys of the Danube, the Ach and Lone, have been the subjects of systematic and continuous studies over the past century (e.g., Schmidt, 1912; Riek, 1934, 1973; Hahn et al., 1973; Hahn, 1988, Conard and Bolus, 2003, 2008; Conard et al., 2015). Additionally, a number of less intensively investigated sites exist in the neighbouring river valleys, including Lauchert Valley, where archaeological work was carried out at the beginning of the last century (Peters, 1936).

Years of research and investigation have produced an extensive literature on the lithic and organic technology represented at the Swabian cave sites, including remarkable examples of portable art and ornamentation ascribed to the Aurignacian (Riek, 1932, 1954; Conard, 2003, 2009; Conard et al.,

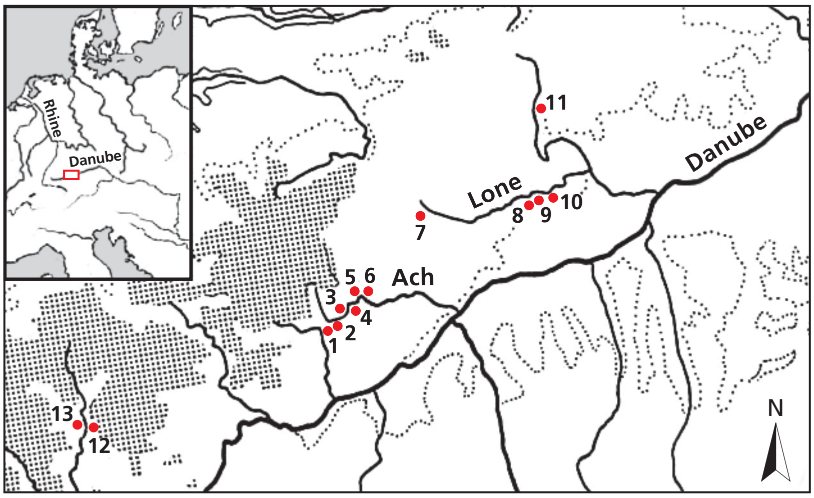

Figure 1 Map showing the main Middle and Upper Palaeolithic sites in the Swabian Jura. (1) Kogelstein, (2) Hohle Fels, (3) Sirgenstein, (4) Geißenklösterle, (5) Brillenhöhle, (6) Große Grotte, (7) Haldenstein, (8) Bockstein, (9) Hohlenstein, (10) Vogelherd, (11) Heidenschmiede, (12) Schafstall, (13) Göpfelsteinhöhle.

2004, 2009; Wolf, 2015). However, bone retouchers have often been dealt with only summarily. The first mention of retouchers in the archaeological record of the Swabian Jura was documented by Robert Rudolf Schmidt (1912), who referred to them as "compresseur". Later, Gustav Riek (1934) adopted the term "anvil" to describe three mammoth ivory fragments from Vogelherd that displayed a combination of percussion, hack and scratch marks. Around the same period, Eduard Peters (1936) published the discovery of various "auxiliary bone tools" from the Mousterian layers of Schafstall and Göpfelsteinhöhle. According to his interpretation, these tools were probably utilized for retouching stone artefacts. However, it was only with the work of Wolfgang Taute (1965) that the Swabian finds were grouped together into a specific tool class based on their functional use. In his study, Taute attempted to define a typological classification system for retouchers and summarized all the evidence available from European sites. Retouchers were subsequently recognized in a great number of assemblages, for example Vogelherd (Niven, 2006), Geißenklösterle (Hahn, 1988), Sirgenstein (Münzel and Conard, 2004) and Brillenhöhle (Riek, 1973; Barth, 2007); but, given their expedient nature, these tools were never studied in great detail. Hence, a growing need for a more comprehensive and exhaustive study has arisen. The present paper addresses this need through a detailed analysis of the retouchers recovered from the Swabian sites, with the objective of exploring inter- and intrasite variability, as well as diachronic shifts in technology.

Sites and archaeological context

The retouchers considered in this study come from five different sites distributed across several valleys: Hohle Fels, Geißenklösterle and Sirgenstein in the Ach Valley; Vogelherd in the Lone Valley; and Schafstall in the Lauchert Valley (**Figure 1**).

Sirgenstein was excavated in the early 20th century by Robert Rudolf Schmidt (1910, 1912), who uncovered a sequence of eight archeological layers ranging from the Mousterian to the Magdalenian. Four retouchers made of horse *(Equus* sp.*)* and giant deer *(Megaloceros giganteus)* bones (Münzel and Conard, 2004) were recovered from the bottom layer of the sequence (layer VII), which Schmidt assigned to the "Mousterian of La Quina type" or "Late Mousterian". Ernst Koken (1912) studied the faunal material from the lower layers. After re-examination by Münzel and Conard (2004), some of the species identified previously were not found; the updated faunal list now includes mammoth *(Mammuthus primigenius)*, horse *(Equus* sp.*)*, giant deer *(Megaloceros giganteus)*, reindeer *(Rangifer tarandus)*, aurochs or bison (*Bos* or *Bison)*, ibex *(Capra ibex)*, cave bear *(Ursus spelaeus)* and hare *(Lepus* sp.*)*. The cave bear was described by Koken as representing the predominant species in the lower horizons, suggesting that the cave was alternately occupied by humans and cave bears throughout the Middle Palaeolithic, though only 17 specimens were collected during the excavation. Koken also observed that most of the remains displayed fracture marks related to human activities. The lithic assemblage associated with the retouchers consists mostly of Levallois artefacts in local Jurassic chert (Çep, 1996). Münzel and Conard (2004) also restudied the retouchers (**Table 1**).

The site of Hohle Fels has been under investigation since the end of the 19th century (Fraas, 1872), yielding one of the most complete archaeological sequences of the Swabian Jura. Excavations started by Joachim Hahn (1977) exposed a succession of nine archaeological horizons spanning the Middle to Upper Palaeolithic. The retouchers analysed in this study were unearthed during the more recent campaigns directed by Nicholas J. Conard between 2001 and 2009 (Conard et al., 2001; Conard and Malina, 2006a, 2008, 2009, 2010) and come from the basal layers of the Aurignacian (Archaeological Horizons III to V), which are separated from the Middle Palaeolithic deposits by a sterile layer. The lithic assemblage of these layers is characterized mostly by pointed blades and nosed and laterally retouched end scrapers on local Jurassic chert (Conard and Bolus, 2006).

Geißenklösterle, located east of Hohle Fels, is another site that yielded important evidence attributed to the Mousterian, Aurignacian, Gravettian and Magdalenian. After the initial excavation directed by Eberhard Wagner in 1973, further fieldwork was carried out by Hahn (1988) between 1974 and 1992 and by Conard in 2001 and 2002 (Conard and Malina, 2002, 2003). The majority of retouchers discovered at this site come from the Aurignacian layers (Hahn, 1988), where bone and antler retouchers were found together with split based antler points. In contrast, few retouchers were recovered from the Gravettian layers (Barth, 2007).

Vogelherd is one of the most important sites of the Lone Valley, with an incredibly high density of finds from the Aurignacian period and a smaller number of Middle Palaeolithic and Magdalenian finds. It was excavated in 1931 by Gustav Riek (1934) with techniques common for that time; thus, the sediments were excavated with shovels and not screened. The excavators did not collect all finds, systematically discarding bone fragments less than 3 cm in length. Between 2005 and 2012, the University of Tübingen, under the direction of Conard, excavated the old backdirt sediments, retrieving a large number of finds, including some zoomorphic ivory figurines (Conard and Malina 2006b; Conard et al., 2007, 2010). Ulf Boger carried out the faunal analysis of the remains from the recent excavation and also noted the presence of retouchers within the assemblage (Boger et al., 2014). These, however, are not taken into account in the present study due to the absence of a secure archaeological context. The faunal material from the old excavations, studied by Lehmann (1954) was re-analyzed by Laura Niven (2006), who recorded the presence of a great number of retouchers from the Aurignacian horizons, layers IV and V. Horse and reindeer are the most abundant species within these levels and seem to have been hunted intensively by the Aurignacian groups. Humans played a major role in the accumulation of the assemblage in contrast to carnivores, which appear to have had a limited impact on the assemblage (Niven, 2006).

The site of Schafstall in the Lauchert Valley was excavated by Eduard Peters (1936) during the first half of the 19th century. The area of the excavation corresponding to Schafstall I yielded several Mousterian artefacts as well as the retouchers presented in this study, and was attributed by Peters to the Middle Palaeolithic. Little information is available for these sites, as Peters was unable to fully publish his work before the outbreak of World War II, when most of the finds and documentation went missing.

In addition, a few other sites yielded lower numbers of retouchers and are worth mentioning (**Table 1**). Brillenhöhle, in the Ach Valley, yielded one bone retoucher assigned to the Gravettian (Barth, 2007), and small collections of Middle Palaeolithic retouchers were found at Hohlenstein-Stadel in the Lone Valley and at Heidenschmiede in the Brenz Valley. Hohlenstein-Stadel yielded three bone retouchers

Table 1 Summary of organic retouchers found at different sites of the Swabian Jura during current and previous analyses. n.s. = not studied.

Site	Current analysis	Previous analyses	Reference
Sirgenstein	4	4	Schmidt, 1912; Münzel and Conard, 2004
Hohle Fels	8	4	Conard and Malina, 2008, 2010, 2015; Münzel, 2013
Geißenklösterle	24	10	Hahn, 1988
Vogelherd	36	161	Riek, 1934; Taute, 1965; Conard and Malina, 2006b; Niven, 2006; Conard et al., 2015
Schafstall	12	19	Peters, 1936
Brillenhöhle	n.s.	1	Barth, 2007
Heidenschmiede	n.s.	7	Peters, 1931; Münzel and Çep, 2017
Hohlenstein-Stadel	n.s.	3	Wetzel, 1961, 1969; Kitagawa, 2014

Table 2 Number and percentage of retouchers from each site with several types of anthropogenic modifications. Percentages are expressed out of the total number of retouchers per site.

Site	Percussion		Cut marks		Retouched edges		Scraping	
Schafstall I	2	16.7%	0	0%	3	25.0%	4	33.3%
Geißenklösterle	5	20.8%	4	16.7%	1	4.2%	13	54.2%
Vogelherd	6	16.7%	4	11.1%	2	5.6%	5	13.9%
Hohle Fels	1	12.5%	1	12.5%	0	0%	3	37.5%
Sirgenstein	1	25.0%	1	25.0%	1	25.0%	2	50.0%

obtained on large-sized mammal limb fragments (Wetzel, 1961, 1969; Kitagawa, 2014). At Heidenschmiede, seven bone retouchers made on elements of reindeer, aurochs or bison, an unidentified large mammal and a small ruminant were recovered; two were published by Peters (1931) and five were recently identified during the current revision of the faunal remains (Münzel and Çep, 2017).

Materials and methods

We analyzed 84 retouchers for this study: four from Sirgenstein, eight from Hohle Fels, 12 from Schafstall I, 24 from Geißenklösterle and 36 from Vogelherd. Some of the retouchers found at Schafstall are probably missing, as Peters (1936) originally identified 19. Since the faunal material of this site is currently under study, it cannot be excluded that more retouchers will be identified in the future. The number of retouchers from Vogelherd presented here constitutes only a minimal part of the large amount recorded by Niven (2006), which contains a total of 161 retouchers. The decision to include a smaller sample was dictated by the fact that most of the retouchers were recorded as questionably belonging to the Aurignacian layers IV and V defined by Riek (1934).

In our analysis of the retouchers, length and breadth of the bones were recorded in millimetres using digital calipers. We then noted the number of use areas with concentrations of retouch marks. The orientation of the marks and their localization followed Mallye et al. (2012). The retouchers were oriented with respect to their longest axis and the orientation of the marks was determined accordingly.

We examined the retouch marks with the aid of a 12x magnifying lens and a 10-20x stereo microscope. The terminology used for their description follows Mozota (2013, 2015, modified from Vincent, 1993): linear impressions, trihedral impressions and widespread chipping or scales. Linear impressions (*sensu* Mozota, 2013) are elongated and more or less straight marks, with V-shaped profiles, that are mostly found superimposed on one another. Impact marks in the form of pits were designated as trihedral impressions. Scales (*sensu* Mallye et al., 2012) are negative impressions left by the detachment of small plaques from the cortical surface of a bone fragment. We also paid attention to the orientation of marks, which could be transverse, parallel or oblique to the long axis of the bone. In the case of oblique marks, we made a distinction between diagonal marks inclined upwards to the right and upwards to the left, a feature which has also been observed in previous studies (Hahn, 1988; Malerba and Giacobini, 2002). The use areas were measured by taking the maximum length and breadth (in mm) only on retouchers that preserved a complete use area, that is, the use area was not broken or bisected.

Table 3 Number of bone retouchers and their respective taxon distributed by Archaeological Horizon (AH) for each site.

Site	MP	Aurig.	Grav.	Magd.
Geißenklösterle	AH IV-VIII	AH II-III	AH I	AH Io
Equus ferus		14	1	
Rangifer tarandus		3		
Capra ibex		1		
small ruminant		1		
Mammoth/*Coelodonta* size		3	1	
Hohle Fels	AH VI-IX	AH III-V	AH II b-e	AH I-II a
Ursus spelaeus		1		
Panthera leo spelaea		2		
Equus ferus		3		
Rangifer tarandus		1		
large carnivore		1		
Sirgenstein	AH VI-VII	AH III-V	AH II	AH I
Equus ferus	2			
Megaloceros giganteus	2			
Vogelherd	AH VI-VIII	AH IV-V		AH II-III
Ursus spelaeus		3		
Panthera leo spelaea		2		
Crocuta crocuta		1		
Mammuthus primigenius		3		
Equus ferus	2	11		
Rangifer tarandus		8		
Ibex/reindeer/red deer size		2		
Horse/bear size	2	2		
Schafstall I				
Bos/bison/giant deer size	10			
Horse/bear size	1			
unidentified	1			

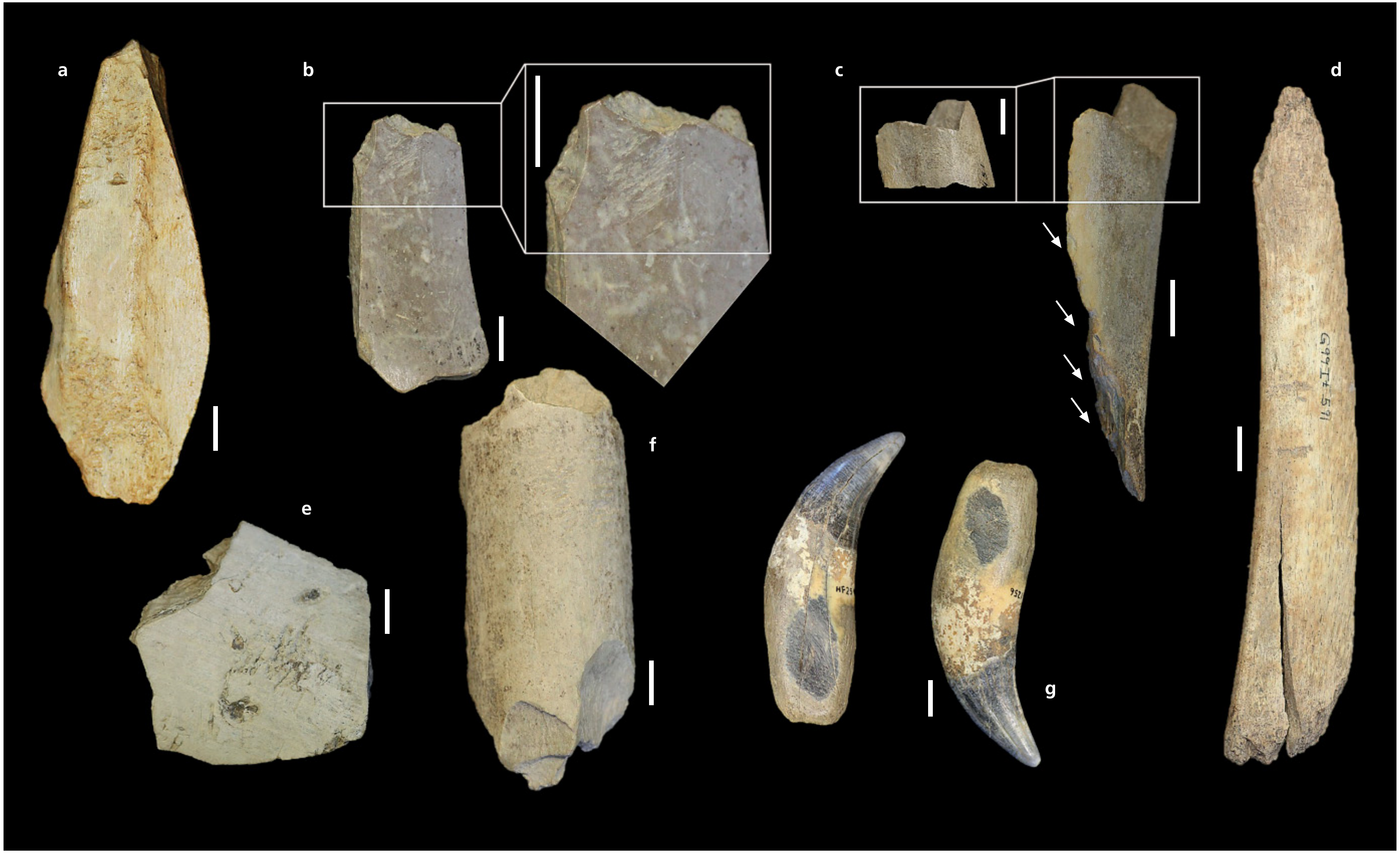

Figure 2 Organic retouchers from the Swabian Jura: a) giant deer tibia, Sirgenstein, Layer VII, Middle Palaeolithic; b) large ungulate long bone, Schafstall I, Middle Palaeolithic; c) horse tibia, Geißenklösterle, Layer IIb, Aurignacian; d) megaherbivore rib, Geißenklösterle, Layer It, Gravettian; e) mammoth ivory, Vogelherd, Layer V, Aurignacian; f) horse long bone, Layer VII, Vogelherd, Middle Palaeolithic; g) lion canine, Hohle Fels, Layer Vaa, Aurignacian. Scale = 1 cm.

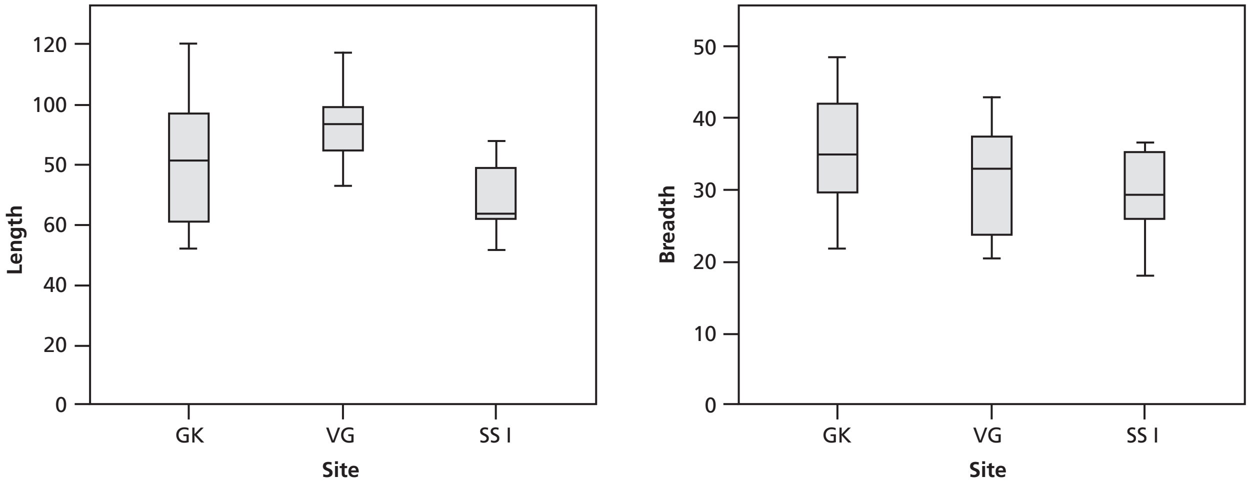

Figure 3 Length and breadth of retouchers made on long bone shafts. Samples from Hohle Fels and Sirgenstein are excluded from the count. Only elements with complete retouched areas are considered. Geißenklösterle = GK (n = 10), Schafstall I = SS I (n = 8) and Vogelherd = VG (n = 13). Measurements in mm.

Results

All the sites presented relatively good bone preservation, although some of the material from old excavations was affected by curation damage. Taphonomic observations on the retouchers show little evidence for bone weathering and no carnivore damage. The only modifications are related to anthropogenic activities. Cut and percussion marks (**Table 2**) typically associated with food consumption activities were distinguished from other types of marks, such as those produced by scraping, which are more likely linked to bone tool preparation.

Choice of raw material

Middle Palaeolithic bone retouchers are represented by a limited number of species. Horse and giant deer bone shafts were utilized at Sirgenstein. Four retouchers on horse/bear size long bones were found at Vogelherd, two of which have been identified as horse bone fragments (**Figure 2f**). At Schafstall I, almost all the retouchers on long bones belong either to a large bovid or to giant deer, even though horse bones dominate the faunal assemblage (**Table 3**; **Figure 2a, b**).

Aurignacian human groups appear to have utilized a broad array of animal resources and bone elements (see **Table 3**). Retouchers on horse long bones are dominant at Geißenklösterle, Hohle Fels and Vogelherd; furthermore, reindeer is the second most abundant species used for this purpose at Vogelherd. Mostly long bones, but also ribs, ivory, antler and carnivore teeth, were employed in knapping. At Geißenklösterle several bone remains of megafauna preserve retouch marks on their surfaces, while ivory retouchers are quite common at Vogelherd (**Figure 2e**). Though retouchers on carnivore remains are known from several Middle Palaeolithic (and earlier) localities across Europe (Auguste, 2002; Jéquier et al, 2012; Abrams et al., 2014; Serangeli et al. 2015), in the Swabian region they occur only in Aurignacian assemblages and are represented exclusively by canine teeth of cave bears, lions and spotted hyenas (**Figure 2g**). The Aurignacian retouchers are therefore characterized by a great variety of bone elements with preferential choice of long bone shafts.

As concerns retouchers on limb bone fragments, the length of the retouchers presents greater variation than the breadth (**Figure 3**). This is to be expected if there was no particular size preference, as complete limb bones are always significantly longer than they are wide. The retouchers of Geißenklösterle show the greatest spread of values in terms of length, while the long bone retouchers of Schafstall I are the shortest. Small and unequal sample sizes

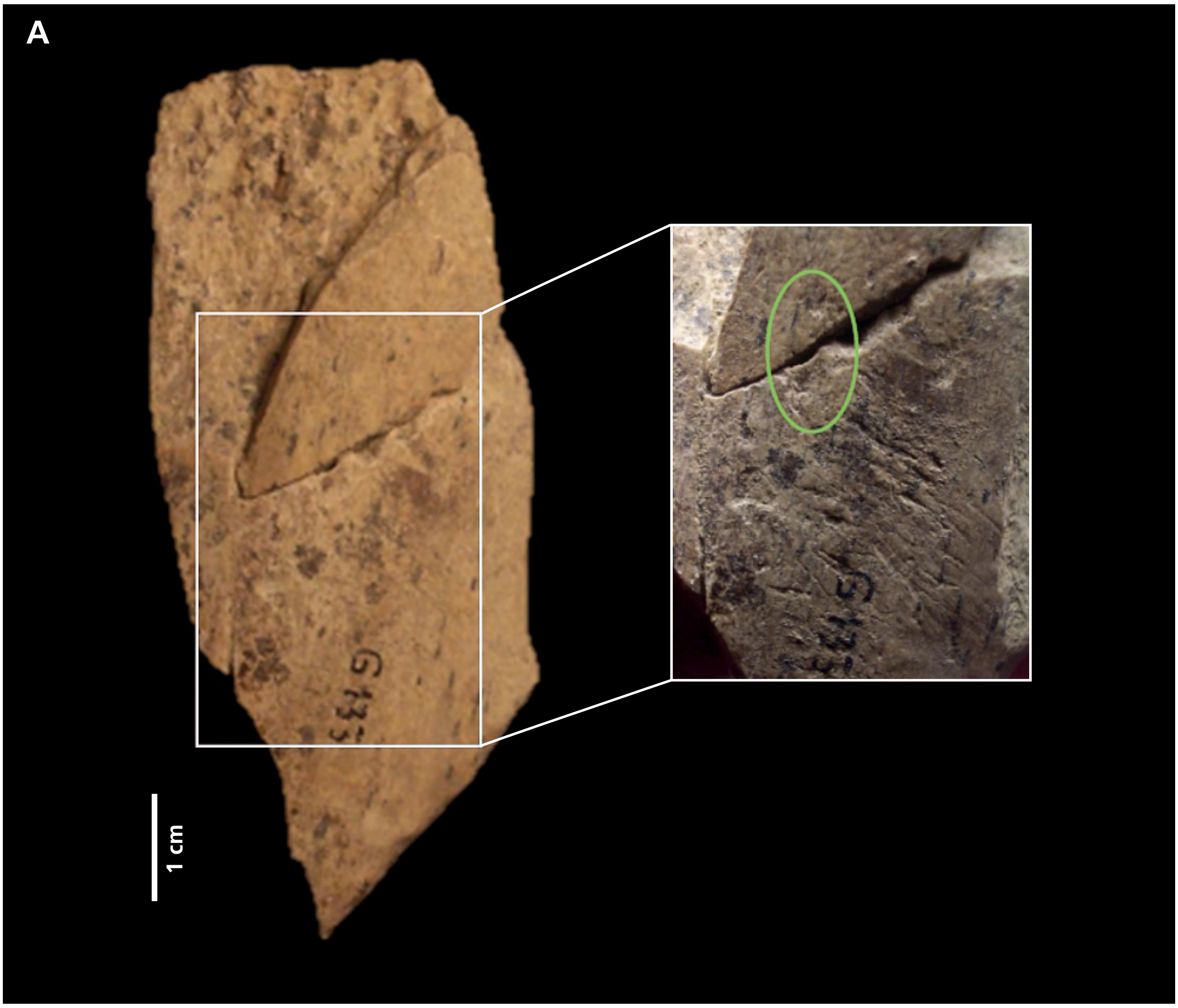

Figure 4 A) Geißenklösterle. Retoucher on a bone fragment that was subsequently splintered (Aurignacian); B) Vogelherd (next page). Retouch on worked antler base with perforation and mammoth relief (Aurignacian). Drawing by Achim Frey.

hindered statistical testing for size standardization across sites. Furthermore, it was not possible to compare retoucher size with general bone fragmentation for each site.

Especially concerning the Aurignacian retouchers, random selection of raw material seems to be supported by the variety of elements used, some of which are also expedient tools, such as bone blanks with splintered ends, similar to those described by Tartar (2012), and with retouched edges (**Figure 2c**). One specimen from Geißenklösterle with splintered ends bears retouch marks that were produced before the action that caused the splintering was performed (**Figure 4a**). These modifications were caused by two consecutive gestures that could have been part of the same *chaîne opératoire*. In this way, the bone blank was firstly used as a retoucher and secondly as a punch. Similar behaviour is also attested at Schafstall I, Sirgenstein and Vogelherd (**Figure 2f**) for the Middle Palaeolithic, where retouchers with modified edges, purportedly related to tool shaping or reduction of the bone blank, occur alongside unmodified bone fragments. Furthermore, in the Aurignacian assemblages, retouch marks also appear on very elaborate pieces. An extraordinary example (**Figure 4b**) is represented by a worked antler base from Vogelherd with the figure of a mammoth carved in half relief (Riek, 1934;

Hahn, 1986). This object also preserves a broken perforation, meaning that it served as a tool and was possibly worn as a pendant. Evidence like this suggests elaborate objects were used as retouchers in parallel with the exploitation of fragments discarded during food consumption.

Use areas and use marks

The number of areas affected by retouch marks varies from one to three (**Figure 5**). The majority of retouchers analyzed display only one use area. At Schafstall I this may be explained by the smaller size of the bone blanks, which corresponds to a smaller working area. Most of the retouchers from Hohle Fels and Sirgenstein exhibit two or three use areas. For Hohle Fels, this pattern can be partially explained by the small sample size and by the prevalence of carnivore canines exploited alternately on the buccal and lingual sides. At Vogelherd, the number of elements with one and two use areas does not differ much, and retouchers with three use areas are rare.

Retouch marks are very distinctive and could be recognized by the presence of linear and trihedral impressions, sometimes coupled with microstriations produced by the edge of the lithic tool impacting the bone surface. On a minority of specimens, these marks were less immediately observable and

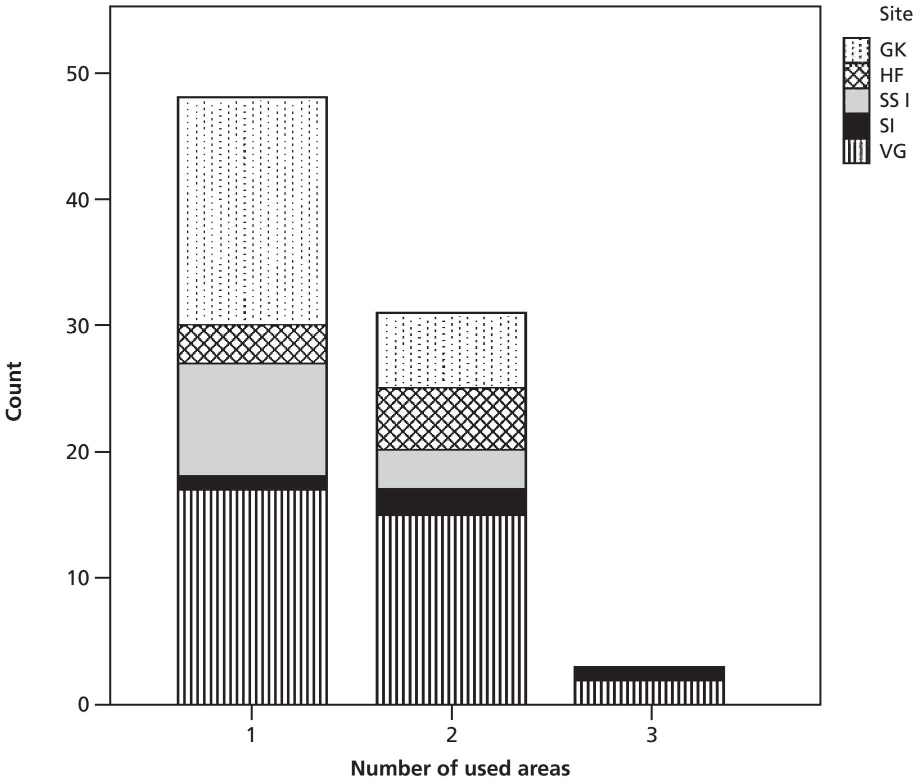

Figure 5 Number of use areas on each retoucher subdivided by site.

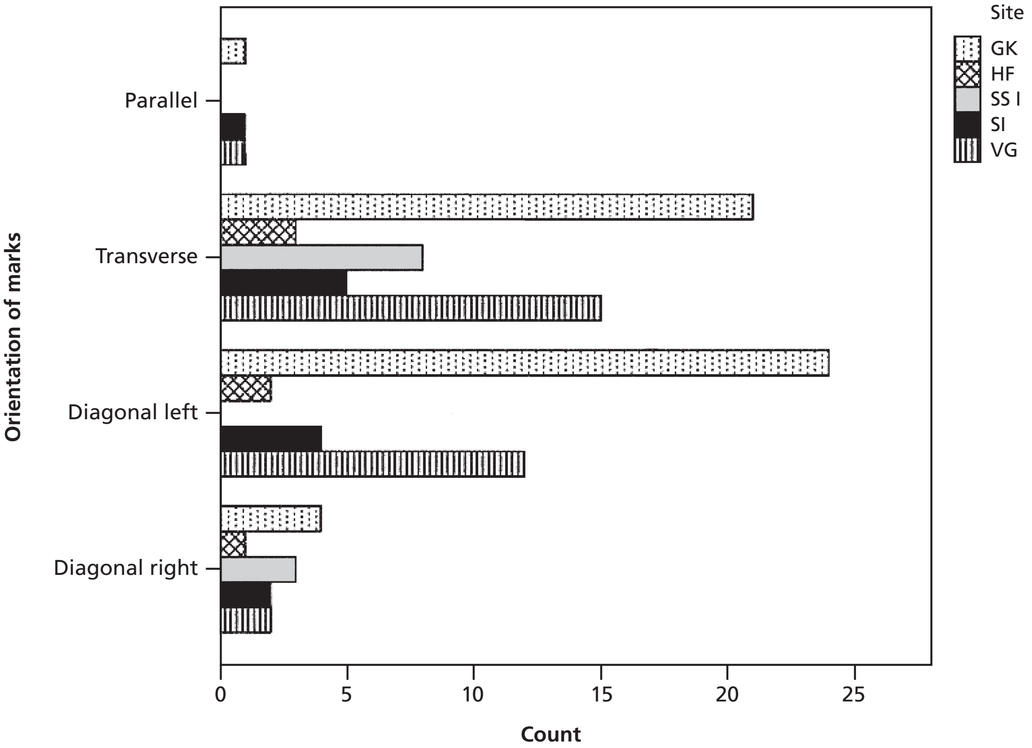

Figure 6 Frequency distribution of the orientation of retouch marks. All retouchers were considered.

were associated with scales. Experimental work carried out by Mallye et al. (2012) has shown that the occurrence of scaled areas while knapping is probably related to loss of bone freshness, thus indicating that bone elements were not always employed while fresh.

Scraping marks are often found underlying the retouched areas (see **Table 2**) and are easily identifiable, being generally long, parallel and extending beyond the use area. At Geißenklösterle, we recorded scraping marks on half of the sample. These appear more frequently on long bone retouchers and are likely related to the removal of the periosteum as a preparatory step of the working area in order to prevent the tool from slipping or rebounding (Vincent, 1993).

The orientation of the retouch marks in each assemblage is predominantly transverse and oblique, with marks inclined upwards to the left. This pattern is different at Schafstall I, where marks oriented obliquely are all inclined upwards to the right (**Figure 6**). More than one type of orientation often occurs in one use area. It has been suggested that the orientation of marks can be related to handedness (Hahn, 1988) rather than to the direction and method of use.

Comparison between samples of the length and breadth of the use areas shows that there is considerable overlap across the various assemblages, although the retouchers of Schafstall I stand out for having the smallest use areas (**Table 4**; **Figure 7**). This is likely related to the smaller size of the retouchers.

Table 4 Length and breadth of the use areas (= ua) for each site. Measurements in mm. Incomplete artefacts are excluded from the count. Number of retouchers with complete used areas per site: GK = 14 ; HF = 5; SI = 3, SS I = 8, VG = 23.

	Mean length	SD length	Mean breadth	SD breadth
GK	25.1	2.6	11.9	0.9
HF	35.4	6.9	20.8	3.0
SI	27.6	1.4	20.1	1.5
SS I	17.4	1.6	11.7	1.0
VG	29.4	2.6	16.3	1.4

Discussion

The scarcity of Middle Palaeolithic retouchers fits with the relatively low density of Mousterian finds from the Swabian sites. According to Conard et al. (2012), this reflects relatively low population densities and settlement intensity of Neanderthal groups in southwestern Germany. The beginning of the Upper Palaeolithic marks a change in this trend and is characterized by a higher find density. Indeed, the Aurignacian retouchers are the most numerous and include a broad range of species. Although the Gravettian and the Magdalenian are well represented at sites like Geißenklösterle, Hohle Fels and Brillenhöhle, only a limited number of organic retouchers were recovered from Gravettian contexts, while none were found in Magdalenian assemblages. The decline of organic retouchers may be related to an increased use of stone for retouching and sharpening the edges of lithic flakes, as Taute (1965) suggested. Moreover, Taute (1965) noted a significant decrease in organic retouchers accompanied by an increase in stone retouchers during the transition to the Mesolithic across the entire Western Palaeartic (**Figure 8**). This may reflect a shift in raw material choice that becomes apparent between the Aurignacian and the Gravettian with changes in weapon technology and ornamentation. Specifically, such changes are signaled by the disappearance of Aurignacian ivory points and their replacement with mammoth rib points during the Gravettian, and by the substitution of double perforated beads, a cultural indicator of the Aurignacian, with drop-shaped ivory beads and tooth pendants (see Barth et al., 2009; Wolf, 2015; Wolf et al., 2016; Münzel et al., 2017). In this respect, the abrupt decline of bone retouchers during the Gravettian could be interpreted as a behavioral change related to raw material choices and could have essentially represented a true cultural change. However, despite the scant evidence, organic percussors appear to have been still used during the Gravettian. In fact, as Moreau

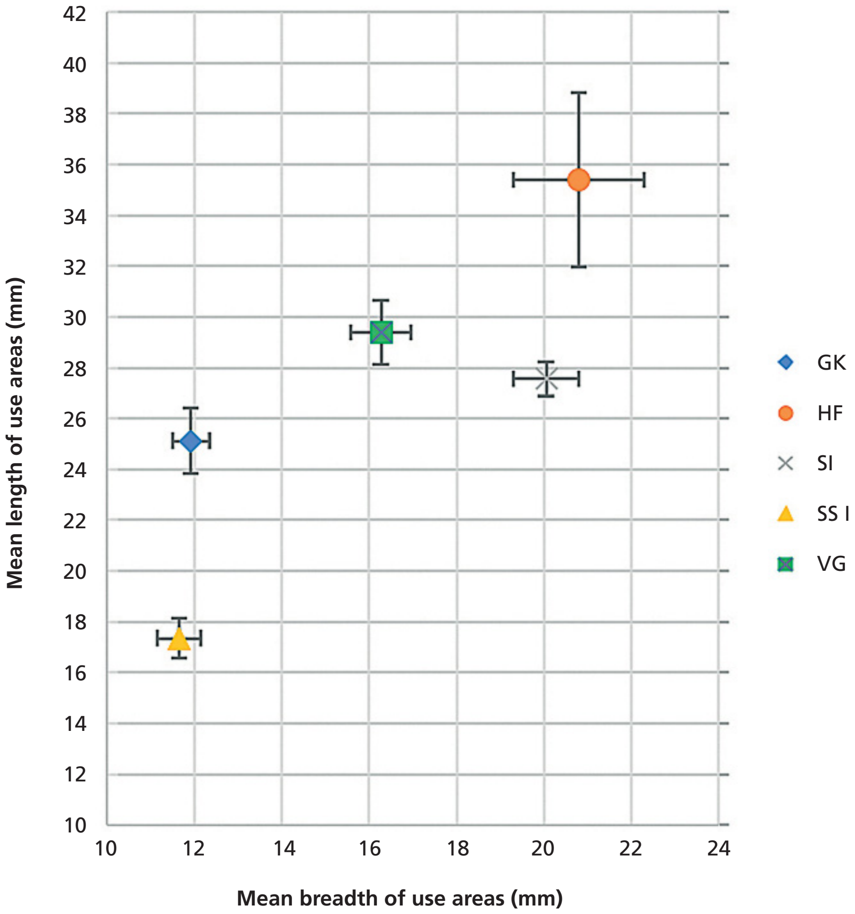

Figure 7 Mean length of use areas plotted against mean breadth of use areas. Number of complete undamaged use areas considered: GK = 18, HF = 8, SI = 7, SS I = 11, VG = 41. Error bars represent standard deviations given in Table 4.

(2009) suggested, there seems to be continuity in knapping techniques between the Aurignacian and the Gravettian. In his analysis of the Gravettian lithic industry of Geißenklösterle, Moreau (2009) was able to recognize, within one refitted nodule, the application of direct soft hammer percussion with organic and stone percussors. This led him to conclude that stone and organic hammers were both used and that only very fine lamellae were produced with stone percussors. There seems to be a discrepancy between the material evidence and the techniques applied; however, the markedly lower number of organic retouchers from Gravettian assemblages seems to fall in the same category of other important technological changes that could relate to a cultural shift in the choice of the raw material.

Consistent evidence for stone retouchers comes from the site of Brillenhöhle, where Riek (1973) reported the presence in the Gravettian and Magdalenian horizons of several retouchers, described as “Drücksteine” or "Retuscheure". With this term, Riek distinguished the small rounded pebbles used for pressure flaking from the much larger and elongated stone hammers used in percussion. This classification can be problematic, as the delineation between stone tools used by pressure or percussion is not always clear. Furthermore, some of the hammerstones described by Riek also exhibit retouch marks, meaning that they were used in different ways. The phallus-shaped siltstone retoucher from Hohle Fels is another example from the Gravettian, as it could have been used also as a hammerstone (Conard and Kieselbach, 2006).

As concerns the organic retouchers presented here, there seems to be no selection of raw material based on size, nor deliberate breakage aimed at retrieving elements of a predetermined size. However, it is reasonable to think that hominins would have preferred elements with morphological traits that facilitated handling. The Aurignacian retouchers, which constitute the bulk of the evidence, were not only made on discarded bone fragments, probably derived from food waste, but also on functional objects, such as decorated antler pendants and bone blanks that could have been used as punches and drills. Indeed, several bone retouchers display removal scars and splintered edges comparable to the type of marks found on worked and unworked osseous tools purportedly used as wedges and chisels, as described by Tartar (2012). Moreover, the occurrence of short, flat ivory fragments with retouch marks at Vogelherd and bone shafts with conspicuous grooves associated with retouch marks suggests that these tools also were used passively, possibly as anvils or chopping blocks. Experimental work conducted by Armand and Delagnes (1998) and Daujeard et al. (2014) has shown that violent percussion of lithic flakes against bone pieces used as anvils leaves marks comparable to those visible on the retouchers described above. It is therefore plausible that retouchers were used in various ways, although it remains difficult to differentiate percussion from pressure retouching and active from passive use. Generally speaking, the size of the use areas seems to depend on the dimensions and morphology of the bone fragment and on intensity of use; to some extent, intensity can be quantified by the number of use areas. This criterion does not account for intensively used retouchers with only one use area covering the whole or the majority of the bone surface (*sensu* Mallye et al., 2012). Retouchers with one use area covering the whole surface were recorded at Vogelherd, where about half of the analyzed sample presented two use areas, thus suggesting that at this site retouchers were exploited quite intensively. Though retouchers with two use areas are also frequent at Hohle Fels, such a pattern can be explained by the relatively high frequency of carnivore canines used on both sides and by the small sample size.

Researchers have occasionally regarded the orientation of retouch marks as an indicator of handedness (Semenov, 1964; Taute, 1965; Hahn, 1988; Uomini, 2011). Semenov's (1964) experimentation on pressure flaking with bone retouchers allowed him to establish the relation between lateralized

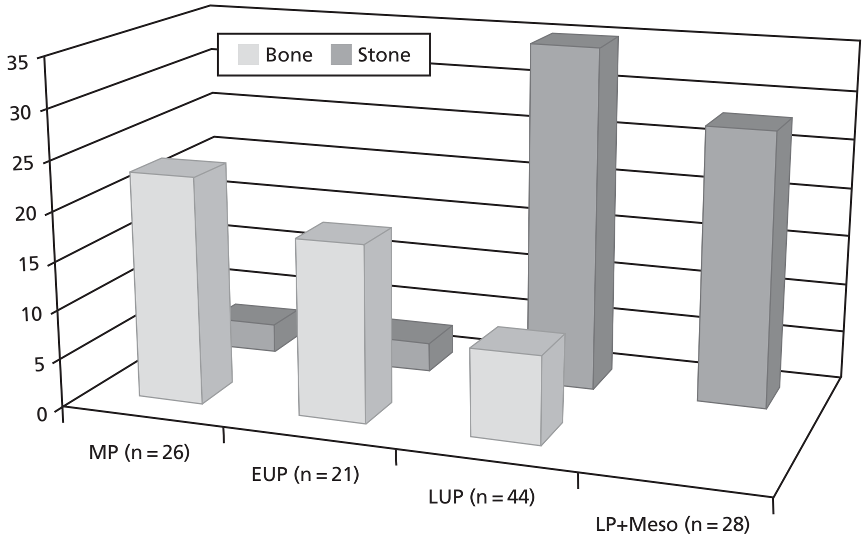

Figure 8 Comparison between bone and stone retoucher counts from Palaeolithic and Mesolithic sites in the Western Palaearctic listed by Taute (1965). MP = Middle Palaeolithic; EUP = Early Upper Palaeolithic; LUP = Late Upper Palaeolithic; LP + Meso = Late Palaeolithic and Mesolithic, as defined by Taute.

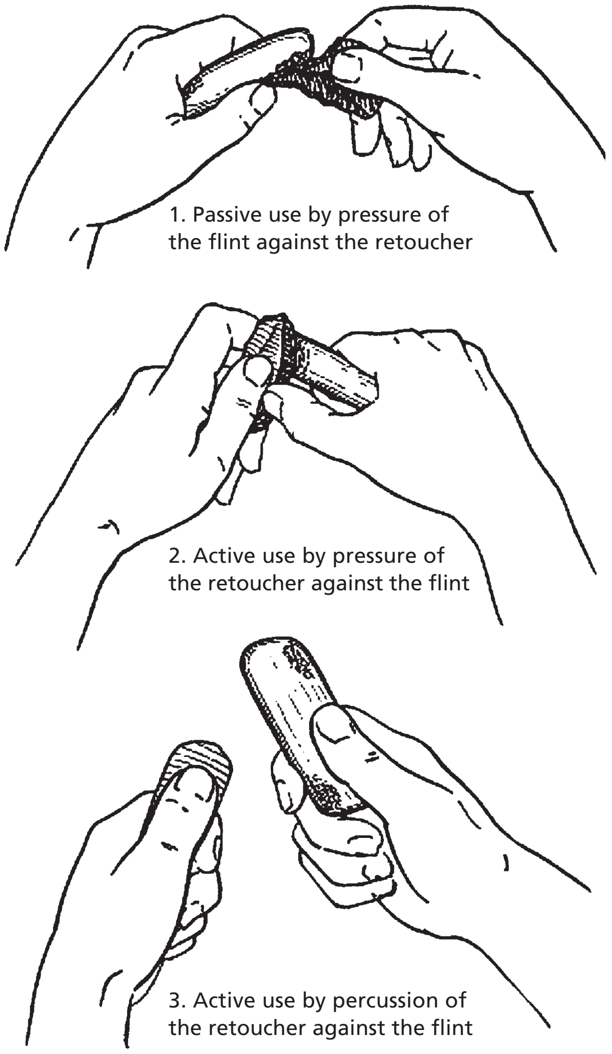

Figure 9 Passive and active uses of retouchers, modified from Taute (1965).

use wear and handedness. According to Semenov (1964), pressure flaking can be carried out by holding the bone retoucher and the flint at an angle of 75-85° and applying pressure on the bone against the flint. This configuration tends to produce a cluster of wear marks on the edge of the bone, which can then be re-used a second time by rotating it 180° around its long axis. If the bone retoucher is held in the right hand and the stone tool in the left, the marks will have an upper right to lower left orientation; held conversely, marks will be oriented in the opposite direction.

Most of the retouchers considered in this study exhibit transverse or diagonal marks with an upper left to lower right orientation; the Schafstall I retouchers have diagonal scars that are all oriented in the opposite direction. If only pressure flaking was used in retouching, then the majority of the retouchers would have been utilized by left-handed hominins. Based on these considerations, only at Schafstall I were the people (or person) exploiting such tools almost exclusively right-handed. This does not agree with other types of evidence indicating that Neanderthals and modern humans were primarily right-handed (Cornford, 1986; Bermúdez de Castro et al., 1988, Trinkhaus et al., 1994, Schmitt et al., 2003, Steele and Uomini, 2005; Uomini, 2011). It seems more likely that the orientation of use marks is also determined by the technique applied and by the active or passive use of the bone. An active use by percussion could perhaps produce marks that have an opposite orientation to those made by pressure flaking. In this respect, Taute (1965) distinguished four modalities: passive percussion and pressure of the stone tool against the bone retoucher, and active percussion and pressure of the bone retoucher against the stone tool (**Figure 9**). He suggested that the use of different retouching techniques influences the location of the retouch marks. Recent experimental work has explored this idea by looking at the relation between the location and types of marks and the different modalities of retouching with bone, also including retouch by counterblow (Karavanić and Šokec, 2003; Ahern et al., 2004; David and Pelegrin, 2009; Daujeard et al., 2014). The orientation of marks could perhaps be another interesting feature to take into account because it is intimately connected to the working angle, which depends not only on the shape of the stone tool being worked but also on the position of the retoucher with respect to the stone. These variables are ultimately associated with the technique applied.

Conclusions

Organic retouchers are a key component in the reconstruction of prehistoric technology. Their study goes hand in hand with that of lithic technology and contributes to our understanding of behaviour and culture among hominins. Our study of organic retouchers provides insight into technological choices adopted by Neanderthals and modern humans in the Swabian Jura. Despite differences in sample sizes and taxonomic representation between the Middle Palaeolithic and Aurignacian, the main trend in the use of osseous retouchers is their decline and eventual replacement by pebble retouchers during the Gravettian. While Middle Palaeolithic retouchers are made exclusively on bone fragments, likely to have been primary food waste, Aurignacian people exploited a broader range of elements, including carnivore canines, elaborated objects, like worked antler bases, and unmodified objects that could have served multiple functions. The morphological variety and different orientation of retouch marks suggest that retouching was carried out with various techniques and that retouchers could have been used not only actively, but also passively as anvils or by pressure flaking.

In contrast, little evidence of bone retouchers is available from Gravettian and Magdalenian contexts. As previously pointed out by Taute (1965), during the Gravettian and Magdalenian, stone retouchers become more frequent and could have played a more prominent role in working lithic artefacts. Changes in raw material use from the Aurignacian to the Gravettian have also been observed for other types of organic artefacts in the Swabian Jura, such as points and personal ornaments (Wolf et al. 2016; Münzel et al. 2017). The decline of organic retouchers during the Gravettian and Magdalenian may fall within the same realm of behavior. Nevertheless, further studies that integrate stone retouchers and lithic technology will prove useful in assessing the validity of this model.

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CAMILLE JÉQUIER · ALESSANDRA LIVRAGHI · MATTEO ROMANDINI · MARCO PERESANI

SAME BUT DIFFERENT: 20,000 YEARS OF BONE RETOUCHERS FROM NORTHERN ITALY. A DIACHRONOLOGIC APPROACH FROM NEANDERTHALS TO ANATOMICALLY MODERN HUMANS

Abstract

Bone retouchers are common in Middle and Upper Palaeolithic contexts. In northern Italy, these tools are abundant in final Mousterian sites. In order to pinpoint the possible cultural similarities or differences in the use of these artefacts, the present study analyses the bone retouchers of two nearby sites: Fumane and de Nadale caves. Fumane cave is a large cavity where various techno-complexes have been identified. For the purposes of this research, we analysed more than 300 pieces from the Discoid, Levallois, Uluzzian and Proto-Aurignacian layers. De Nadale cave is a single occupation site attributed to the Quina Mousterian. This site, although still under excavation, includes a high number of bone retouchers – about 200 elements have so far been identified. These elements were subjected to a multidisciplinary study, dealing with their archaeozoological, taphonomic, technological and functional characteristics. The faunal remains on which the retouch stigmata occur are similar, especially throughout the whole of the Fumane sequence, although the general faunal spectrum changes over time. Similarities are also found in the anatomical portions used as retouchers in the different techno-complexes under review. From a functional standpoint, the differences are more obvious. The intensity of use varies diachronically, as the number of identified stigmata changes from one techno-complex to the next. This contribution offers a wide overview of the cultural differences and similarities of this little elaborated tool from a chronological standpoint.

Keywords

Retouchers; Middle and Upper Palaeolithic; Northern Italy; Bone technology

Introduction

Bone retouchers have been sporadically identified in various archaeological assemblages, from the Lower Palaeolithic onwards (Blasco et al., 2013; Moigne et al., 2016; Serangeli et al., 2015; van Kolfschoten et al., 2015). They are more frequently recognised in archaeological sites related to the Middle Palaeolithic (Auguste, 2002; Mozota, 2007, 2009; Daujeard and Moncel, 2010; Jéquier et al., 2012, 2013; Mallye et al., 2012; Peresani et al., 2012; Daujeard et al., 2014) and the Upper Palaeolithic (Taute, 1965; Castel et al., 1998, 2003; Castel and Madelaine, 2006; Tartar, 2012a). Their eventual disap-

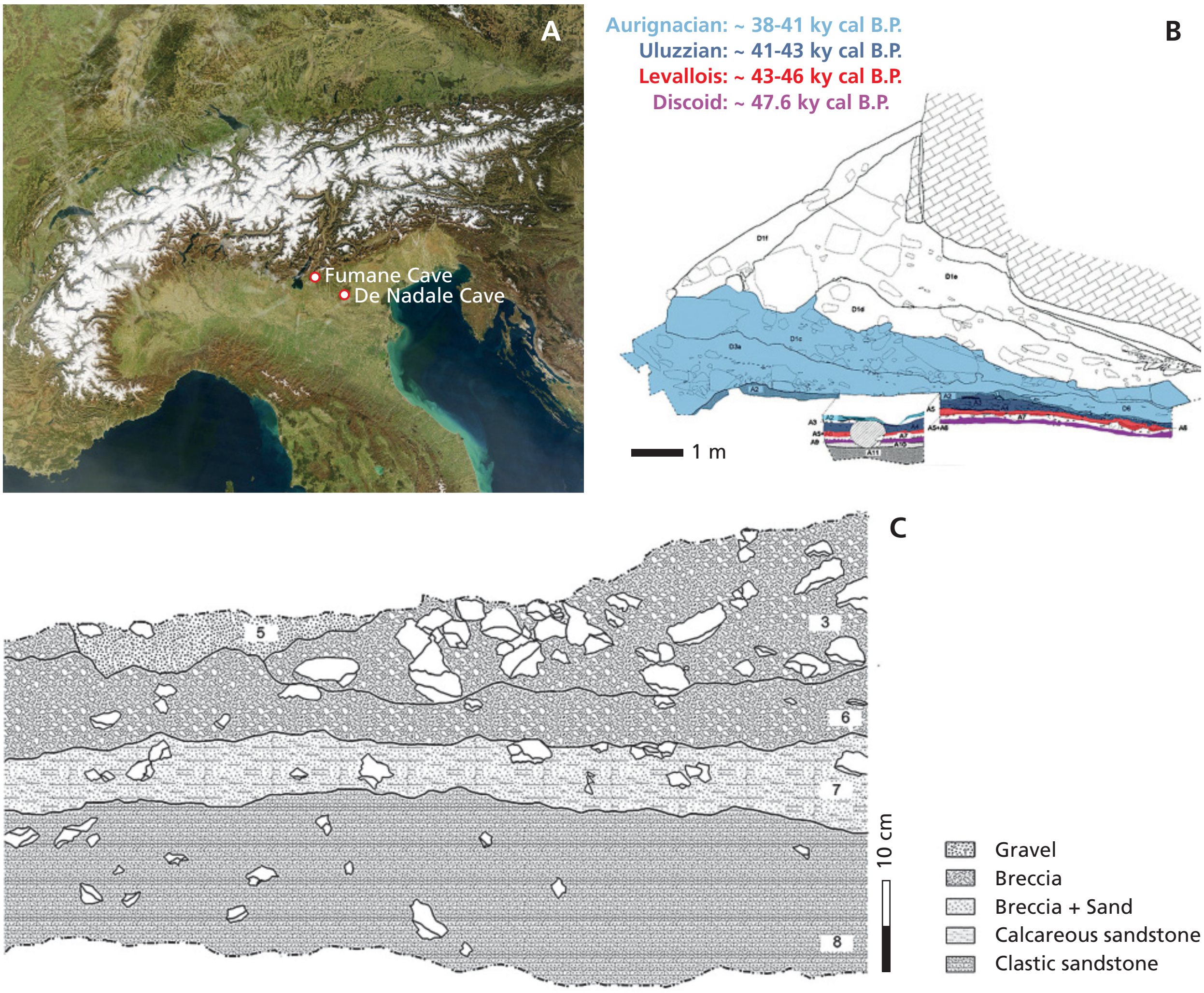


Figure 1 Geographical and stratigraphical context: a) position of Fumane and de Nadale caves in northeast Italy; b) stratigraphical context of Fumane cave; c) stratigraphical context of de Nadale cave.

pearance seems to coincide with the advent of the metal ages and the disuse of stone as a raw material to produce tools. From a geographical standpoint, and throughout this very long time span, retoucher assemblages are found in various contexts, from the Middle East to Russia (Filipov and Lioubine, 1993; Blasco et al., 2013), although Europe yields most of these finds (e.g., Taute, 1965; Patou-Mathis, 2002; Mallye et al., 2012; Daujeard et al., 2014), which is probably the result of bias related to research intensity.

These tools are mainly used during the final stages of the lithic *chaînes opératoires*, although some evidence suggests that during the beginning of the Upper Palaeolithic bone retouchers might have been used to detach bladelets from cores (Tartar, 2012b). Retouchers can be used through percussion or pressure (e.g., Bordes, 1961), although the former is more widely employed. Even though the different techniques can be difficult to extrapolate, Mozota (2013) demonstrated that "trihedral impressions", which we here refer to as punctiform impressions, were more often present when the bone shafts were used in pressure activities.

During the Lower and Middle Palaeolithic, bone is the osseous raw material almost exclusively used to retouch artefacts. From the Aurignacian *sensu lato* onwards, ivory and antler were used for the same purpose. Moreover, their symbolic value could vary with raw material. Castel et al. (2003) suggest ivory elements and ursid canines, in particular, could convey more significance than bone retouchers, as bone was more readily available among the food waste.

Although the available data on bone retouchers has exponentially increased during the last decade, quantitative and qualitative analyses from recently excavated sites and in the context of varied techno-complexes are still lacking. The current state of research is focused mainly on one techno-complex and does not evaluate bone retouchers in the context of large collections from different techno-complexes.

With this current research, we present the results of the study of several hundred bone retouchers from various techno-complexes at two archaeological sites in northern Italy: Fumane cave (Discoid, Levallois, Uluzzian and Aurignacian) and de Nadale cave (Quina) (**Figure 1a**). The main aim is to determine if discrepancies between the different techno-complexes can be identified from an archaeozoological or a technological standpoint. Moreover, the differences observed in the retouched lithic tools promote an interest in further investigating whether different types of retouch observed on the blanks induced different stigmata on the bone surfaces, possibly implying different uses for and management of these little elaborated tools.

Fumane cave

Fumane cave is located at the foot of the Lessini Mountains (see **Figure 1a**). The site represents one of the most important stratigraphic sequences of Mediterranean Europe, owing to its rich archaeological record and optimal preservation conditions. The sequence covers more than 80,000 years of hominin prehistory, from the Mousterian to the Last Glacial Maximum (Martini et al., 2001; Broglio et al., 2003; Fiore et al., 2004; Peresani et al., 2008; Higham et al., 2009). For the purposes of this research, we studied the bone retouchers from the Discoid (A9), Levallois (A5+A6 and A6), Uluzzian (A3-A4) and Proto-Aurignacian (A1-A2) levels (**Figure 1b**; Peresani, 1998; Broglio et al., 2005; Peresani et al., 2013; Tagliacozzo et al., 2013; Romandini et al., 2014; Peresani et al., 2016).

Through the sequence, a shift can be observed in the spectrum of animal species represented (Cassoli and Tagliacozzo, 1994; Fiore et al., 2004; Tagliacozzo et al., 2013; Romandini et al., 2014). During the late and final Mousterian, the main taxa represented are red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*), with a sporadic presence of giant deer (*Megaloceros giganteus*) and large bovids (*Bos/Bison* spp.). Starting from the Uluzzian, cervids decrease in favour of medium-sized bovids, mainly represented by ibex (*Capra ibex*). The same trend can be observed for chamois (*Rupicapra rupicapra*), which, although present during the Mousterian, clearly increases in the Aurignacian with the onset of a colder phase in the region leading up to the harsh conditions associated with Heinrich Event 4, as suggested by the oscillation recorded within the small mammal assemblages (López-García et al., 2015).

Although some rare carnivore gnawing marks are observed on the bone surfaces, anthropic activities are responsible for the faunal accumulation. Frequent impact notches, percussion cones as well as many striae attributed to the various phases of the butchery process have been identified in all layers considered. Moreover, burnt and calcinated bone fragments have also been recorded. The prominent anatomical elements represented are the hind and front limbs, especially diaphyses, although axial remains are also present (Cassoli and Tagliacozzo, 1994; Romandini et al., 2014).

The Discoid flint industry in layer A9 is typically represented by thick flakes, pseudo-Levallois points, backed flakes with a thin opposite edge, polygonal and triangular flakes, scrapers, points, and denticulates (Peresani, 2012). The lithic evidence of the A5-A6 stratigraphic complex shows close similarities with A11, A10V, and A10 based on the extensive use of a blade-focused, unipolar Levallois technology (Peresani, 2012). Levallois blades, blade-flakes and other by-products were shaped into simple or convergent scrapers and points. The Uluzzian in layer A3-A4 is a flake-dominated industry featuring Levallois technology in the initial phase (layer A4), but is replaced in A3 by more varied flaking procedures and light increase in bladelets and flake-blades. Sidescrapers, points, splintered pieces, backed knives and other items compose the tool-kit (Peresani et al., 2016). The Proto-Aurignacian lithic implements are blades, bladelets and microbladelets shaped into common tools like end-scrapers, burins and retouched blades, as well as points and Dufour bladelets using marginal abrupt retouch (Broglio et al., 2005).

De Nadale cave

The de Nadale cave is a small cavity located in the Berici Hills, in the province of Vicenza (see **Figure 1a**), whose excavation is still ongoing. Situated at 50 m ASL, the entrance faces south at the base of a small cliff. The first excavation was conducted in 2013 in order to remove a superficial disturbed layer (1Rim) off the excavation area. Since then, successive excavation campaigns have unearthed a single archaeological layer (Unit 7) containing a large amount of bone fragments and lithic implements (**Figure 1c**). The archaeological material is either very scant or altogether absent in the other layers, except Unit 6, where some archaeological remains were discovered in a channel dug by a fossorial animal. One date obtained on a *Megaloceros* molar attributes the formation of Unit 7 to 70 ± 1 ka minimum age, placing the occupation of the cave to at least the onset of MIS 4 (Jéquier et al., 2015).

Out of the 319 identified faunal elements in Units 6 and 7, the most frequent species is giant deer (*Megaloceros giganteus*), followed by red deer (*Cervus elaphus*) and large bovids (*Bos/Bison, Bison priscus* and *Bos* cf. *primigenius*). To a lesser extent, roe deer (*Capreolus capreolus*), chamois (*Rupicapra rupicapra*) and ibex (*Capra ibex*) have also been identified. Carnivores, in particular ursids, are sporadically present. The faunal association indicates a relatively open environment, characteristic of a cold-temperate climate with boreal forests and steppes.

The preservation of the faunal remains is excellent, except for the presence of natural alterations due to root dissolution, manganese oxide staining, concretions and rare corrosion notches. Superficial modifications attributed to rodents, carnivores and exfoliation are extremely rare. On the contrary, the proportion of burnt and calcinated fragments, as well as the frequency of anthropic modifications identified on the osseous surfaces, is high.

The lithic industry is technologically and typologically Quina, with cores, cortical and ordinary flakes, and several scrapers of different types made of non-local flint due to its absence in proximity of the site (Jéquier et al., 2015).

Materials and methods

Bone retouchers from Fumane and de Nadale caves were identified and registered during excavations or, in case of small bone fragments, were retrieved during sieving. The pertinent pieces were usually identified without the aid of a lens. However, in some cases, a Leica S6 D Greenough electronic microscope (magnification 6.3x-40x) was used to confirm and photograph the stigmata. In both sites, the excellent preservation conditions allowed for the conservation of the osseous surfaces. A few post-depositional modifications have been ascribed to concretions or manganese oxide staining, and rarely to root dissolution. Very few bone retouchers are burnt or calcinated, most of which are very small fragments.

Each retoucher has been determined taxonomically and anatomically with the reference collections present at the Section of Prehistoric and Anthropologic Sciences of the University of Ferrara and the National Museum of Prehistory and Ethnography "L. Pigorini" (Rome) by M. Romandini and A. Livraghi.

Since the pieces observed in other contemporaneous contexts have smaller dimensions than those under study here (Cassoli and Tagliacozzo, 1994; Tagliacozzo et al., 2013; Romandini et al., 2014; Livraghi, 2015), the authors include red deer (*Cervus elaphus*) in the large-sized ungulate category, along with giant deer (*Megaloceros giganteus*), bovid (*Bos/Bison*) and elk (*Alces alces*). Ibex (*Capra ibex*) was considered as a medium-sized animal, along with roe deer (*Capreolus capreolus*) and chamois

(*Rupicapra rupicapra*). When taxonomic attribution was not possible, the bone shaft was categorised by its thickness: large, medium-large, medium, medium-small and small sized.

At Fumane cave, a total of 363 retouchers were recovered from the four techno-complexes (**Table 1**). The Uluzzian retouchers are fewer in comparison with the other groups, probably due to the more sporadic visits to the cave during that period. The proportion of complete and fragmentary elements is similar throughout the sequence.

The de Nadale cave retoucher inventory currently contains 204 elements (see **Table 1**). This number is likely to increase as the excavations continue. Contrary to the Fumane cave, the proportion of fragmentary elements is much higher at de Nadale cave. A possible reason could be that the elements discovered until now are situated near the entrance of the cave and were subject to greater post-depositional perturbations. Since the cave is a single occupation site, we grouped the pieces from the reworked unit with those found *in situ*.

The maximum length, width and thickness (mm) and the weight (g) of the shafts were measured. The latter is only mentioned cursorily since post-depositional processes lead to weight loss; thus, the current weight does not correspond to the original weight of the retoucher.

We then proceeded to the analysis of the technological stigmata on the bone surface, counting each trace according to its category, describing the position of the area of occurrence, its orientation with respect to the longitudinal axis of the fragment, density of stigmata and the number of functional areas, including their surface areas in mm². For all data, we first performed descriptive statistics, including arithmetic mean, median and standard deviation. Next, we conducted a set of univariate and bivariate statistical analyses on the measurements, in particular the lengths-to-width ratios, using Microsoft Excel 2013 and Past 3.10 software. Since the data available for the Uluzzian layers only consisted of ten entries, we did not take them into account for the statistical analysis. We performed a Shapiro-Wilk normality test to ascertain the normal distribution of the data. The results demonstrate that our available data on the length-to-width ratios were not normally distributed. As a result, we performed a Kendall's tau correlation test on the lengths vs. widths and lengths vs. thicknesses of each complete retoucher, separated by techno-complex.

We also studied the type of fractures present on the bone shafts in order to determine whether the elements were obtained from fresh or dry bones (Villa and Mahieu, 1991; Outram, 2001; Wheatley, 2008). This analysis was useful to understand if the elements were to be considered as complete or fragmentary, and to determine, when possible, if the fractures were post-depositional or linked to deliberate retouch. Fragmentary elements were not included in the metric analyses. We identified a fragmentary element based on the presence of fresh fracture margins and/or where the fracture crosses one or more of the use areas.

The stigmata have been subdivided into four categories (**Figure 2**), partially following Mozota's classification (2007, 2009):

1) Punctiform impressions: sometimes referred to as "trihedral", these impressions are the most frequent stigmata in all techno-complexes;

Table 1 Inventory of complete and fragmented bone retouchers at Fumane and de Nadale caves.

	Fumane								de Nadale	
	Aurignacian		Uluzzian		Levallois		Discoid		Quina	
	NR	%	NR	%	NR	%	NR	%	NR	%
Complete	51	53.7	10	47.6	84	50.3	50	62.5	75	36.8
Fragment	44	46.3	11	52.4	83	49.7	30	37.5	129	63.2
Total	95	100	21	100	167	100	80	100	204	100

(NR = Number of Remains)

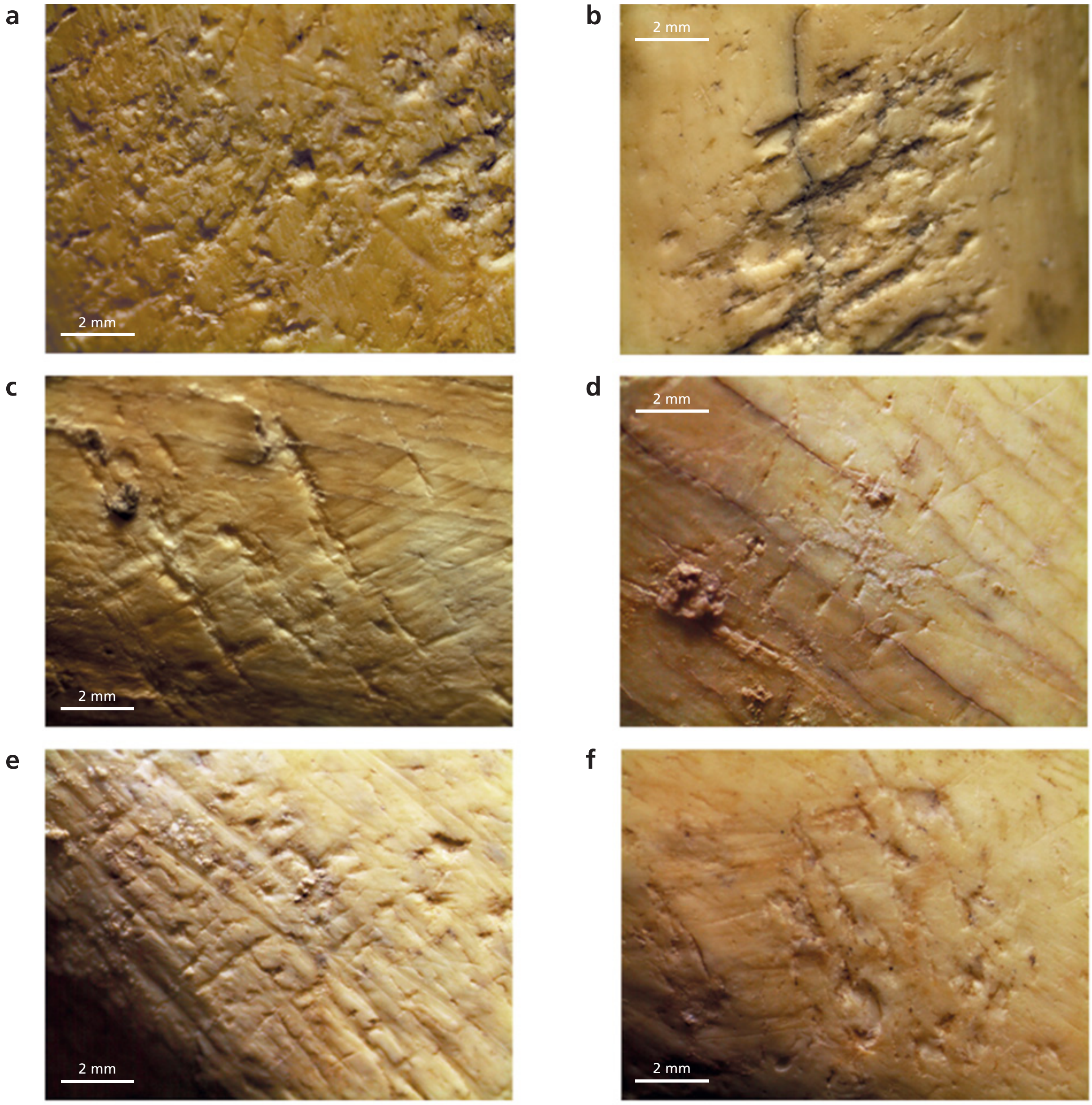


Figure 2 Types of stigmata: a) intersection between two use areas with punctiform and linear impressions vs. punctiform impressions; b) linear impressions and notch; c) linear impressions with scraping traces under the retouch-induced stigmata; d) linear impressions; e) linear and punctiform impressions; f) punctiform impressions and scraping.

2) Linear impressions: large and wide impressions, long and deep;
3) Retouch-induced striae: usually short, parallel, and shallower than linear impressions;
4) Notches: deep depressions due to repeated percussions on the bone surface. Features vary according to the freshness of the bone, force implied, the number of previous percussions, and the type of principal stigmata.

Results

Raw materials

Throughout the entire stratigraphic sequence at Fumane cave the edges of the osseous shafts used as retouchers show that their fracturing mostly occurred on fresh bones. This is demonstrated by the frequent occurrence of spiral fractures and smooth fracture margins (Villa and Mahieu, 1991; Outram, 2001; Wheatley, 2008), as well as by the recurrent presence of impact notches and negatives along the diaphyses. All the abovementioned fracture features are diagnostic elements for the recovery of bone marrow or other butchery processes.

For the Aurignacian at Fumane cave, out of the 51 complete elements, 22 bear traces of butchery, while two pieces have been successively used like a wedge, as some impact negatives attest (Tartar, 2012b). In the Uluzzian layers, out of the ten complete elements, only three bear clear signs of anthropic fracturing, while the retouchers assigned to Levallois context have fracture marks on 31 of the 84 complete elements. Finally, 34 of 50 complete pieces from Discoid context bear diagnostic fresh fractures. It should be noted that the incidence of butchery marks could be influenced by the degree to which some bones were used as retouchers, which could have led to overprinting of previous traces on the bone surfaces due to extensive use.

The faunal spectrum is fairly similar throughout the whole sequence: bones from *Cervus elaphus* are always, and by far, selected first, followed by *Megaloceros* (**Table 2**). Interestingly, the number of *Capra ibex* blanks used as retouchers in the Aurignacian layers is noticeably higher than in the Levallois techno-complex. In the Uluzzian and Discoid assemblages, no *Capra ibex* remains have been identified. The use of carnivore bones is rare, but is attested in the Levallois and Uluzzian layers.

Tibiae and femora are the most frequently selected anatomical portions (**Table 3**). Except for the Discoid layers, the proportions between these two elements are fairly similar. Aside from these elements, humeri and ulnae have often been selected. Retouchers on metapodials (both metacarpals and metatarsals) are also observed. Finally, one bear phalanx and a few mandible fragments were discovered in the Levallois (Jéquier et al., 2012, 2013) and Discoid layers. The absence of epiphyses, sometimes mentioned in other archaeological con-

Table 2 Faunal spectrum of the bone retouchers from Fumane and de Nadale caves.

	Fumane								de Nadale	
	Aurignacian		Uluzzian		Levallois		Discoid		Quina	
	NR	%	NR	%	NR	%	NR	%	NR	%
Ursus arctos	-	-	1	6.7	1	0.9	-	-	-	-
Ursus sp.	-	-	-	-	1	0.9	-	-	-	-
Carnivora	-	-	-	-	-	-	-	-	1	0.9
Cervus elaphus	43	55.1	10	66.7	73	68.2	33	62.3	26	24.3
Alces alces	-	-	-	-	-	-	1	1.9	1	0.9
Megaloceros giganteus	4	5.1	-	-	7	6.5	6	11.3	36	33.6
Capreolus capreolus	1	1.3	-	-	2	1.9	1	1.9	-	-
Cervidae, large	5	6.4	2	13.3	17	15.9	7	13.2	16	15.0
Cervidae, medium-large	-	-	1	6.7	1	0.9	-	-	-	-
Cervidae, medium	-	-	1	6.7	-	-	-	-	-	-
Bison priscus	-	-	-	-	-	-	2	3.8	5	4.7
Bos / Bison	7	9	-	-	1	0.9	-	-	21	19.6
Bovidae	1	1.3	-	-	-	-	-	-	-	-
Capra ibex	9	11.5	-	-	2	1.9	-	-	1	0.9
Rupicapra rupicapra	4	5.1	-	-	2	1.9	2	3.8	-	-
Caprinae	4	5.1	-	-	-	-	1	1.9	-	-
Total	78		15		107		53		107	

(NR = Number of Remains)

Table 3 Anatomical portions identified at Fumane and de Nadale caves.

	Fumane								de Nadale	
	Aurignacian		Uluzzian		Levallois		Discoid		Quina	
	NR	%	NR	%	NR	%	NR	%	NR	%
Antler	-	-	-	-	2	1.2	-	-	-	-
Horn core	-	-	-	-	-	-	-	-	1	0.5
Mandible	1	1.1	-	-	2	1.2	2	2.5	2	1.0
Scapula	1	1.1	-	-	-	-	-	-	1	0.5
Rib	3	3.2	1	4.8	3	1.8	-	-	3	1.5
Humerus	8	8.4	1	4.8	10	6.0	6	7.5	12	5.9
Ulna	8	8.4	1	4.8	12	7.2	7	8.8	16	7.8
Metacarpal	9	9.5	2	9.5	13	7.8	5	6.3	11	5.4
Phalanx	-	-	-	-	1	0.6	-	-	-	-
Pelvis	-	-	-	-	-	-	-	-	2	1.0
Femur	20	21.1	6	28.6	30	18.0	7	8.8	17	8.3
Tibia	16	16.8	3	14.3	39	23.4	17	21.3	37	18.1
Metatarsal	7	7.4	2	9.5	7	4.2	8	10.0	10	4.9
Metapodial	2	2.1	1	4.8	1	0.6	-	-	2	1.0
Indeterminate	20	21.1	4	19.0	47	28.1	28	35.0	90	44.1
Total	95		21		167		80		204	

(NR=Number of Remains)

texts – Mousterian (Auguste, 2002; Valensi, 2002; Abrams et al., 2014) or more ancient (Serangeli et al., 2015; van Kolfschoten et al., 2015) – can to a certain point be justified by the intense, intentional fragmentation of the faunal remains throughout the whole stratigraphic sequence. Moreover, these anatomical portions might have been used as fuel, as the burnt and calcinated part of the assemblage is rich in epiphyseal fragments (Romandini, 2012). Finally, at Fumane cave, these parts of bones were not selected for use as retouchers, as they do not fit the characteristics that the diaphysis offered, although, as previously stated, some sites do contain bone retouchers on epiphyses (Auguste, 2002; Abrams et al., 2014).

The number of fragmentary bone retouchers at de Nadale cave is much greater than at Fumane. Out of the 204 retouchers, 75 were considered complete; 60 of these bear traces of green bone fracture.

The faunal spectrum shows that the retouchers were mainly obtained from *Megaloceros giganteus* (33.6%) and *Cervus elaphus* (24.3%) bones (see **Table 2**). Bovids are also represented, in particular *Bison priscus* (4.7%). Medium-sized taxa are represented by only one fragment of ibex. A significant proportion (34.6%) of bone fragments could only be determined as ungulates. It was, however, possible to determine that they were mostly from large-sized animals. The taxonomic distribution of bones used as retouchers is proportional to that of the overall archaeozoological assemblage.

Diaphyses have been mainly selected. No epiphysis was identified as being used as a retoucher. The most frequent anatomical portion is the tibia (18.1%) (see **Table 3**). Femora (8.3%), ulnae (7.8%), humeri (5.9%), metacarpals (5.4%) and metatarsals (4.9%) have also been used, although to a lesser extent. Some other bone fragments have also been rarely used as retouchers: a scapula fragment, a possible horn core base and two pelvic fragments. Moreover, one of two mandible fragments was utilised with two teeth still embedded. As for the faunal spectrum, the number of undetermined elements is high (44.1%).

Table 4 Summary of descriptive statistics on retouchers from Fumane and de Nadale caves.

	Fumane			de Nadale
	Aurignacian	Levallois	Discoid	Quina
Length (mm)				
Mean	85.2	88.3	75.9	80.4
Stand. dev	19.6	21.8	19.6	19.3
Median	85	85.5	73.5	77
Width (mm)				
Mean	26.4	27.4	27.0	30.9
Stand. dev	8.8	6.0	6.5	7.5
Median	25	27	27	29
Thickness (mm)				
Mean	6.7	6.5	7.7	9.0
Stand. dev	2.3	2.0	2.4	2.8
Median	6	6	7	8

Table 5 Kendall's tau correlations between retoucher measurements at Fumane and de Nadale caves.

	Fumane			de Nadale
	Aurignacian	Levallois	Discoid	Quina
Length / Width	0.24882	0.19946	0.13583	0.24980
p	0.00997	0.00723	0.16396	0.00152
Length / Thickness	-0.02146	-0.04493	0.07456	0.12360
p	0.82410	0.54517	0.44486	0.11667

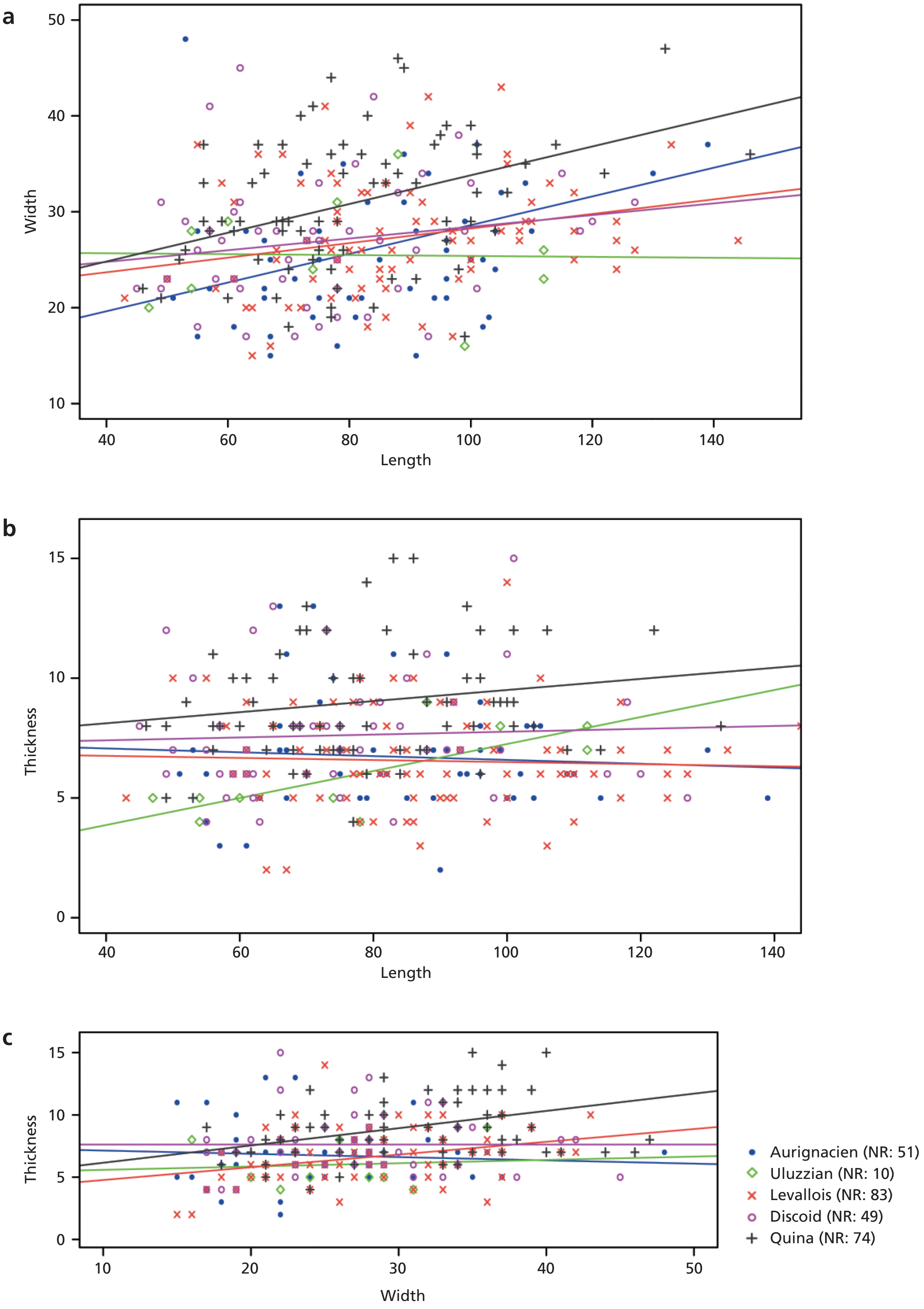
Metric data

The measurements of the complete retouchers vary appreciably throughout the whole sequence and within the techno-complexes at Fumane cave. However, the Levallois and Discoid retouchers show a remarkably similar correlation between their lengths and widths (**Figure 3a, Table 4**), meaning that the sizes are fairly similar between the two techno-complexes. The Aurignacian retouchers, however, are often longer than wide. Interestingly, the length-to-thickness (**Figure 3b, Table 4**) and width-to-thickness (**Figure 3c, Table 4**) ratios are fairly similar and show that the thickness of the bone retouchers does not dramatically vary according to their length or width. The importance of long, smooth retouchers was mentioned by Bourguignon (2001) for the organic retouchers used during the Quina retouch to enhance the knapper's precision.

Indeed, except for the Levallois techno-complex, where a correlation between the length-to-width ratio could not be made (**Table 5**), all techno-complexes show a very strong correlation between length and width of the shaft. The length-to-thickness ratio, cannot be correlated as such.

The general morphology of the bone retouchers is usually rectangular, elongated and flat. As far as weight is concerned, the Levallois elements are the heaviest, while the Aurignacian, Uluzzian and Discoid greatly overlap in weight (see **Figure 3d**). In all instances, however, most of the retouchers weigh between 10 and 20 grams.

At de Nadale cave, the retouchers are usually larger than those from Fumane cave; the shafts are longer, wider and thicker (see **Figure 3a-3c; Table 4**) than any of the techno-complexes present at Fumane. Moreover, the thickness of the elements is indicative of the fact that the fragments were derived from large-sized taxa, as they all exceed the mean thickness of the retouchers from Fumane. In contrast to the increase in size, the general morphology of the retouchers remains the same: they are typically rectangular in shape, longer than wide, possibly to allow for a good handle of the shaft. The length


a
Width
50
40
30
20
10
40
60
80
100
120
140
Length
b
Thickness
15
10
5
0
40
60
80
100
120
140
Length
c
Thickness
15
10
5
0
10
20
30
40
50
Width
● Aurignacien (NR: 51)
◇ Uluzzian (NR: 10)
× Levallois (NR: 83)
○ Discoid (NR: 49)
+ Quina (NR: 74)

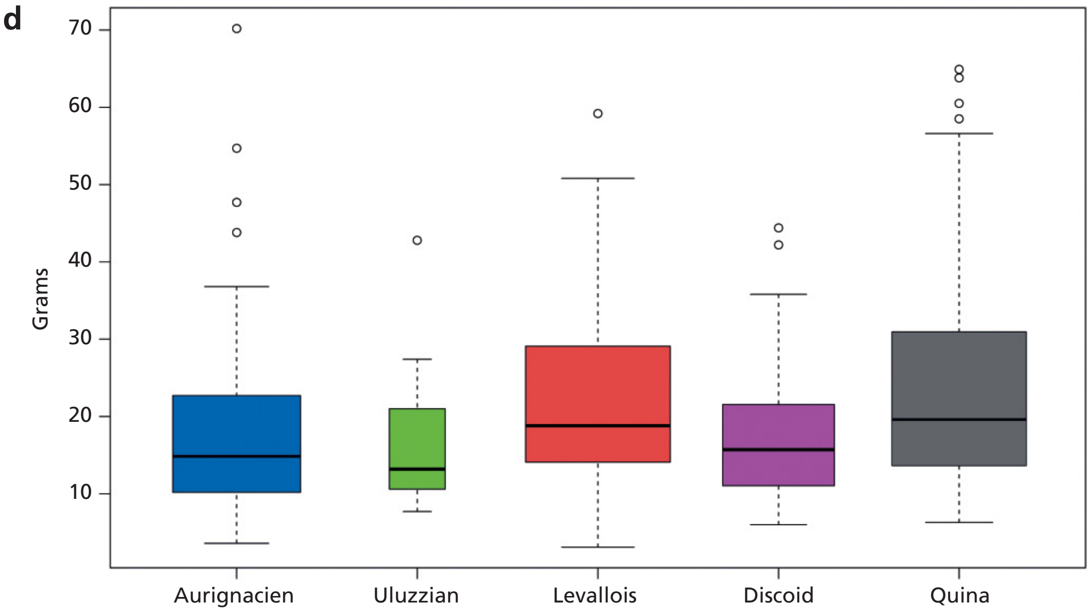


Figure 3 Metric data: a) length vs. width ratios; b) length vs. thickness ratios; c) width vs. thickness ratios; d) weight.

of the Quina bone retouchers is correlated to the width but not to thickness (see **Table 5**). In terms of weight, most of the retouchers weigh between 10 and 20 grams, although their range is large (see **Figure 3d**). The median weight (17 g) is similar to the Levallois retouchers from Fumane cave.

Functional areas and stigmata

Retouch-induced stigmata are usually grouped into small use areas. In all of the stratigraphic units at Fumane cave, the shafts have been used only once in more than 70% of the cases, with 72% for the Levallois, 76% for the Aurignacian and 86% in the Discoid layers. Some elements have up to three use areas. The Levallois layers contain more two-use area retouchers than the rest of the stratigraphic units, while the Aurignacian pieces have more of the three-use area retouchers. When two use areas are present, they are usually located on the two extremities of the bone shaft/fragment. In cases with three use areas, two often overlap, and can be separated by the different orientations of the stigmata or a distinction in the degree of use. It is interesting to note that in all cases, the second and/or third use area is always less intensively utilised than the first, i.e., there is always a "principal" use area and one or more "secondary" use areas (**Figure 4**).

All four stigmata categories are present on the Fumane cave retouchers: linear impressions, punctiform impressions, retouch-induced striae and notches. Punctiform impressions are predominant in all the techno-complexes, followed by linear impressions. Retouch-induced striae and notches (indicating intensively used areas) are rarely observed. In some cases, the stigmata seem to indicate that retouch activities were undertaken when the bones were semi-dry, as the observed stigmata are similar to those reported by Mallye et al. (2012).

The medium and medium-large-sized taxa show fewer stigmata than their large-sized counterparts in all techno-complexes, except for the Uluzzian, where no complete medium-sized elements were found. This has been observed for all four types of stigmata combined, as well as for each type individually.

The use areas of the Aurignacian and Discoid retouchers are reduced in comparison to those of the Levallois and Uluzzian (**Figure 5**). In particular, the use areas of the Discoid retouchers are smaller and are more homogenous. Their median use area

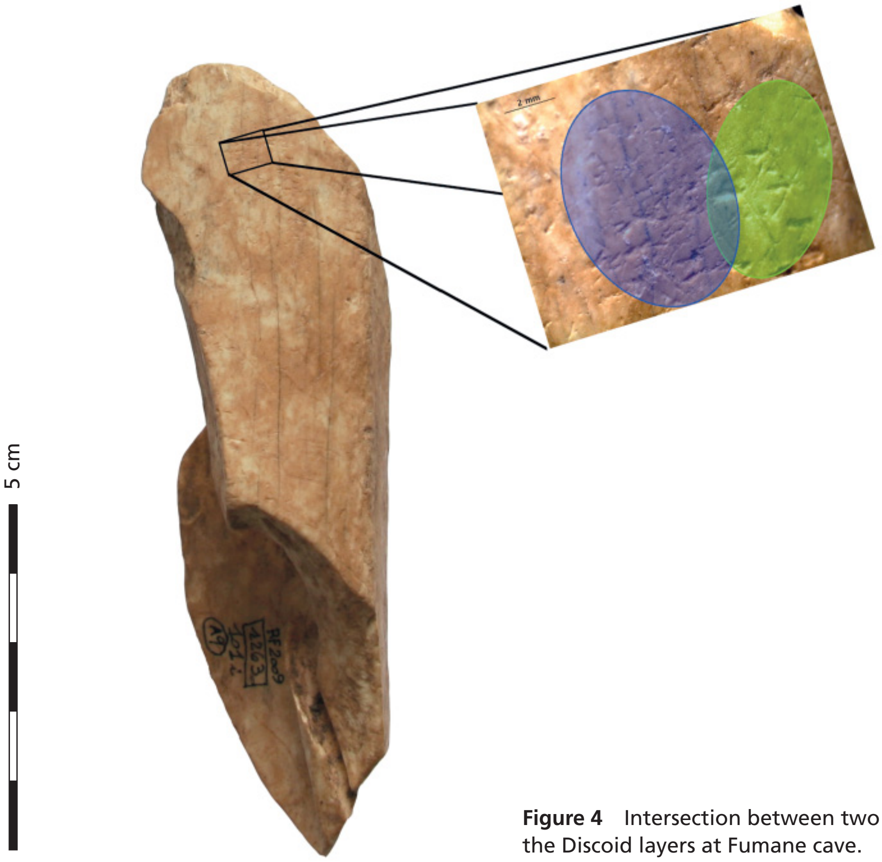


Figure 4 Intersection between two use areas on a retoucher from the Discoid layers at Fumane cave.

dimensions are also significantly lower than those of the retouchers from the other techno-complexes.

In rare instances, subtle surface scraping was observed underneath the stigmata. These striae are always oriented parallel to the long axis of the bone and cover an area slightly larger than that of the retouch-induced stigmata, but never cover the entire shaft fragment.

As is the case for Fumane, most de Nadale cave retouchers have one use area (54 elements in total, 72.0%), although elements with two (17; 22.7%) are relatively frequent. Retouchers with three use areas are rare (3; 4.0%). Finally, one element showed four use areas, accounting for 1.3% of the total.

The bone retouchers also bear all four types of stigmata in similar proportions to those from Fumane cave, although the punctiform impressions represent almost 70% of the total traces, followed by linear impressions, retouch-induced striae and, finally, notches. As with the different techno-complexes at Fumane cave, the morphologies of the stigmata seem to indicate a semi-dry state of the bones when they were used – the margins of some of the stigmata show the diagnostic micro-removals of the osseous surface.

Preliminary scraping has been observed on 21 pieces (28.0% of the total). As with Fumane cave, scraping does not cover the whole surface of the bone shaft, but systematically encompasses the use area.

The use areas occupy a surface between 8 and 840 mm², with a mean of 143 mm² (see **Figure 5**). In the vast majority of cases, the use areas are located in the central, apical part of the shaft; in some other instances, the stigmata are situated along the fractured margin of the shaft (**Figure 6**).

Discussion and conclusion

In a broad sense, the bone shafts that were selected for retouch activities present similar characteristics throughout all of the techno-complexes under re-

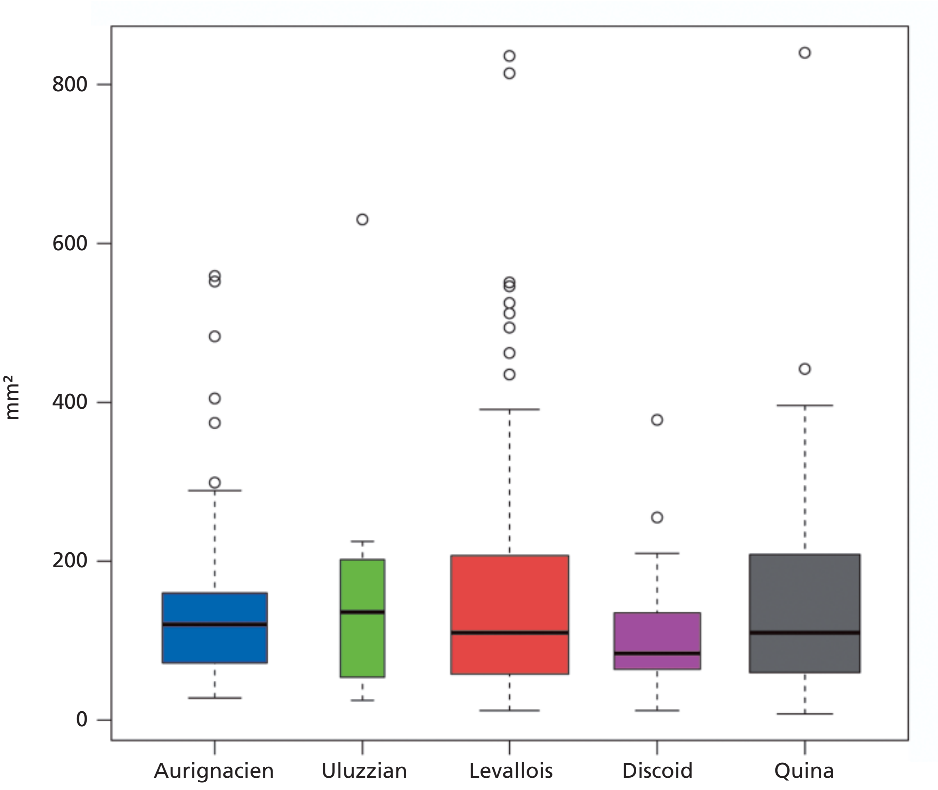


Figure 5 Surface areas (mm²) affected by stigmata on the retouchers of Fumane and de Nadale caves.

view. Their morphology is comparable: long, with relatively straight margins and flat surfaces. In all of the techno-complexes, bone fragments from the limbs have been preferentially selected. This is comparable to the general archaeozoological context, where a clear abundance of limbs has been noted. Although the dimensions of the bone retouchers are not particularly standardised, there is a positive correlation between the length and width in the retoucher sample. In other words, the longer they are, the wider they become. Moreover, one of the determining criteria seems to be mass, as most of the pieces weigh between 10 and 20 grams, irrespective of the techno-complexes. Mozota (2009), in his experimentation to understand the gestures and the processes necessary for the recovery of suitable bone shafts, concluded that the knappers were looking to obtain, in an intentional manner, retouch-adequate handles, with a preference for rather thick elements.

At Fumane and de Nadale caves, systematic fragmentation of long bones was aimed at the recovery of bone marrow. A generalised fragmentation scheme is evident at both caves and through all the techno-complexes: the epiphyses were detached through direct percussion, followed by the breaking of the diaphysis, also through direct percussion, at specific points of weakness. These observations on the selection of homogeneous pieces with similar characteristics must be considered in conjunction with the use of oddly-shaped skeletal elements (scapula, mandible, rib) and bones derived from medium-sized taxa. The choice of these less sturdy raw materials could be assigned to a different use, possibly for less intense *façonnage*. This could possibly be verified by the fact that large-sized bone shafts always bear more stigmata than smaller bone shafts.

Quina retouchers have bigger dimensions than all of the other techno-complexes. This can probably be attributed to the taxa selected at de Nadale cave (i.e., mainly giant deer, bison and red deer), which are larger in size than those from Fumane (mainly red deer). Moreover, the technological requirements

Figure 6 Retouch-induced stigmata on the margins of a bone shaft from the Levallois layers of Fumane cave.

for the removal of large and thick flakes (Bourguignon 2001; Mozota 2013) in shaping Quina scrapers, implies the need for more robust blanks in order to avoid fragmentation of the bone shaft. As far as the Quina lithic industry is concerned, the rarity of medium-sized taxa, as well as the greater thickness of the shafts at de Nadale cave, confirms the suggestions of Mozota (2009). In fact, it is interesting to note the similarities between de Nadale cave and Axlor, Spain (Mozota, 2009), as both assemblages are attributed to the Quina techno-complex, although geographically separated.

While the general faunal spectrum indicates a prevalence of ibex in the Aurignacian layers at Fumane cave, the main species used for the retouchers continues to be red deer, although ibex proportions are higher than in the other techno-complexes. This may indicate that instead of a random selection of diaphyses readily available on site, there was a marked preference for a given thickness. In particular, the thickness of the shaft seems to play an important role in choosing a bone with a suitable handle.

Compared to the other techno-complexes at Fumane cave or that of de Nadale cave, the Discoid elements stand out for their smaller use areas, lighter stigmata and overall lower number of traces. This is ascribed to the low rate of retouch of the lithic elements found in these Discoid layers (Peresani, 2012).

All four types of stigmata are present in all the techno-complexes, but in varying proportions, possibly as a result of the different uses for the retouchers. In any case, they follow the same pattern: punctiform impressions are predominant, followed by linear impressions, retouch-induced striae and notches. Punctiform impressions represent 69.9% of the total stigmata on the Quina retouchers, while the proportion of linear impressions in the Discoid technocomplex reaches 28.8%. However, these differences are not sufficient to accurately demonstrate that the gestures used in the retouch of one type of lithic industry lead to the formation of a specific pattern of stigmata unique to a particular techno-complex. In other words, the bone retouchers are not chronologically diagnostic at the current state of research and might never become a relevant marker for a chronological period.

The fact that the retouchers often bear only one use area is probably due to the abundance of available raw material on-site. This has been observed in various other archaeological sites (Mozota, 2009; Mallye et al., 2012; Tartar, 2012a; Jéquier et al., 2012; 2013; Daujeard et al., 2014). The intensity of use can vary extensively, which is confirmed in other works on the Quina techno-complex. Indeed, Verna and d'Errico (2011) and Mozota (2007, 2009) indicate an intense use of the surfaces of the bone fragments. Similarly, the Quina retouchers at de Nadale cave seem to have been repeatedly and intensively used. In their extensive experiments on retoucher stigmata, Mallye et al. (2012) demonstrated the correlation between the degree of use and the amount of stigmata and notches.

At de Nadale cave, where the stigmata are heavily impressed on the bone surface, the force necessary to create them was greater than in the other techno-complexes under review. Moreover, the invasive and abrupt retouch in the Quina industry calls for a more prominent use of force than what is required for the other techno-complexes. Since some of the lithic implements bear the diagnostic characteristics of a blow given through direct percussion with a soft, likely organic material, it is possible that some of the diaphyses may have been used as percussors and not only as retouchers (Jéquier et al., 2015). Further investigation is required in order to verify this hypothesis.

In the Aurignacian layers at Fumane cave, the re-use of tools as retouchers has been observed. This pattern is also seen in other Aurignacian contexts (e.g., Tartar, 2012a). In the case of awls, their use as retouchers is secondary to the primary function of the tool. However, two diaphyses have been used as retouchers and later as a wedge, similarly to that demonstrated by Tartar (2012b).

Finally, in all of the techno-complexes under review, the retouch-induced stigmata reflect repeated contact with flint and are consistent with the findings of Mallye et al. (2012). The punctiform impressions seem to correspond to a type of stigmata more frequently associated with flint than with other lithic raw materials. This result is not surprising since the main lithic raw material is flint at both Fumane (Peresani, 2012; Peresani et al., 2016) and de Nadale caves (Jéquier et al., 2015).

The preliminary scraping of the use areas has been identified at various archaeological sites, most notably in Spain (Mozota, 2009) and France (Mallye et al., 2012; Tartar, 2012a; Verna et al., 2012; Daujeard et al., 2014). These authors attribute this type of trace to the preparation of a clean surface, without organic residues such as sinew, meat or periosteum, in order to create a better contact surface with the lithic edge. However, we postulate that it could be the result of preparing of the margins of the lithic blank before retouch can start. Indeed, these scraping traces are quite localised and always occur underneath the retouch-induced stigmata. Moreover, experimental data (in preparation) indicates that the bone shaft can still be suitable as a retoucher even with the periosteum still present.

Organic retouchers are important for understanding the dynamics of the lithic *chaînes opératoires*. Moreover, the processes and gestures that lead to the fragmentation of the bones are central to comprehending the mechanisms of blank selection. Although little elaborated and generally without a determined form, these tools present similar characteristics throughout the different techno-complexes, chronologies and geographical areas covered by *Homo neanderthalensis* and *Homo sapiens*. They are all longer than wide, usually robust, easily held in the hand and have smooth surfaces. These features allow for a precise percussion against the lithic margin to be retouched.

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UPPER PALAEOLITHIC BONE RETOUCHERS FROM MANOT CAVE (ISRAEL): A PRELIMINARY ANALYSIS OF AN (AS YET) RARE PHENOMENON IN THE LEVANT

Abstract

The use of bone fragments to retouch stone tools is presently recognised as a widespread phenomenon in the Palaeolithic of Europe, since Middle Pleistocene times. However, in the Palaeolithic record outside Europe, evidence for the use of retouchers is scarce. With the sole exception of the late Lower Palaeolithic site of Qesem Cave (Israel), virtually no retouchers have been recognised in the Levant region. Here, we present the first evidence of this type of tool documented for the early Upper Palaeolithic of Manot Cave, western Galilee, Israel. Subsequently, we discuss the absence of retouchers in other Middle and Upper Palaeolithic sites in the Levant, and suggest that either Levantine hominins did not habitually use bone retouchers, or researchers working in the Levant have not yet identified them as such.

Keywords

Early Upper Palaeolithic; Levant; Bone retouchers; Manot Cave

Introduction

The use of bone fragments to retouch stone tools is presently recognised as a widespread phenomenon in Europe that began in Middle Pleistocene times, with the bulk of the evidence coming from the Middle and Upper Palaeolithic (Vincent, 1993; Malerba and Giacobini, 1998; Armand and Delagnes, 1998; Patou-Mathis, 2002; Schwab, 2002, 2005; Castel et al., 2003; Mozota, 2009, 2015; Tartar, 2009; Tejero, 2010, 2013; Jequier et al., 2012; Mallye et al., 2012; Abrams et al., 2014; Schwab, 2014; Mozota, 2015; Tejero et al., 2016a). According to detailed studies performed mostly in the course of the last couple of decades, retouchers formed an integral part of some lithic production sequences during these periods. Many bone blanks used as retouchers were not chosen randomly, but rather carefully selected based on certain characteristics (e.g., Tartar, 2009; Mallye et al., 2012; Tejero et al., 2016a). This demonstrates the importance of the phenomenon of retouchers for studying Palaeolithic lifeways.

In the Palaeolithic record outside Europe, evidence for the use of retouchers is scarce. Specifically in the Levant region, with its long history of hominin occupation and richness of sites, no bone retouchers have been recognised, with the sole exception of the late Lower Palaeolithic (ca. 420-200 ka) site of Qesem Cave (Blasco et al., 2013; Rosell et al., 2015). No other cases of bone retouchers have been published for the entire Palaeolithic record of the Levant. Some formal bone tools were identified from the succeeding Epipaleolithic (Natufian) Period (Stordeur, 1988). Here we present three bone specimens that we have identified as retouchers, excavated from the early Upper Palaeolithic sequence of Manot Cave in the western Galilee region of Israel. This first evidence of retouchers in the Levant, other than those from Qesem Cave, contributes new data on the adaptation of early Upper Palaeolithic modern humans in the Levant. We present these specimens in light of the associated archaeological remains of Manot Cave, and discuss whether these retouchers constitute an extra-regional technology that appears periodically in Levantine prehistory. Alternatively, these bone retouchers from Manot Cave may be just the “tip of the iceberg” of an under-recognised phenomenon.

Manot Cave

Manot Cave is an active karstic cavern situated within the Mediterranean vegetation belt of western Galilee, Israel (**Figure 1**). The cave is located at roughly 220 m asl, ca. 10 km northwest of the Upper Palaeolithic occupation site of Hayonim Cave and about 50 km northeast of the Mount Carmel Caves.

The cave consists of an elongated main hall (ca. 80 m long, 10-25 m wide) with two lower chambers (**Figure 2**). Rock falls and colluvium apparently blocked the original entrance to the cave ca. 30,000 years ago. During six field seasons between 2010 and 2015, 12 areas were excavated (labelled A to L in **Figure 2**; Hershkovitz et al., 2015; Barzilai et al., 2016; Marder et al., in press). Two intensively investigated areas, designated Areas C and E, contain well-preserved early Upper Palaeolithic assemblages. Both areas display thick (ca. 3 m) stratigraphic profiles and are extremely rich in finds, including flint artefacts, animal bones, bone and antler tools, shells, ochre and charcoal.

Area E is located at the western end of the cave (see **Figure 2**), on top of the talus, where the original entrance is thought to have been situated. Two distinct sedimentological units were identified: Unit 1 is a colluvial accumulation, ca. 1 m thick, with scant archaeological finds in secondary deposition; Unit 2 consists of compact, reworked sediments with cemented crusts in various degrees of brecciation. This unit contains nine distinct archaeological horizons (Unit 2 Layers I-IX). The upper archaeological horizons of Unit 2 (Layers I-III) are composed of a series of well-preserved combustion features. Based

Figure 1 Map showing the location of Manot Cave and other sites mentioned in the text.

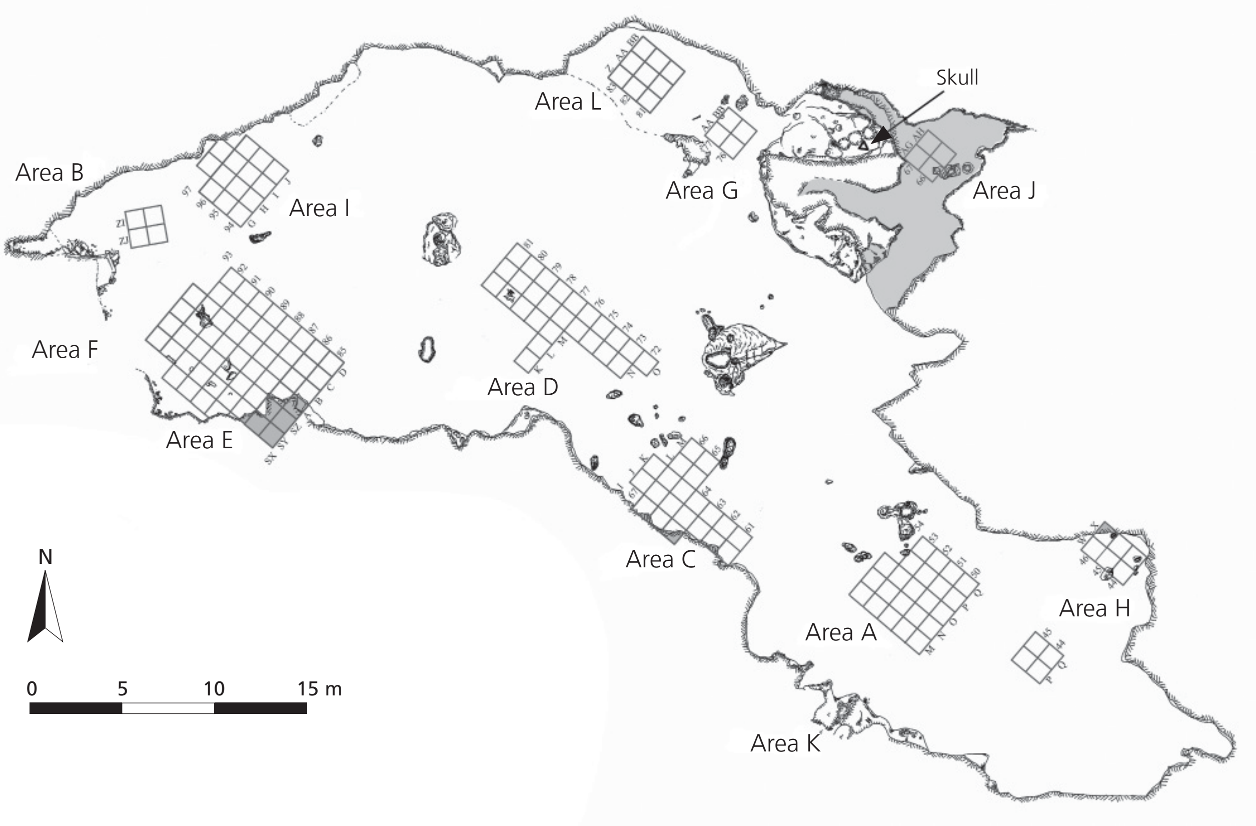

Figure 2 Plan view of the excavations at Manot Cave. Retouchers were recovered from Area C.

on the small lithic assemblages, these horizons are understood as corresponding to post-Aurignacian entities (Barzilai et al., 2016; Marder et al., in press). The lower archaeological horizons of Unit 2 (Layers IV-IX) display dense archaeological assemblages rich in flint artefacts, bone tools, animal bones and shells. The lithic assemblages are comprised of typical Levantine Aurignacian tools, such as nosed and carinated scrapers, as well as blades displaying Aurignacian retouch and a few atypical el-Wad points (Barzilai et al., 2016; Marder et al., in press). The shell assemblages include mostly *Patella* sp., while various species of the scaphopod genus *Antalis* were also found (Barzilai et al., 2016).

The stratigraphy of Area C was defined according to sedimentological criteria and subsequently divided into eight units (**Figure 3**). The archaeological assemblages are rich in finds, including large quantities of flint artefacts and animal bones. Also found were bone and antler tools, charcoal pieces, ochre and basalt ground stones. Due to the nature of the talus, some mixing occurred between the stratigraphic units, although preliminary analysis of the lithic assemblages and radiocarbon chronology suggest that chrono-cultural distinctions can be defined (Barzilai et al., 2016; Marder et al., in press). Considering the freshness of the lithic material, the discovery of complete lithic production sequences (cores, tool debitage and numerous small artefacts < 2 cm) and the preservation of charcoal pieces, the assemblages do not indicate high levels of movement down the slope. The archaeological assemblages from Units 2-4 (ca. 1.5 m thick) are dominated by an Aurignacian lithic component, similar to that described for Area E, as well as antler projectile points (Barzilai et al., 2016). The archaeological assemblages from Units 5-6 (ca. 1 m thick) include both Ahmarian and Aurignacian elements, while Units 7-8 (ca. 1 m thick) are composed almost exclusively of the Ahmarian component, with numerous blades/bladelets produced from single and opposed platform cores, retouched bladelets and el-

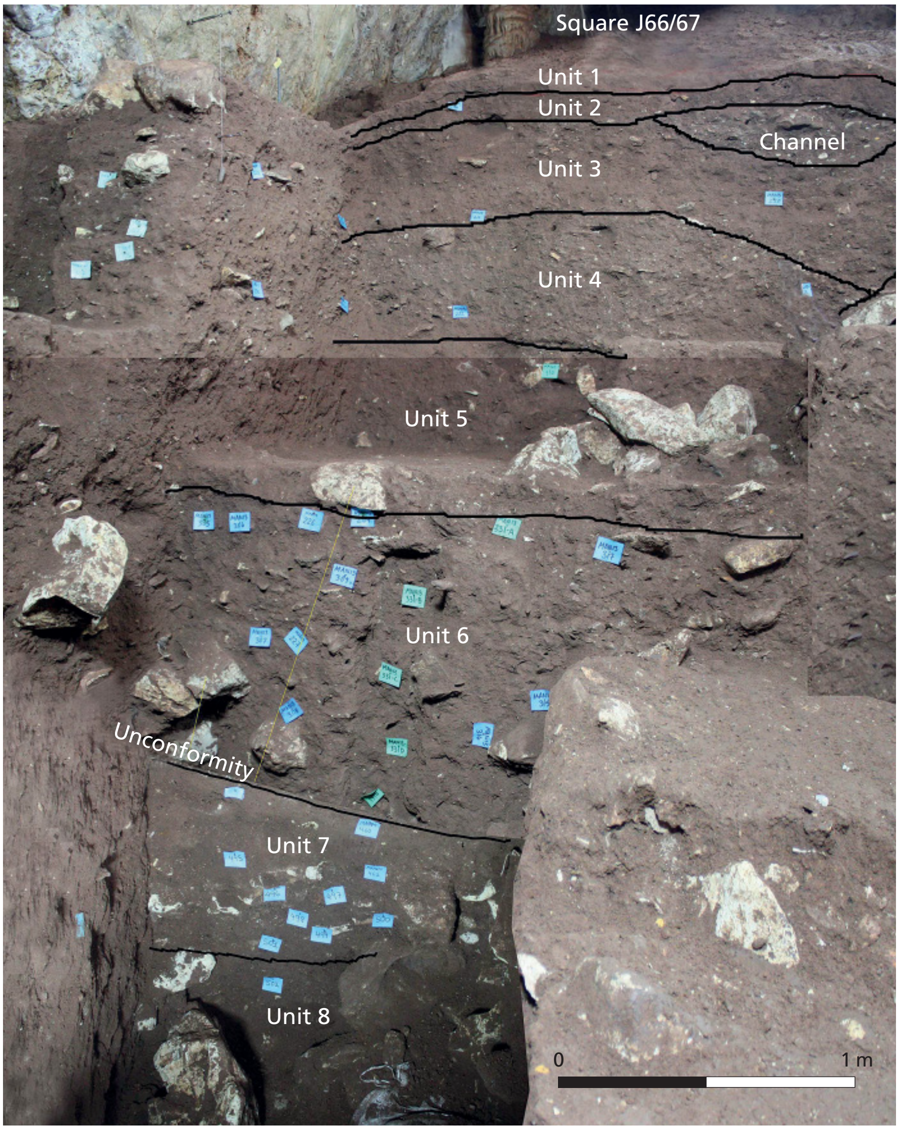

Figure 3 Stratigraphic sequence of Area C, Units 1-8, in Squares J66-67, facing west.

Wad points (Barzilai et al., 2016). The shell assemblages from Area C included *Columbella rustica* and *Nassarius gibbosulus*, which were used for personal ornamentation, and *Patella* sp., which was probably consumed as food (Marder et al., 2013).

The Aurignacian entity at Manot Cave (Areas C and E) is dated to 38-34,000 cal. BP, while the Ahmarian entity (Area C) is dated to 46-42,000 cal. BP (Barzilai et al., 2016). Several Uranium-Thorium dates retrieved from flowstone layers that seal the archaeological horizons in Area C range between ca. 41,000 and 33,000 BP, roughly corresponding with the radiocarbon dates (Hershkovitz et al., 2015).

The Manot Cave retouchers

As part of our on-going analysis of the faunal remains from Manot Cave, which includes the study of bone and antler technology (Tejero et al., 2016b), three retouchers have been identified in Units 5 (n=2) and 6 (n=1), the mixed Ahmarian / Aurignacian levels of Area C (**Table 1**; **Figure 4**). Retouching modifications were found on a medium-sized ungulate (probably fallow deer, *Dama mesopotamica*) femur fragment (Manot.28.C.B3699). A second tool (Manot.29.C.B3803) was identified as a metapodial shaft from a medium-sized ungulate (probably fallow deer, *Dama mesopotamica*). A third retoucher

Table 1 Description of the retouchers found in Manot Cave.

N°	Taxon	Anatomical part	L×W×T (mm)	Use area (mm)	Scraping area (mm)	Use trace orientation
M28	Medium ungulate (cf. *Dama mesopotamica*)	femur	74×29×6	21×18	34×20	perpendicular
M29	Medium ungulate (cf. *Dama mesopotamica*)	metapodial	48×15×6	26×17	—	oblique
M30	Large ungulate (cf. *Bos primigenius*)	femur / humerus	80×29×8	15×14	42×22	perpendicular

(Manot.30.C.B3773) was made from an upper limb bone shaft (femur/humerus) of a large ungulate (probably *Bos primigenius*). Concerning morphology, the three retouchers are roughly similar in size, with thick cortical bone being an important parameter for selection. The cross sections of the three blanks are plano-convex.

The breakage planes of two of the retouchers (M28 and M30) display curved v-shaped outlines, oblique angles, and smooth edges along their apical edges (relative to the position of the use traces), indicating that the bones were fresh when fractured (Villa and Mahieu, 1991). In contrast, the basal portions of both pieces display straight breakage planes without patina, as found on the rest of the bone, and are of a different colour. This indicates that these fractures likely occurred during the excavation. The third retoucher (M29) has straight breakage planes in both the apical and basal poritons. In this case, the breakage planes show the same patina and colour as the rest of the bone, suggesting that these dry fractures were produced by post-discard taphonomic processes, likely sediment compaction or trampling.

The preservation of the bone surface of the three pieces is good (see **Figure 4**). Although some sediment concretions and a loss of cortical bone fraction are displayed in retouchers M28 and M30, these

Figure 4 The Manot Cave retouchers: M29, M28, M30 (left to right).

Figure 5 Scraping marks and superimposed retouching marks on retoucher M28.

modifications do not affect the use areas. A single use area is documented for each retoucher. Following the terminology of Mallye et al. (2012), the use areas are centred on the tool. The concentrated and superimposed traces we observed in retouchers M28 and M30 consist of numerous triangular pits and rectilinear scores oriented perpendicular to the long axis of the bone. The third retoucher (M29) is marked by dispersed, rectilinear scores with oblique orientations. The extensions of the respective use areas (length×width) measure 21×18 mm, 26×17 mm and 15×14 mm. Differences in the traces found on the three retouchers are likely related to the more intensive use of pieces M28 and M30, resulting in the formation of scaled use areas on both retouchers. Overall, the traces on retoucher M29 are scarcer, and none of the individual traces are superposed.

The use areas of the retouchers M28 and M30 were prepared by scraping before the objects were used (**Figure 5**). The respective extensions of the scraping (length×width) are 34×20 mm and 42×22 mm. The scraping marks are oriented parallel or slightly oblique to the longitudinal axis of the bone, and its timing is revealed by the overlap of the different bone surface modifications – the functional use traces (pits and scores) are always above the scrape marks. The correlation between the scraped surfaces and the extension of the use areas signifies that the scraping of the bones was not related exclusively to the processing of meat. The effect of the scraping on the cross-section of the bone is negligible. Therefore, the purpose of scraping was not to regularise the surface or prepare a working plane, but probably was to eliminate remains of the periosteum, fat, meat or other animal tissues, which might otherwise impair the functionality of the retoucher.

Discussion and conclusions

Our identification of bone retouchers at Manot Cave contributes a new cultural element to the study of early Upper Palaeolithic entities in the Levant. By itself, the osseous industry of this period is a significant marker of new cultural habits and ideas (Tejero, 2014; Goutas and Tejero, 2016; Tejero et al., 2016b). The identification of retoucher use at Manot Cave raises the question of why this was apparently such an isolated occurrence in the Middle and Upper Palaeolithic of the Levant. This region includes many deeply stratified Middle-to-Upper Palaeolithic cave sites that contain large and well-preserved faunal assemblages, collected and analysed by modern working procedures (e.g., Rabinovich, 2003; Stiner, 2005; Speth and Tchernov, 2007; Yeshurun, 2013). Therefore, the near absence of retouchers in this region cannot generally be attributed to a meagre archaeological record, partial recovery, degraded preservation of bone surfaces or a lack of taphonomic studies. We suggest two possible explanations: either Levantine hominins did not habitually use bone retouchers or researchers working in the Levant have not yet identified them as such.

The first explanation, that bone retouchers were not routinely used in these periods of the Levant, should be evaluated. The Manot Cave retouchers are confidently dated to the early Upper Paleolithic, but due to their intermediate stratigraphic position (Area C, Units 5-6), it is unclear whether they were used during the Ahmarian, the Aurignacian or both. If these items belong to the Aurignacian, we may hypothesize that the two cases of retoucher use discovered so far in Israel may be associated with lithic industries that share little in common with the other Levantine industries: the Acheulo-Yabrudian at Qesem Cave and the Aurignacian of Manot Cave. It has been suggested that the former be detached from both the preceding Acheulian and the succeeding Mousterian (e.g., Barkai and Gopher, 2013; Zaidner and Weinstein-Evron, 2016). Similarly, the Aurignacian has been interpreted as a European intrusion into the Levant, in contrast to the "local" Ahmarian industry (e.g., Bar-Yosef and Belfer-Cohen, 2010). It may be that the use of bone retouchers in the Palaeolithic of the Levant was a relatively short-lived, imported cultural habit and was not, for some reason, practiced by the local population. This suggestion obviously requires scrutiny of the cultural context of retoucher use in the early Upper Paleolithic sequence at Manot Cave in our subsequent research.

Before such an explanation is further investigated, our second hypothesis, the non-identification of retouchers by researchers in the Levant, must be disproved. As it stands now, the non-identification hypothesis may better explain the absence of retouchers. The detailed taphonomic studies of bone surface modifications published from the Levant have evaluated numerous types of bone damage, including butchery and intentional breakage by humans, carnivore and rodent gnawing, damage from weathering, abrasion, trampling and burning (e.g., Bar-Oz, 2004; Stiner, 2005; Speth and Tchernov, 2007; Yeshurun et al., 2007, 2011; Rabinovich et al., 2012; Yeshurun and Yaroshevich, 2014). However, these and other research projects have not included retouchers as part of the specific research design, something apparently attributable to a lack of interest or awareness. Therefore, it is entirely possible that the retoucher phenomenon, if encountered, was either misinterpreted or entirely unrecognised by researchers conducting their analyses. Following the initial identification of this phenomenon in the Levant (Blasco et al., 2013), the ongoing taphonomic analysis of the rich faunal assemblages of Manot Cave and other current research projects in the region are now explicitly incorporating the search for retouching traces on bones, something which will certainly assist in clarifying this matter.

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SELENA VITEZOVIĆ

RETOUCHING TOOLS FROM THE POST-PALAEOLITHIC PERIOD IN SOUTHEAST EUROPE

Abstract

One of the earliest confirmed uses of osseous raw materials was for retouching, sharpening and repairing stone tools, dating from the Lower Palaeolithic and throughout the Pleistocene period. Considerable changes to subsistence strategies, technology, and overall lifeways occurred among European hunter-gatherer communities during the Holocene. In turn, the role of retouching tools was also modified. Although less common, retouching tools were still present among the Mesolithic and Neolithic communities across Europe. This paper provides an overview of the available evidence for the presence of retouching tools in the Mesolithic and Neolithic, focussing on southeast Europe. Their technological traits, distribution, functions and their significance within Mesolithic and Neolithic societies will be discussed.

Keywords

Mesolithic; Neolithic; Southeast Europe; Bone technology; Retouching tools

Introduction

Retouchers are artefacts used for retouching, repairing and/or sharpening stone tools. They may be made out of different materials, including bone, antler or teeth, and may be used in their natural form or modified (Patou-Mathis and Schwab, 2002). Retouchers can be easily distinguished from other tools by the specific use traces, usually consisting of one or several zones of use with small punctiform pits and/or parallel linear marks on the distal ends of their surfaces. Use traces are often dense and overlapping, creating small, localized surfaces of damage on the bones (Leonardi, 1979; Averbouh, 2000; Patou-Mathis and Schwab, 2002; Schwab, 2002; Valensi, 2002; Karavanić and Šokec, 2003; Mallye et al., 2012; David and Sørensen, 2016). Although these characteristic marks are clearly the result of stone working, different types of stone working tools (e.g., punches, pressure flakers, hammers, retouching tools) cannot always be easily distinguished.

Retouching tools are one of the earliest types of artefacts made from osseous materials, and some of the earliest recognized bone tools (e.g., Henri-Martin, 1906, 1908; Siret, 1925). A great deal of attention has been paid to the occurrence of osseous retouching tools during different stages of the Palaeolithic and their importance for studying early stages of technology (e.g., Chase, 1990). However, their study is often neglected during later periods, particularly from the Holocene. One of the reasons may be the fact that, for a very long time, most of the studies of osseous industries from later prehistoric periods focused mainly on morphology and on typological classification based on forms. Furthermore, retouching tools may have been overlooked in those sites where faunal remains were not carefully collected, not thoroughly analysed, or where studies of osseous industries were restricted to formal tools. Therefore, it is reasonable to expect that the quantity and diversity of such finds, as well as their geographical and chronological distribution, will increase with future analyses.

The Holocene period brought on important changes among European hunter-gatherer communities, in subsistence practices, lifeways, and also technology (see Bailey and Spikins, 2008, and references therein). As flint industries changed, so too did other associated technologies, including retouching tools. As a general trend, they became less common over the course of the Holocene. Although they were *ad hoc* tools to a certain extent, they often display more careful manufacture, more formal shapes and evidence of longer use lives. Overall, they were still a relatively rare group of "tool-making tools" (Chase, 1990), i.e., tools used exclusively for the production and maintenance of other tools.

In this paper, I offer a short overview of the retouching tools of the Mesolithic and the Neolithic periods, with special focus on the region of southeast Europe (**Figure 1**). Their role in daily activities and craft production will be discussed.

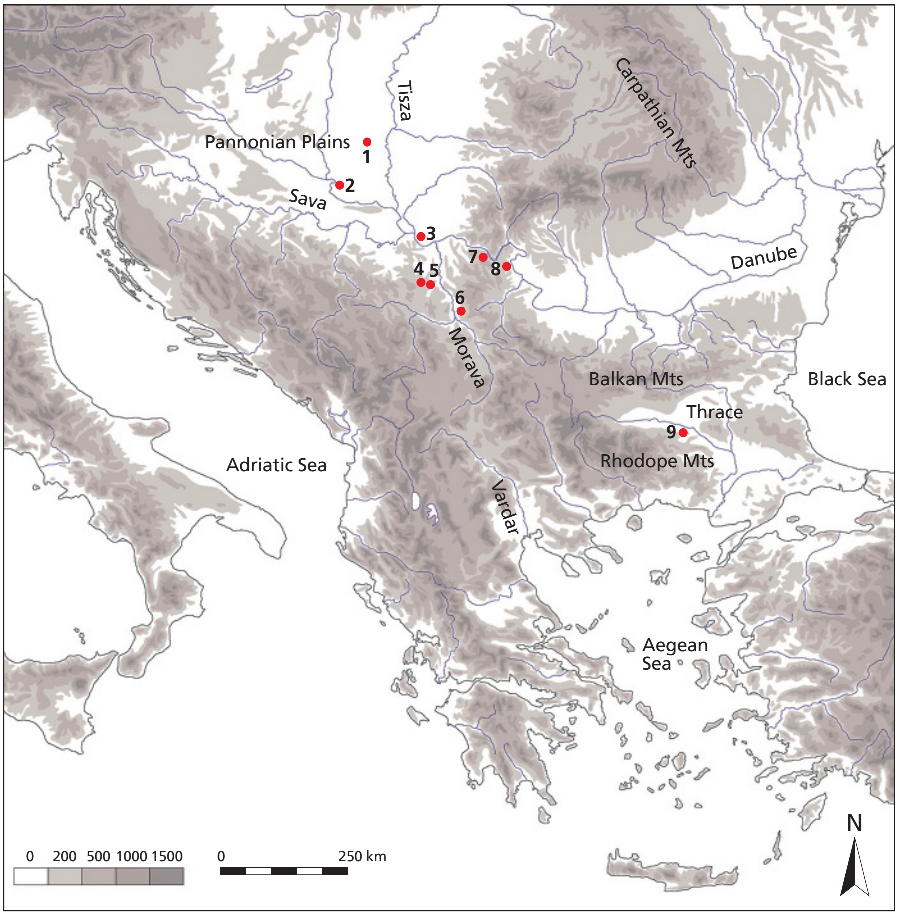

Figure 1 Sites from southeast Europe mentioned in the text: 1. Ludaš-Budžak; 2. Donja Branjevina; 3. Starčevo-Grad; 4. Grivac; 5. Divostin; 6. Drenovac; 7. Vlasac; 8. Kula; 9. Nova Nadezhda.

Retouching tools in the Mesolithic

Mesolithic in the Iron Gates

The Iron Gates region is a part of the Danube valley, today forming the border between Serbia and Romania, where several sites dated to the Mesolithic were discovered: Lepenski Vir, Vlasac, Padina, Hajdučka Vodenica, Schela Cladovei, Ostrovul Corbului, Ostrovul Banului, Icoana and others (Bonsall, 2008; see also Radovanović, 1996, and references therein). These Mesolithic communities practiced fishing and large game hunting, and their material culture included lithic and osseous tools, weapons and non-utilitarian items, such as ornamented stones and sculptures (Srejović and Letica, 1978; see also Radovanović, 1996, and references therein). Unfortunately, most of the finds were collected during rescue excavation projects from the 1960s-1980s, when faunal material was hand-collected, sometimes in haste, and not all of it was thoroughly examined. Furthermore, the taphonomic conditions for bone survival were unfavourable at some of the sites, so the quantity and the preservation of bone artefacts are sometimes very poor (e.g., at Kula; Vitezović, 2011b; see also Radovanović, 1996, and references therein).

The chipped stone industry included artefacts made from quartz, quartzite, silicate rocks, obsidian, flint and chalcedony (Radovanović, 1981), with quartz and quartzite particularly abundant at some of the sites (e.g., at Kula; Sladić, 1986, 2007; see also Radovanović, 1996, and references therein). Retouched tools included end and side scrapers, retouched flakes, burins, retouched blades, perforators, awls, retouched bladelets and geometric microliths, among others (Radovanović, 1981, 1996). The abundance of retouched tools varied from site to site and over time. For example, at Răzvrata they comprised only 1.6% of the total chipped stone assemblage, at Vlasac between 5.0% and 6.6% in different horizons, 15.0-23.0% at Padina and 16.0-31.9% at Ostrovul Banului (Radovanović, 1996:233).

Osseous industries included a large number of antler tools, mainly implements with working edges used for cutting/chopping (chisels, wedges, axes or mattocks), and various hammers, scrapers, burnishers, pointed tools and weapons (projectile points and harpoons). Retouching tools are recognized from at least two sites. During the 1970s excavations at the site of Vlasac on the Serbian side of the Danube River, a large bone assemblage of almost 4000 artefacts was recovered and analysed mainly from a typological viewpoint (Srejović and Letica, 1978). Although the original report does not mention retouching tools, they can be recognized by specific use wear traces. These include one antler beam artefact with incised net decoration over its surface that was probably also used as a scraper or burnisher (Srejović and Letica, 1978:plate LXXVI) and perhaps a few other antler implements interpreted as cutting or percussion tools.

Two poorly reserved retouching tools were uncovered at Kula, another site on the Serbian side of the Danube (Vitezović, 2011b). One retoucher was made from a red deer *(Cervus elaphus)* antler tine segment. The base was simply cut or broken off and it has traces of scraping and whittling on its mesial side. The working tip is heavily worn and has deep, parallel incisions and grooves. The second tool is also made from red deer antler tine (**Figure 2**). The basal part has traces of grooving from the cut-and-break method used to detach the antler blank. The natural tip of the tine was preserved at the distal end and it was probably used as a punch. Deep, parallel grooves and incisions are visible over the entire distal and mesial portions. These traces are compatible with use as a retouching tool (Leonardi, 1979; Averbouh, 2000; Patou-Mathis and Schwab, 2002; Valensi, 2002; Karavanić and Šokec, 2003; Schwab, 2003; Mallye et al., 2012).

Vlasac and Kula have low numbers of retouched tools (Sladić, 1986, 2007; Radovanović, 1996), but this may be connected with preservation issues, recovery methods or differences in the character of the excavated portion of the site (such as activity areas). The circumstances of site occupation may be relevant, as it is not clear whether these settlements were occupied year-round and by all members of the community. The absence of retouchers at sites

Figure 2 a) Retouching tool from the site of Kula, Mesolithic; b) Detail.

on the Romanian side of the Danube (Beldiman, 2007) may also be explained by these factors.

Mesolithic in Europe

Rich Mesolithic assemblages from northern and eastern Europe also yielded different osseous tools related to stone working. Retouching tools were reported from several sites of the Butovo culture, in the Volga-Oka region in Russia, such as Ozerki 5, Okaemovo 5, Ivanovskoe 7 and Stanovoe 4 (Zhilin, 2013, 2014). These tools were made from diverse raw materials: bear canines, beaver mandible fragments and incisors, different long bones, ribs and antlers. Bone retouchers, such as a rib segment of a large ungulate from Ivanovskoe 7, were not intentionally shaped, but simply selected from among broken pieces of bone. Unmodified bear canines were also used, generally displaying heavy damage from use as both intermediary tools and in direct retouching. These bear canines were relatively numerous at Ozerki 5, for example, where 13 such tools were discovered (Zhilin, 2013, 2014). Antler retouching tools are known from Stanovoe 4, made from a diversity of antler segments modified mainly by scraping, and one has traces of being repaired (Zhilin, 2014). Retouching tools made of beaver incisors from Ivanovskoe 7 and Stanovoe 4 were reworked several times and used for different purposes; their final function was for pressure flaking (Zhilin, 2014).

Rare finds of possible retouching tools were reported from other sites in the Baltic region (David and Pelegrin, 2009). Mesolithic sites in present-day Denmark and adjacent areas also yielded a number of osseous tools used in indirect and pressure lithic reduction. Most were made from red deer antler, but elk *(Alces alces)* antler and bone were also used. Four possible types of tools were identified: pectoral pressure sticks, punch tools, shoulder/elbow pressure sticks and lever pressure sticks (David and Sørensen, 2016).

Recent studies of the Mesolithic sites in the Adriatic region suggest that osseous retouching tools were used in these communities as well. For example, the site of Vlakno on the island of Dugi otok in Croatia yielded a relatively rich osseous industry, with a few antler tines possibly used for retouching flint (Radović et al., 2016).

Retouching tools in the Early Neolithic

Starčevo culture

The first farming communities in the central Balkans and south Pannonian plain are attributed to the Starčevo culture (roughly 6200-5500 BC; see Whittle et al., 2002), part of the Starčevo-Körös-Criş cultural complex. Numerous portable finds were uncovered from several dozen settlement sites that have been excavated up until the present day.

The chipped stone industry included the following retouched artefacts in varying abundances at different sites: retouched flakes, retouched blades (sometimes quite long), perforators, side scrapers,

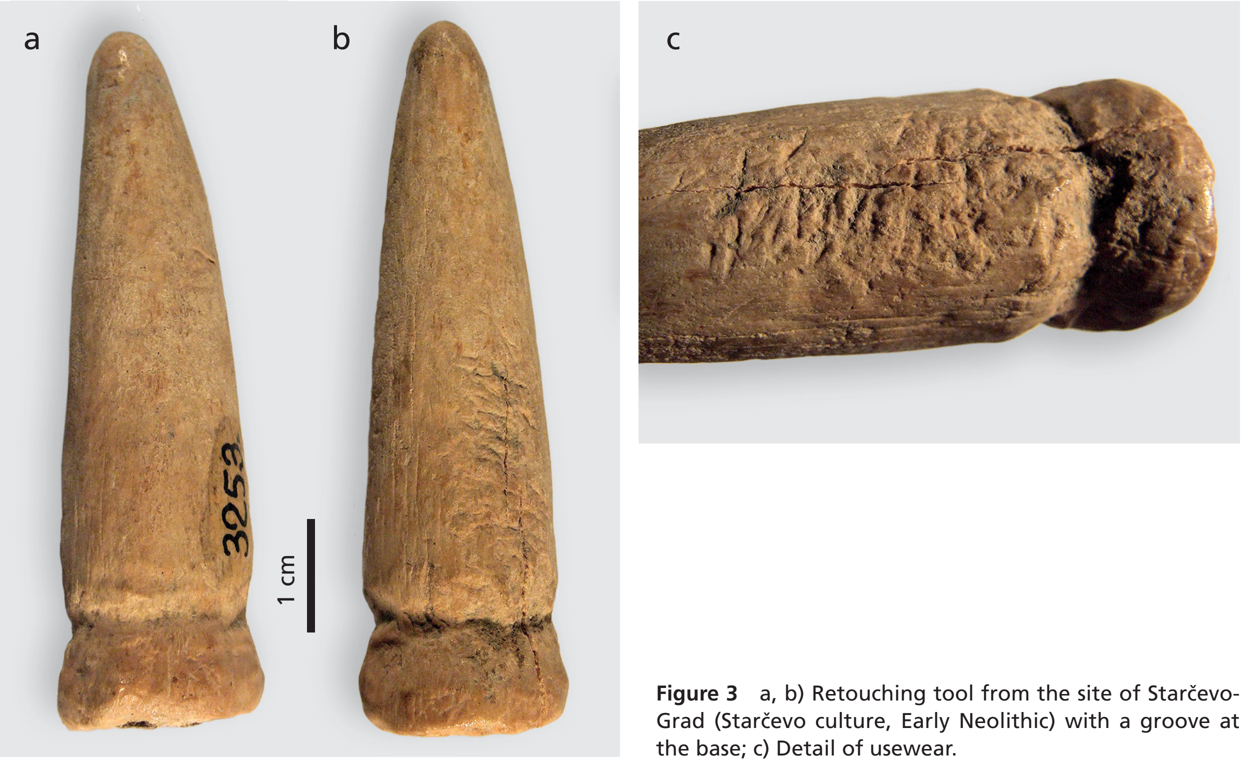

Figure 3 a, b) Retouching tool from the site of Starčevo-Grad (Starčevo culture, Early Neolithic) with a groove at the base; c) Detail of usewear.

end scrapers and double side scrapers (see Šarić, 2014, and references therein). The osseous industry was relatively abundant, and included mainly small tools used in diverse crafts (awls, needles, spatulae, scrapers, chisels, etc.), heavy-duty tools (axes, adzes, percussion tools), hunting gear (projectile points and rare fishhooks) and jewellery (pendants, beads, bracelets, buckles). Bone was the predominant raw material, followed by red deer and more rarely roe deer *(Capreolus capreolus)* antlers, with occasional use of teeth and mollusc shells (Vitezović, 2011a). Most of the bone tool assemblages were collected during excavations carried out in the early and mid-20th century, and the faunal remains were not collected uniformly and carefully. Although some assemblages include several hundred tools and technical pieces, at most sites there are only a few well-preserved tools now stored in various museum collections.

Artefacts identified as retouchers/pressure-flaking tools were noted at seven sites: the eponymous site of Starčevo-Grad, Donja Branjevina and Ludaš-Budžak, located in Vojvodina, on the Pannonian Plain; and at Anište-Bresnica, Grivac, Divostin and Drenovac, situated in Pomoravlje, central Serbia (Vitezović, 2007, 2011a, 2013a, 2013b).

STARČEVO-GRAD Two tools with characteristic use traces were identified. The first is made from a small red deer antler tine. It has a blunt tip and its use traces consist of deep, dense notches and incisions. Its base features a deep groove, perhaps used for

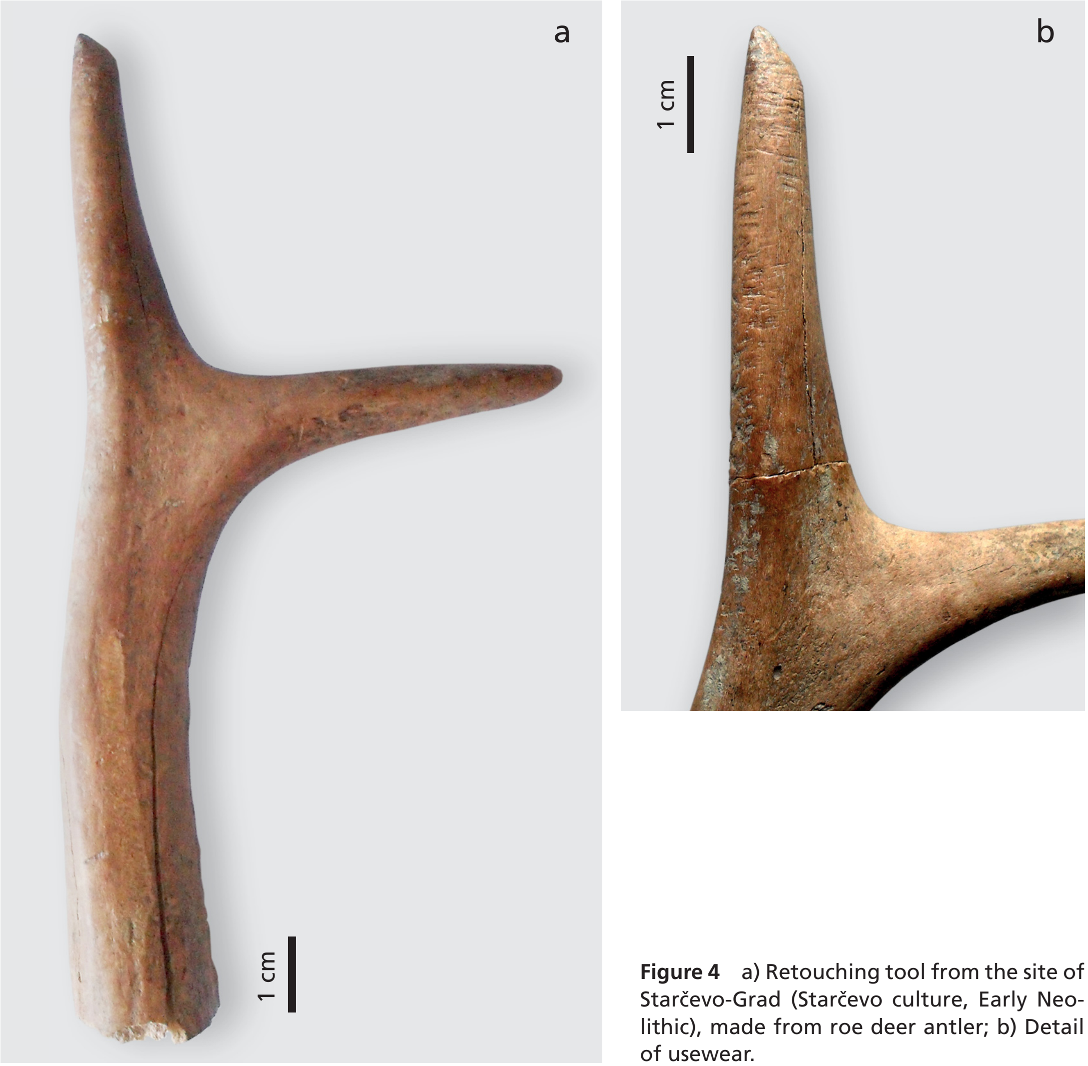

Figure 4 a) Retouching tool from the site of Starčevo-Grad (Starčevo culture, Early Neolithic), made from roe deer antler; b) Detail of usewear.

Figure 5 Retouching tool from the site of Donja Branjevina (Starčevo culture, Early Neolithic) from red deer antler tine.

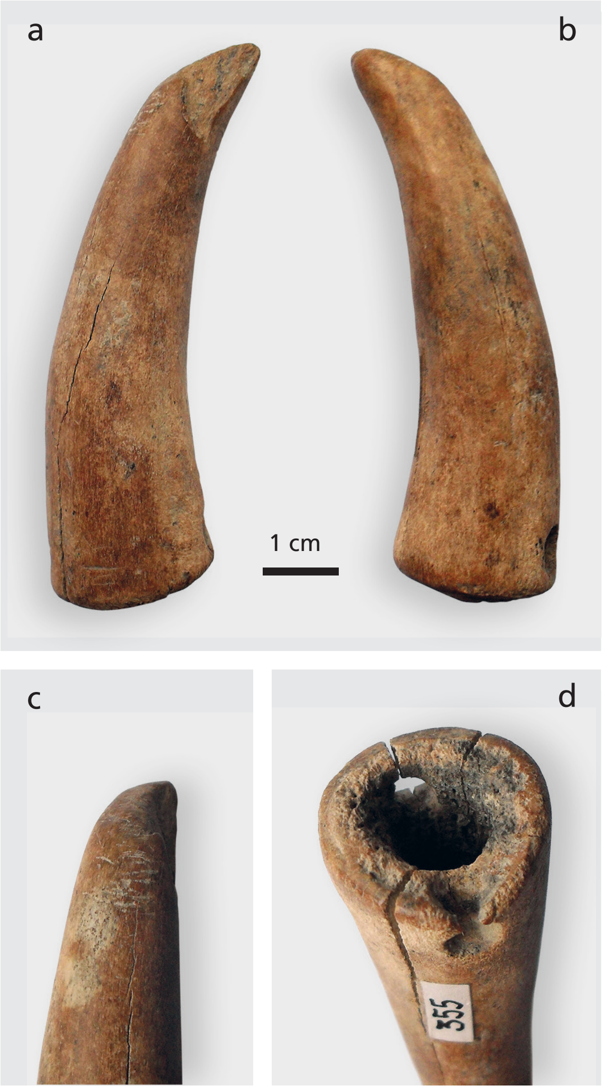

Figure 6 a, b) Retouching tool from the site of Donja Branjevina (Starčevo culture, Early Neolithic); c) Detail of distal end; d) Detail of the perforations at the base.

attaching the tool (**Figure 3**). The second artefact was made from a roe deer antler segment, which consisted of the beam with a crown and one tine. The entire tine is covered by dense, deep, parallel incisions and grooves from use (**Figure 4**).

DONJA BRANJEVINA Three retouching tools were identified, all made from red deer antler tines. Two have their natural tine tips transformed into small, rounded surfaces (ca. 5 mm in diameter), blunt and worn from use (**Figure 5**). Fine traces of cutting related to manufacture can be observed at the proximal ends, and most of the naturally rough outer surfaces of the antlers were smoothed by scraping with a flint tool. Traces of use, visible on the distal portions of both tools, consist of partially overlapping, short and deep furrows, grooves and incisions, oriented perpendicular to the long axis of the tool.

The third tool was carefully made from the tip of a small antler tine (**Figure 6**). The base was carefully cut and the spongy tissue partially carved out. Nearly the entire outer surface was smoothed. The tool had perforations at the base, 4-5 mm in diameter – one entirely preserved, another broken and a third perforation was started, but remained un-

Figure 7 a) Retouching tool from the site of Ludaš-Budžak (Starčevo culture, Early Neolithic); b, c) Detail of the usewear at the distal end.

finished. The active end is partially damaged; nevertheless, its end has been modified into a semicircular surface. Deep and dense lines, incisions and grooves, perpendicular to the long axis of the tool, are visible at the distal end. Perforations were probably made so that the artefact could be attached to a belt or otherwise carried on the body. The broken perforation likely resulted from such use.

LUDAŠ-BUDŽAK One retouching tool was discovered, made from a red deer antler tine tip (**Figure 7**). The base was cut off and the entire surface is covered by dense use traces. In the distal portion of the tool, several zones exhibit overlapping grooves and diagonal incisions. The tip was modified into a circular surface and covered with dense lines and incisions.

ANIŠTE-BRESNICA One retouching tool was discovered, made from a red deer antler tine (**Figure 8**). The basal portion was cut off and the distal surface was smoothed by scraping with a fine chipped stone tool. The distal end was shaped into a small circular surface, and the entire distal portion of the tool is covered with deep, dense incisions and grooves.

DIVOSTIN A rich antler industry discovered at the site of Divostin included four retouching tools, all made from red deer antlers. Three tools were made from tines; the natural tips were shaped into a small

Figure 8 a, b) Retouching tool from the site of Anište-Bresnica (Starčevo culture, Early Neolithic); c, d) Detail of use; e) Detail of manufacture traces.

circular surface on two specimens, while the third object has a damaged tip that was previously modified by cutting. Traces of use are very intense on all specimens and consist of dense, deep incisions and grooves. The fourth artefact is a hammer made from the modified base of a shed red deer antler (**Figure 9**). The natural base was used as a hammer-like working surface, and the beam was thinned for use as a handle. The natural base of the antler was also modified (or possibly repaired) by removing small flakes prior to or during use as a hammering surface. The opposite end was not preserved. After the tool broke or became blunt, the handle was secondarily used for the manufacture of chipped stone artefacts; dense, deep, short incisions and furrows are visible on its surface.

GRIVAC Two retouching tools were identified, both made from small tine fragments of red deer antlers. The natural tips were modified into a circular surface on both tools (**Figure 10**). On the first tool, the tip was cut off by grooving and cutting; on the second, two flakes were removed from two sides by direct percussion. The outer surface of the first tool was also scraped with a flint tool. Apart from damage on the tip, the distal ends are entirely covered with incisions and grooves. One of the retouchers was discovered in an excavation unit associated with a pit dwelling and was possibly abandoned at the place where it was used.

DRENOVAC Two small antler tines were used as retouchers but only minimally modified. The first has traces of cutting at the base from gradual thinning with a flint tool; the natural antler tip was modified into a small circular surface by cutting. Its entire mesial and distal parts are covered with dense, somewhat irregular, short incisions and grooves, thus, forming a zone of damage caused by intensive use (**Figure 11**). The tip is blunt and damaged from use.

Figure 9 a, b) Hammer modified into retouching tool, from the site of Divostin (Starčevo culture, Early Neolithic); c) Detail of usewear.

Figure 10 a) Retouching tool from the site of Grivac (Starčevo culture, Early Neolithic); b) Detail of usewear in the distal portion; c) Detail of manufacture traces; d) Detail of distal end.

Figure 11 Retouching tool from the site of Drenovac (Starčevo culture, Early Neolithic).

The second retoucher is not completely preserved, but numerous incisions and grooves from use are visible on the distal part.

Karanovo I culture

The first farming communities in the Eastern Balkans, present-day Bulgaria, are labelled the Karanovo I culture (see Boyadzhiev, 2009, and references therein). The chipped stone industry is marked by macroblade technology, in particular by the presence of blades with high retouching, sometimes of considerable dimensions, and also by irregular blades, retouched flakes and perforators (see Gatsov and Nedelcheva, 2009, and references therein). As for the bone industry, the problem of sample bias is evident – faunal remains from most of the older excavations were not carefully collected nor examined for possible traces of manufacture and use. At present, only a few bone assemblages have been analysed in great detail, including Ovčarovo (Zidarov, 2014), Karanovo (Lang, 2005) and Yabalkovo (Guadeli, 2014), but no retouching tools were identified at any of these sites.

The recently excavated site of Nova Nadezhda, however, yielded possible tools related to retouching activities. The site is situated in eastern Thrace near the town of Khaskovo, Bulgaria, and was excavated as part of a rescue project in 2013-2014. Excavations revealed Early Neolithic settlement structures (houses, pits, ditches), several graves and archaeological remains from later periods (Bacvarov et al., 2014, 2015). In addition to numerous ceramic finds, many lithic and osseous artefacts were also uncovered.

The osseous industry from the Early Neolithic at Nova Nadezhda is relatively rich and includes some characteristic techno-types for this period, such as

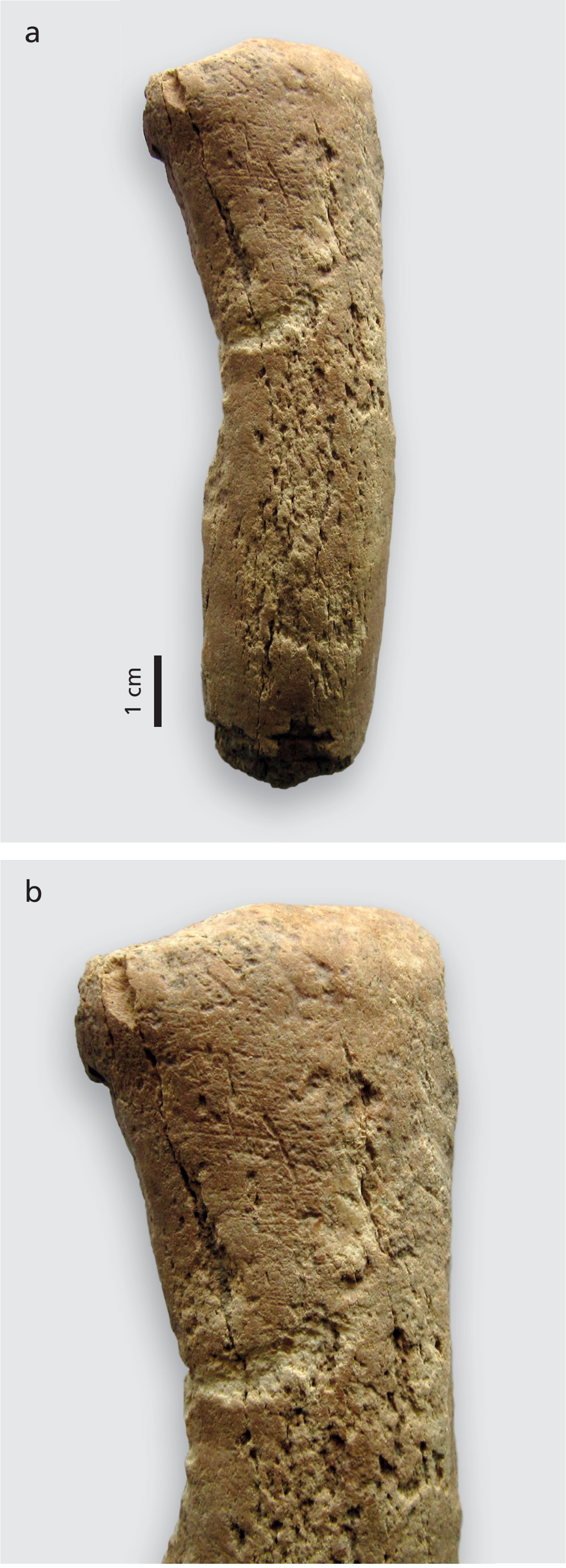

Figure 12 a) Hammer with traces of being use as retouching tool from the site of Nova Nadezhda (Karanovo I culture, Early Neolithic); b) Detail of usewear.

awls, needles, spoons, chisels, etc. Animal bone was the predominant raw material, followed by red and fallow deer *(Dama dama)* antlers, teeth and shells. In general, antler was poorly preserved, but did serve as the raw material for a number of small punching tools, scrapers and burnishers. One finely made but badly preserved specimen was discovered within the Early Neolithic ditch at Nova Nadezhda. This small hammer tool was completely smoothed and burnished and was made from a beam segment of either a red or fallow deer antler. It has traces of use that may be interpreted as retouching marks: deep, perpendicular incisions and punctiform pits creating clusters of heavy damage on the surface (**Figure 12**). Another interesting find is a fallow deer antler pedicle, discovered below a Chalcolithic structure, but most likely belonging to disturbed Early Neolithic layers. This implement includes no traces of manufacture, but preserves dense traces of use in the form of short, deep incisions and grooves on its surface (**Figure 13**). It was most likely used as an anvil or support.

Retouching tools in the Late Neolithic

Vinča culture

The Vinča culture represents the Late Neolithic/Early Chalcolithic culture in the central Balkans and south Pannonian region (present-day Serbia, Oltenia and Transylvania in Romania, eastern parts of Croatia and Bosnia and Herzegovina), covering the time span between 5400 and 4500/4450 cal BC (Borić, 2009; Tasić et al., 2015).

The Vinča culture is characterized by developed craft production (Tringham and Krstić, 1990), with rich lithic and osseous industries. Chipped stone industries are generally abundant and included both local raw materials and imported obsidian. Retouched tools, including flakes, blades, scrapers, etc., were present in varying abundances at different sites and over time (Kaczanowska and Kozlowski, 1990; Antonović and Šarić, 2011). Osseous assemblages mainly included tools for diverse crafts: awls, needles, massive pointed tools, spatulae, scrapers, chisels, axes, hammers and other percussion tools. Hunting and fishing gear (harpoons, fishhooks) and jewellery (bracelets, pendants, appliqués) were made mainly from domestic animal bones, red and roe deer antlers, boar tusks and mollusc shells, including imported *Spondylus* (Bačkalov, 1979; Lyneis; 1988, Russell, 1990; Vitezović, 2007, 2013a).

Retouching tools were rare, identified at only two sites thus far: Selevac and Drenovac, both in the Pomoravlje region of Serbia. At Selevac, at least four tools have been identified as pressure flakers (Russell, 1990), three made from antler and one from a rib segment. All have been shaped into a broad, blunt point, and the area beneath the tips show clusters of characteristic scars. Several other artefacts have unclear or poorly preserved micro-wear, but are likely to have been used for pressure flaking, including three lozenge-shaped pieces of antler.

Two retouching tools were discovered within the Starčevo culture layers at Drenovac. Another retouching tool made from a large red deer antler tine

Figure 13 a) Antler pedicle with traces of use, probably as an anvil for retouching, from the site of Nova Nadezhda (Early Neolithic); b) Detail usewear.

likely belongs to the Vinča culture layers (Vitezović, 2007). Its tip is damaged, but several deep, overlapping horizontal grooves from use are visible on the distal end.

Neolithic in Europe

Retouching tools have been reported from a few Neolithic sites in central and western Europe.

In Hungary, the Late Neolithic site of Aszód Papi yielded a very rich osseous industry, including 90 pieces used as intermediate punches or pressure flakers. All were made from red deer antlers, except for three made from roe deer antlers (Tóth, 2013). From the Pre-Cucuteni site of Târgu Frumos in Romania, three pieces made from red deer antler segments were probably used for retouching stone (Vornicu, 2013).

A total of 29 antler retouching tools were also reported from Chalain 4 in France (Maigrot, 2003). All were all made from elongated segments of red deer antler tines modified by abrasion, except for one roe deer crown and one basal segment. They were used both for retouching by compression and by percussion. In fact, careful microscopic examination at high magnifications allowed Maigrot (2003) to distinguish 15 percussion and 14 retouching tools. Some of these tools were re-utilized, originally functioning as cutting/chopping tools or “sleeves” for hafting stone axes.

Finally, the most interesting and probably the most recent of these finds comes from the equipment carried by the mummy, known as Ötzi, discovered in the Ötzal Alps on the border between Austria and Italy. Amongst other possessions, he carried one tool made from a section of a stripped lime tree branch, which was cut off at one end and sharpened at the other. An antler rod, 6.1 cm long, was hammered into the core of the branch, so the total tool length was 11.9 cm, although the antler spike stuck out no more than 4 mm. The distal end of the antler had also been hardened by firing. The tool was easily sharpened like a pencil when the antler tip became blunt from use (Spindler, 1995; Fleckinger and Steiner, 2000). This tool, with its bark haft, is a unique find in prehistoric Europe, and provides insight into how these tools were used during the Neolithic and earlier times.

Chalcolithic bone industries from European contexts are insufficiently studied; therefore, the presence or absence of retouching tools cannot be adequately assessed. In southeast Europe, retouching tools are absent from carefully collected and thoroughly analysed assemblages, such as from the site of Bubanj in Serbia (personal observation) and from Chalcolithic layers at Karanovo in Bulgaria (Lang, 2005). However, as mentioned earlier, sample bias may be a contributing factor to this apparent absence.

Discussion

The evidence for osseous retouching tools in the Mesolithic period is relatively sparse. To date, such tools have been reported from northeastern Europe and from the Iron Gates region. However, studies of the material from recent excavations (Radović, et al., 2016), as well as re-examinations from older excavations (David and Sørensen, 2016), show that the distribution and overall quantity of osseous tools used in stone working are much higher than the current results suggest. Although the relatively small number of known retouching tools does not allow for generalizations, some trends can be noted. The predominant raw material is antler, followed by teeth and the occasional use of the other skeletal elements. The retouchers are also rarely unworked, *ad hoc* artefacts, but rather intentionally shaped tools. Furthermore, they were used for longer periods and sometimes even re-worked and repaired.

The preference for antlers continues into the Neolithic period. In the Starčevo culture, except for one roe deer antler tool from the Starčevo site, all artefacts were made from red deer antler segments. The possible use of fallow deer antlers is also noted in the Thrace region. Tine tips were preferred, although other antler segments may be encountered. The natural tips of the tines are usually shaped into smaller circular or elliptical surfaces, and sometimes entire tools were smoothed by scraping and burnishing. In most cases, the tools resemble small punches made from truncated antler tines. It is possible that some of the punches were also used for retouching, but the characteristic use traces were not preserved or the retouchers were used for too short a time for the traces to be visible.

The retouchers in the Vinča culture are mainly modified antler tines as well, similar to small punching tools. Additional retouching tools may be unidentified, either because the assemblages were not examined carefully or the use traces were not well preserved.

If we arrange retouchers from Starčevo sites along an imaginary manufacturing continuum (*sensu* Choyke, 1997, 2001; Choyke and Schibler, 2007), they cover a wide range, from minimally modified tools to carefully made pieces involving considerable investments in time and labour. Strictly *ad hoc* objects are absent, but broken antler tools were sometimes secondarily used as retouchers (e.g., the broken hammer from Divostin; see **Figure 9**). The manufacture of most of the tools was planned – they were made in a uniform way from strictly chosen raw material. Some of the specimens are very well crafted, particularly the piece from Donja Branjevina (see **Figure 6**), with its carefully cut basal part and basal perforations. Traces of repair can also be observed on this particular tool. After one of the perforations broke, another one was started but not finished; perhaps the remaining perforation was sufficient or the distal end broke off and the tool became unusable. This tool and another example from Starčevo were probably portable (see **Figure 3**) – they could have been worn attached to the belt, at hand and ready for use. Such carefully made examples have not been discovered in Vinča culture assemblages thus far. However, the Vinča retouching tools discovered were planned and worked artefacts, not simple *ad hoc* tools.

Examples from the Neolithic sites in Switzerland display similar patterns: antler was the preferred raw material, strictly *ad hoc* tools were not noted and there are a few carefully shaped examples that were likely worn on a belt.

Extended use lives, as well as considerable time and labour investments, suggest these tools held some importance in craft production. The possibility that some of these tools were worn visibly argues in favour of the idea that the skill these tools implied were valued (Choyke and Schibler, 2007). However, the available data does not allow any further generalizations regarding their exact position within the organisation of production. Were they used frequently or only occasionally? Were retouchers made from osseous raw materials rare or common? What was their relation to retouching tools made from stone materials? These questions remain unanswered.

Most Neolithic retouching tools were used for a long time, sometimes even repaired. Preserved use traces suggest that they were used for both percussion and pressure flaking. Detailed microscopic examination of the retouching tools from Chalain 4 demonstrated both functions were equally represented (Maigrot, 2003). Examined under low magnification, use traces on the pieces from the Starčevo culture can be roughly divided into two groups: 1) incisions and grooves, perpendicular or diagonal to the long axis of the tool, located around the small circular working end; and 2) use areas consisting of dense concentrations of incisions, grooves and furrows, located across the surfaces, especially in the distal portion. These different types of damage suggest two modes of use: for percussion and pressure flaking. Some of the tools were used in both ways, but some have preserved just one type of use trace (Vitezović, 2011a).

Conclusion

Flint-knapping represented a valued skill, not just for early humans, but also throughout the entire prehistoric period. Knowledge of flint-knapping itself was valued, and the resulting artefacts, with their investments in labour and time, could have been objects of prestige (Sinclair, 1995, 1998; Hayden, 1998). Retouchers represent one of the most widespread tool types made from osseous raw materials, covering a wide chronological and geographical distribution. They are also made from a wide range of raw materials, different tools include various levels of modification and their final shapes are variable.

The study of retouching tools, their first appearances, distribution, raw material choices, etc., is important for studying human technological behaviour. In the Holocene, when important changes occurred in most segments of life (e.g., subsistence practices, lifeways, worldviews), retouching tools also underwent certain changes that reflect transformations in overall technological practices. *Ad hoc* use of osseous remains declined, and more careful selection of raw materials is notable. In the eastern European Mesolithic, retouching tools were made from carnivore and beaver teeth, as well as antlers, while antler was the preferred raw material in most other Mesolithic and Neolithic communities. Unlike during the Palaeolithic period when all osseous raw materials were used, often without any selection (Leonardi, 1979; Leroy-Prost, 2002; Valensi, 2002: Schwab, 2003; Mozota, 2007; see also Patou-Mathis, 2002, and references therein), the predominance of antler is apparent in the Mesolithic and Neolithic. Antler is generally more resilient to shock and more convenient for use as a percussion tool (Billamboz, 1977; see also Christensen, 2004, and references therein); therefore, such a preferred raw material choice may be related to the less expedient character of these tools and their longer duration of use.

Over time, retouchers became planned tools, sometimes very skilfully made, with considerable time and labour invested in their manufacture. They were often used for a long time and repaired. Some retouching tools were even made publicly visible (possibly hanging from the belt), perhaps giving to their owner a certain status.

Future detailed examination of already recovered faunal remains or new excavations will certainly add to the quantity and morpho-typological diversity of retouching tools from the Holocene period. Judging from the currently available data, retouching tools gradually disappear from the Chalcolithic period in most parts of Europe, when the overall technology underwent dramatic changes largely related to the introduction of metallurgy.

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THE ORIGINS OF BONE TOOL TECHNOLOGIES: CONCLUSIONS AND FUTURE DIRECTIONS

The origins of bone tool technology lie with the use of bones in lithic manufacture and maintenance. Such behaviour extends as far back as a half million years, if not earlier, and continued until as recent as 5000 years ago. This volume examines in great detail the circumstances of these origins, particularly how these bone tools were integrated into the entire suite of emerging Palaeolithic technologies and how these cumulative innovations influenced hominin lifeways.

The "Retouching the Palaeolithic" conference on which this volume is based was organized around four interconnected themes related to the use of bones and other osseous materials in lithic production: 1) Identification, methodology and terminology; 2) Form and function; 3) Time and space; and 4) Associated archaeology and human behaviour. These themes are woven throughout the individual papers in this volume, with significant attention paid to the archaeological contexts in which these bone tools have been recovered. From these themes, a coherent methodology for the analysis of these bone tools has emerged, together with a set of experimental protocols to verify or reject interpretations of these artefacts; the various pits and scores on these bone tools have been considered in relation to a range of possible functions to determine their role(s) within the overall lithic *chaîne operatoire*; local and regional chronologies for the use of these bone tools have been improved; and most importantly, the complete archaeological contexts in which these bone tools were recovered, including the associated lithic industries and faunal assemblages, have been scrutinized to reveal economic decisions and organisational strategies of Palaeolithic populations.

Identification, methodology and terminology

Exploring the origins of bone tool technologies hinges on the accurate identification of pits, scores, and other markings on bones and other osseous materials related to lithic manufacture and maintenance. We must adhere to strict scientific standards of identification in order to trace the development of this technology over time, beginning with the oldest Palaeolithic faunal assemblages up to the more recent Mesolithic and Neolithic periods. Images and descriptions of these artefacts have been available for decades, but manuals and reference works dedicated to various bone surface modifications provide little coverage on the specific markings to define bone tools used in lithic manufacture. Only with the publication of *Retouchoirs, Compresseurs, Percuteurs…Os à Impressions et Éraillures* (Patou-Mathis, 2002) did such guidelines become available for the standardized identification of these bone tools. This collection of papers published under the sponsorship of the *Commission de nomenclature sur l'industrie de l'os préhistorique (Société* *préhistorique française)*, remains enormously influential and has been referenced extensively by all the contributors to this present volume. This synthesis of *retouchoirs, compresseurs* and *percuteurs* from the European Palaeolithic represented the culmination of research by numerous scholars extending back to the turn of the 20th century, and significant developments have been achieved since 2002.

Toward an updated set of guidelines for identification and methodology, Mozota (2018) chronicles the history of archaeological and experimental research on bone retouchers and similar bone tools and provides a much needed anthology of the different classification schemes employed by various researchers to define specific "use traces" on bones related to lithic manufacture and maintenance. Mozota's meticulous review charts the "approximate equivalences" across various terminologies, which seeks to clarify any unintended discrepancies encountered with the translation of original French terms to English. Along the way, Mozota also details the historical developments of experimental studies, and with a nod to the future, outlines a methodological approach to guide archaeological interpretation toward more quantitative, explanatory, and verifiable results. This inferential framework is a critical component of formulating and testing hypotheses about the behavioural significance of the use of bone tool technologies during the Palaeolithic.

In regards to methodology, the individual contributors to this volume drew from a wide range of existing qualitative and quantitative procedures as a basis for their analyses. Together with the various methodologies prescribed in Patou-Mathis (2002), nearly every author converged on the conventions and protocols outlined by Mallye et al. (2012). These simple methods of recording the orientation, location, distribution and morphology of use traces have proven beneficial to the standardization of basic observational data. We strongly support the continued use this methodology for describing these various bone tools.

Much of this volume deals with pits, scores and other marks left on bone surfaces indicative of stone tool manufacture and maintenance. Recognition of this type of damage has grown steadily over the past decades, and archaeological case studies often interpret the damage as the result of retouching the edges of stone tools. Consequently, the bones on which these marks are found have been termed "retouchers", from the original French word *retouchoir.* This is the preferred terminology used throughout this volume, and we agree with the individual authors in their interpretation of these artefacts, but we caution that the use of the term "retoucher" carries with it a specific definition, together with an inferred mode of use and singular function. In simple terms, a "retoucher" is a percussion implement that is struck against a lithic tool (or flake) thereby resharpening or reshaping its edge. Ungulate limb bone shaft fragments were the preferred raw material for retouchers throughout much of the Palaeolithic period, but we emphasize that retouchers cannot be identified by the form of the bone or bone fragment itself; rather, it is the diagnostic pits, scores, and other marks left on the bone's surface by a lithic edge that positively identifies a bone as a retoucher. But, not all bones or other osseous materials bearing these types of marks are created equally. Characteristic pits and scores can be imparted by varying degrees of force, by percussors (*percuteur* in French) or other hammer-like implements. Compressors (*compresseurs* in French) work by applying pressure to the lithic edge. Bone anvils (*enclumes* in French) used in a passive manner may also bear marks related to various lithic knapping activities. Thus, the appropriate terminology should be dictated by the motion involved in utilization, whether active or passive, and technique applied, whether through percussion or pressure. In a broad sense, "retoucher" has become a catch-all term for bones with marks resulting from the manufacture and maintenance of stone tools, regardless of its use in an active or passive manner, through percussion or pressure, or otherwise. We argue that this generalization obscures the variability in use and function of these bone tools. Furthermore, in archaeological examples, the motions (active or passive) and techniques (percussion or pressure) involved must be inferred based on the characteristics of individual or groups of pits and scores. Even with decades of experimental studies, the distinction between pits and scores created through different motions and technique is not entirely clear. Thus, the term "retoucher" has come to be used somewhat imprecisely, similar to the use of the term "scraper" in lithic studies. A "scraper" is truly a scraper only if its use-wear indicates its usage in scraping tasks. Likewise, a "retoucher" can only be defined as such if it preserves surface modifications resulting from shaping the edge of a lithic tool by percussion. For the sake of clarity, the continued use of term should be accompanied by a qualifier: retoucher *sensu lato* to describe the broader category of bone tools used in lithic production, including retouchers, precussors, compressors, etc.; and retoucher *sensu stricto* for actual bone retouchers used for shaping a lithic edge by percussion.

As a synonym for bone retoucher *sensu lato*, we suggest the reuse of the French phrase "os à impressions et à éraillures", shortened to "os à impressions", to describe the entire class of bone tools bearing pits, scores, and other marks related to lithic manufacture and maintenance; Daujeard et al. (2018) also advocate for the use of the general term "impressions et éraillures" to describe these marks (see also Patou-Mathis, 2002). "Os à impressions" loosely translates to "bones with impressions", but we prefer to use the original French phrase to avoid any confusion or loss of meaning through translation. This phrase offers a neutral description of the bone tools, without ascribing specific functions, and can be used synonymously with the phrase "minimally modified bone artefacts" (Villa and d'Errico, 2001) or "bone expediency tools" (see Lyman, 1984). In the broadest sense, the key element of this terminology relates directly to the pits, scores, and other marks ("impressions") on the bone surfaces imparted during lithic production. These marks may be indicative of how the tool was used (motion and technique) and for what function (retoucher, percussor, hammer, compressor, anvil, etc.), the specifics of which must be made explicit based on contextual and experimental data.

Form and function

Equating form and function could be used a means to link various "os à impressions" with specific elements of associated lithic assemblages at archaeological sites, thus placing these bone tools within the lithic *chaîne operatoire*. However, it is apparent that the gross morphology of the bone tool has little interpretive bearing on the function of the tool. Flat or convex surfaces are common, and the tools must be of a minimum size to be useful, but other morphological features are quite variable. Therefore, we contend that the individual pits, scores, and other "impressions" must serve as the defining feature of these tools, not the form of the tool itself or the anatomical element from which it is derived.

Throughout the Palaeolithic, a vast majority of faunal remains with pits, scores, or pieces of embedded lithic material originated from ungulate long bone shaft fragments of various dimensions and from small to very large animals. Overall, the selection of materials for such tools seems to have occurred on a rather *ad hoc* basis. It can be reasoned that the smaller and thinner examples functioned as more light-duty retouchers, while the larger, thicker specimens and complete bones were used as percussors or hammers. This does appear to be the case with the complete and fragmentary equid metapodials from Schöningen 13II-4 described by Hutson et al. (2018), but those bones also show evidence of use in multiple tasks related to lithic manufacture and maintenance. Other bones, such as ribs, limb epiphyses, and phalanges, in addition to teeth, ivory, and antler, are also known to have been used in lithic manufacture. As these more rarely used source materials were often recovered alongside large accumulations of bone refuse, the intentional selection of alternative osseous remains may imply functions different from that of long bone shaft fragments used as retouchers. This is likely the case with a variety of antler fragments interpreted as pressure and punch tools from the Mesolithic of northern (David and Pelegrin, 2009; David and Sørensen, 2016) and southeastern Europe (Vitezović, 2018). Apart from these few exceptions, the functions of the bone tools in question can only be determined through analysis of the use traces.

Several authors have suggested that compressors used in pressure tasks may display short linear impressions, sometimes with secondary striations, as well as an increased occurrence of scaled use areas, whereas percussion traces on retouchers are characterized by long linear impressions, sometimes with internal scaling, abundant punctiform or trihedral impressions, and less frequent scaled use areas (e.g., Rigaud, 1977; Ahern et al. 2004; David and Pelegrin, 2009; Mozota 2013). Costamagno et al. (2018) outlines a system to differentiate retoucher types based on use area characteristics and features of individual marks, but these classifications are quite specific to bone retouchers used in the production and maintenance of Quina scrapers at Les Pradelles, France. Thus, despite the collective body of experimental research on bones used in the manufacture and maintenance of lithic tools, there are no universally applicable links between particular tasks or functions and specific categories of use traces (see Mozota, 2018). Variables such as anatomical element, bone freshness, bone density, type of lithic raw material, lithic tool type, duration of use, and user experience, to name just a few, are important in the creation of use traces, but have received only little experimental inquiry on an individual basis. Furthermore, different combinations of these and other variables have not been fully evaluated, nor has overprinting of different types of lithic manufacture and maintenance tasks. These lines of experimental research are ripe for further investigation, and, after rigorous testing, would provide valuable insight into the spectrum of utility for these bone tools.

Time and space

Matters of temporal and geographic scale are important in discussing the origin and development of bone tool technologies. Whereas two possible bone hammers from Bed II at Olduvai Gorge, Tanzania (Backwell and d'Errico, 2004), point to a very early origin of bones used as tools in Africa more than one million years ago, similar implements used in the manufacture and maintenance of lithic tools only re-appear in sub-Saharan contexts at 75,000 years ago in South Africa (Henshilwood et al., 2001; d'Errico and Henshilwood, 2007). On the other hand, the use of bone retouchers and similar tools in Europe appeared around 500,000 years ago at Boxgrove, UK, during the Lower Palaeolithic (e.g., Roberts and Parfitt, 1999) and survived until at least Neolithic times (e.g., Taute, 1965). These osseous technologies were integrated into a multitude of local and regional lithic industries, and were not only shared among both *Homo heidelbergensis* and *Homo neanderthalensis*, but also persisted through the replacement of Neanderthals by anatomically modern humans *(Homo sapiens)* in Europe. In this regard, Europe and the adjacent Levant is presently the only region where the development of these technologies over time and space can be studied in great detail.

The corpus of works in this volume comprises regional syntheses, temporal overviews, and site-specific depictions of bone tool use covering much of Europe and the Levant from 400,000 to roughly 5000 years ago. Northern and southern France are particularly rich in Palaeolithic sites with bone retouchers (Costamagno et al., 2018; Daujeard et al., 2018; Sévêque and Auguste, 2018). Spanish sites are not featured in this volume, but the use of bone retouchers on the Iberian Peninsula spans the entire Palaeolithic period (e.g., Mozota, 2009; Rosell et al., 2015; Moigne et al., 2016; Tejero et al., 2016). To the north in Belgium, research through museum collections has revealed a trove of bone tools dating from the Middle Palaeolithic (Abrams, 2018). Continued work on these collections is likely to yield even more bone tools from older and younger periods. In Germany, bone retoucher use is well-studied from the Swabian Jura in the south (Toniato et al., 2018) and extends deep into the Middle Pleistocene with the metapodial hammers and other bone tools from Schöningen on the northern Plains (Hutson et al., 2018). The Italian peninsula, particularly in the Alpine north, contains numerous archaeological sites with bone retouchers (Jequier et al., 2018; Thun

Hohenstein et al., 2018). Further to the east, tools made from a variety of osseous materials span from at least the Middle Palaeolithic in Czech Republic (Neruda and Lázničková-Galetová, 2018) to the Neolithic in the Balkan Peninsula (Vitezović, 2018). In the adjacent Levant region, evidence suggests the potential for a longstanding tradition of bone retoucher use covering the entire Palaeolithic period (Rosell et al., 2018; Yeshurun et al., 2018).

Altogether, the works presented here offer a wide-ranging view of bone retoucher use across time and space. We have focussed mainly on Europe and the Levant, but similar technologies are known from nearly every corner of the globe. And yet, this is merely a glimpse of the potentially unknown temporal and spatial distribution of bones, antlers, ivory, teeth, and the like, used in the manufacture and maintenance of lithic tools. Continued investigations of existing collections, not just in Europe, but globally, will undoubtedly yield a more clear view of the origins and development of bone tool technologies. Building upon a more complete temporal and geographic continuum, we may refine our ideas about the technological, behavioural, and cultural significance of bone tools use, as well as formulate equally important explanations for the absence of such technology

Associated archaeology and human behaviour

The most important and lasting outcomes of this volume are the conclusions drawn about the significance of bone tool technologies for the study of human behavioural evolution. Examining both the lithic and faunal assemblages associated with these tools, together with their depositional settings, provide a holistic view of the economic decisions and organisational strategies of Palaeolithic peoples. In this respect, we can use this class of bone tools as a medium to explore the biological, behavioural and ecological dynamics of technological innovation.

With the keynote paper, Davidson (2018) revisits the question of language origins and the potential importance of bone tool technology for understanding modern human cognition. Davidson theorizes on the affordances brought about by the development of bone tool technology and how we may arrive at a better understanding of hominin niche construction and adaptation through analyses bone tools within the archaeological record. In this way, tool use, language, and cognition become intimately entwined as driving factors behind hominin behavioural evolution.

While the bulk of bone retouchers are known from Palaeolithic contexts in Europe, the oldest examples of bone tool technology presented in this volume come from the Lower Pleistocene in the Levant, at Qesem Cave in Israel, dating to perhaps 400,000 years ago. Here, Rosell et al. (2018) describe a series of bone retouchers attributed to the Acheulo-Yabrudian Cultural Complex used in the production and maintenance of Quina and demi-Quina scrapers for hide-working activities within the cave.

Beyond Qesem Cave, bone retouchers were thought to be absent from the Levant region. Based on the findings of Yeshurun et al. (2018) from Ahmarian / Aurignacian deposits at Manot Cave, Israel, the use of retouchers in the Levant now extends to the early Upper Palaeolithic. Owing to the long hiatus between the use of retouchers at Qesem and Manot, bone retouchers may not have been a permanent feature of local tool-kits, but an imported cultural tradition, together with other Aurignacian technologies. Equally possible, and perhaps even more encouraging for future studies, is that bone retouchers are simply an (as yet) unrecognized phenomenon in the rich faunal record of the Levant.

Another rare occurrence, or perhaps underreported, are the metapodial hammers from the Schöningen 13II-4 "Spear Horizon" in Germany presented by Hutson et al. (2018). The Middle Pleistocene hominins inhabiting the Schöningen lakeshore environment, armed with their wooden spears, used horse metapodials for breaking bones and in lithic maintenance. No hammerstones have been reported from the "Spear Horizon" or other nearby sites; thus, it seems bone hammers replaced hammerstones for a variety of tasks, a behaviour that is unique to Schöningen.

Moving to southern Germany, Toniato et al. (2018) continue a long tradition of research in the Swabian Jura with a review of retouchers from five Middle and Upper Palaeolithic archaeological sites. This comparative study details the prevalence of bone retouchers made from limb shaft fragments during the Middle Pleistocene, which were succeeded by a broader range of skeletal parts used as tools during the Aurignacian, and eventually replaced by stone pebble tool retouchers during the Gravettian. The Swabian Jura is well known for its many sites with personal ornaments and portable art objects made from a variety of osseous materials, and continuing work is revealing that objects made from bone were also an integral part of the human technological repertoire well into the Upper Palaeolithic.

France has a long history of archaeological research on "os à impressions", and Daujeard et al. (2018) offer a reappraisal of bone retoucher use in southeastern France, from the Lower and Middle Palaeolithic. Bone retouchers at the oldest sites (MIS 11) are rare, but their frequency grows during MIS 9 and 7, and become very prevalent in deposits associated with MIS 5. At these more recent sites, there does not appear to be a single factor that governs the presence/absence or abundance/rarity of retouchers in southeastern France, but is likely tied to a combination of scraper production, mobility strategies of the tool-kit, and the types of activities performed in and around the site.

Sévêque and Auguste (2018) take a similar comparative approach with bone retouchers from a number of Lower and Middle Palaeolithic sites in northern France. As is apparent in southeastern France, the presence of bone retouchers in the north is multi-factorial, and cannot be explained in relation to the production of specific tools or site function alone.

In what is one of the largest collections of bone retouchers from a single site, Costamagno et al. (2018) detail 408 bone retouchers from Middle Palaeolithic deposits at Les Pradelles in southwest France. This remarkable series of bone retouchers is associated with Quina Mousterian lithic technology and the secondary processing of a large number of reindeer. The abundance of bone retouchers made from the bones of reindeer carcasses transported back to the site indicates their vital nature at task-specific butchery sites. Bone retouchers actually outnumber Quina scrapers at the site, suggesting that a many of the lithic tools were exported for use at nearby locations. Altogether, the holistic view of bone retoucher use at Les Pradelles shows that the exploitation of animals for subsistence and as a source for raw materials was well integrated into the system of lithic production.

To the north in Belgium, Abrams (2018) highlights the need for the continued study of museum collections with the documentation of 535 bone retouchers from 14 recent and historic excavations of Middle Palaeolithic sites. Preference for bone tool raw material mirrors that of the most common large mammalian ungulates, but the rare cave bear and Neanderthal bones were also used as tools. The *chaîne opératoire* determined for the production of four conjoining retouchers made from a cave bear femur suggests a certain degree of predetermined form.

On the Italian peninsula, bone retouchers and similar tools are not particularly numerous, but Thun Hohenstein et al. (2018) discuss 79 tools from two Middle Palaeolithic cave sites in the pre-Alpine north. The bones selected for use were limb bone shaft of medium- to large-sized ungulates, which are the most abundant remains from the sites. This pattern is duplicated at most sites with bone retouchers and marks the selection of bones from the remains of recently butchered animal carcasses or from debris littering the sites.

Jequier et al. (2018) also studied the retouchers from two north Italian sites. Retouchers associated with large Quina scrapers are larger, thicker, more intensively used, and the pits and scores are heavily impressed in the bone. This appears to be an intentional selection of the most robust skeletal elements available for production of Quina scrapers. Another interesting point raised during this study is that scraping marks associated with the pits and scores produced by retouch may not be related to the preparation of the bone surface or the removal of the periosteum, but rather the preparation of the margins of the lithic blank prior to retouch.

Remaining in the Middle Palaeolithic, but moving east to the Czech Republic, Neruda and Lázničková-Galetová (2018) describe two unique retouchers made of mammoth ivory from Micoquian layers at Kůlna Cave. As compared to the earlier deposits, the Micoquian records a shift in the relationship between mammoths and Neanderthals in terms of subsistence and the use of ivory as tools.

Finally, Vitezović (2018) rounds out the volume with a review of retouching tools from the Mesolithic and Neolithic in southeastern Europe. While Palaeolithic bone retouchers and similar tools are quite simple and required little modification before use, this trend did not continue into the Mesolithic and Neolithic. Tools from these later periods were rarely unworked, *ad hoc* fragments of bone and antler, but intentionally shaped, heavily curated, and highly prized items. Antler appears to be the preferred raw material, mostly used for pressure flaking or as punch tools.

From these pages, a more clear view on the origins and development of bone tool technology is emerging. The early use of bone in the manufacture and maintenance of stone tools constituted a conceptual transformation of bone refuse to bone as an exploitable raw material. Whether we can equate this phenomenon with the modern concepts of recycling, reuse, repurposing, or something similar is a topic for debate, but the more important matter is that around 500,000 years ago, and probably earlier, Palaeolithic hominins began to view the living world around them differently. Animals once exploited only for their meat and other edible parts also contained bone and other hard, osseous materials suitable for modifying stone. Fresh bone, and even-semi-dry bone, has certain elastic properties that may have offered an advantage over stone when sharpening the edge of a tool, and it is clear that these properties were known to Palaeolithic hominins.

The means of acquiring bone, antler, ivory, teeth, etc., for maintaining lithic tool-kits have consequences for Palaeolithic hominin mobility. One reliable source of these materials would have been from carcasses killed directly by hominins. There is evidence from even the earliest sites that bone retouchers and percussors were fashioned from the bones of recently dead animals during the butchery process. While cutting meat from an animal carcass, the cutting edge of a tool becomes dull; thereafter, a bone is selected from among the debris, the surface of the bone and the lithic edge are prepared, and then the bone is used to rework the dulled tool. These short sequences of events are recorded in the butchered and utilised bones. At other sites, there is evidence that some bones used as retouchers were selected from the remains of a previously butchered animal carcass. This is common at habitation sites, such as caves, where bones accumulated over repeated visits. Open-air hunting and butchery sites also include bone refuse used as retouchers. Such locations with readily available and abundant bone for use as tools would have been an important resource on the landscape, further affecting the reoccupation of habitation sites and the reuse of butchery sites. When viewing animals in this technological sense, as a source of raw material, hominins become somewhat less reliant on stone and perhaps less tethered to known sources of lithic raw material. In some contexts, bones may have been transported across the landscape for use in an array of lithic maintenance tasks. Over time, retouching tools made from bone, and especially antler, became a common feature of an increasingly mobile tool-kit. Even the ill-fated Ötzi, who died atop the Tyrolean Alps some 5000 years ago, kept with him an antler retoucher or pressure flaker to sharpen his flint dagger and arrowheads, despite also carrying a bronze axe.

Future directions

This volume builds on more than a century of research on the influence of bone tool technologies for the study of human behavioural evolution. The last major compilation of papers specific to bone retouchers and the like, *Retouchoirs, Compresseurs, Percuteurs…Os à Impressions et Éraillures* (Patou-Mathis, 2002), left an indelible mark on the field and stimulated a renewed interest in Palaeolithic bone tool technologies. Since that publication, great strides have been made in the conceptual, methodological, and technical study of these tools. The works presented here reflect that progress, with the optimism to inspire future studies on the origins and development of bone tool technologies.

An important point moving forward is to not lose sight of the importance of bone retouchers and similar tools when discussing prehistoric technology. These tools, once relegated as mere curiosities and often overlooked, can now be regarded as critical components of many archaeological assemblages and should no longer be considered rare or unusual; nor should we restrict our expectations of where these artefacts ought to be found to their current geographic and temporal distributions. The absence of these tools from a site, region, or time period can be just as informative as their presence and should be noted together with other taphonomic features of faunal assemblages. At sites where organic preservation is an issue, we may be able to indirectly infer the use of bone retouchers through features in the lithic assemblages. In other cases, their complete absence provides an interesting contrast in terms of site function and organizational strategies. Above all, it is essential to consider the presence and absence of bone retouchers in conjunction with lithic knapping strategies and the treatment of animal carcasses, as some activities appear to have been reliant on the extensive use of retouchers, such as the Quina method to produce tools used in processing animal hides (e.g., Costamagno et al., 2018). In this respect, we need to look beyond the individual bone tool for answers to broader questions about hominin behaviour; we must take a holistic view of the complete archaeological record to trace the origins, development, and significance of bone tool technologies.

All of this begins by acquainting the next generation of researchers with the existence of bone retouchers and similar osseous technologies and incorporating current methods for identification of these tools into regular zooarchaeological instruction. We add to that a call to renew or continue investigation of museum collections in order to fill in the supposed temporal and geographical gaps in our understanding of bone tool technologies.

Once bone tools have been identified, we must take advantage of the most up-to-date digital imaging technologies to record the impressions, or marks, on the bone surfaces. Modern digital microscopes, scanners, and other three-dimensional imaging technologies capture high-resolution surface topographies of a variety of materials, including bone and other osseous materials, allowing for individual marks to be studied in great detail with powerful image analysis software. These techniques will become invaluable tools for identifying different types of marks at the micro- and macroscopic levels, and will lead to a better understanding of how different measurable characteristics of marks may equate to different functions. While these machines and software may be costly (although there are open-source software options), the entire field of archaeology has become increasingly reliant on virtual methods of data collection, and a failure to adopt these new methods of analysis would be a missed opportunity for progress.

We conclude with a call for more rigorous experimental programmes to clarify the spectrum of utility for bone retouchers and similar tools. Important in this regard are scientifically structured experiments to address specific research questions and to test hypotheses. These experiments (together with new imaging technologies) can help move beyond the simple identification of bone tools and begin to address larger questions regarding the functional, logistical, and behavioural contexts for these implements during the Palaeolithic and into the Neolithic.

Looking to the future, it is important to keep in mind that these tool-making tools are more than just prehistoric artefacts. They represent a novel approach to better understand technology and innovation, features that are ingrained in what it means to be human.

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This volume is a collection of papers from the conference titled "Retouching the Palaeolithic: Becoming Human and the Origins of Bone Tool Technology" held in October 2015 at Schloss Herrenhausen in Hannover, Germany. With major funding from the Volkswagen Foundation's Symposia and Summer School initiative, the conference brought together an international group of scientists from an array of research backgrounds to explore the origins and development of bone tool technologies in prehistory, specifically retouchers, compressors and percussors used in various lithic knapping activities. The diverse conference attendance generated an assortment of perspectives on bone tool use covering western Europe to the Levant, from the Lower Palaeolithic to Neolithic times. Collectively, these papers provide an overview on how the integration of bone tools with other Palaeolithic technologies influenced human subsistence and other socio-economic behaviours over time and space. In the end, this volume is not just about bone tools. Rather, this compilation is intended to stimulate broader ideas on technology and innovation, for the ability and desire to create new tools truly lies at the core of what makes us human.

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