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A newly discovered antler flint-knapping hammer and the question of their rarity in the Palaeolithic archaeological record: Reality or bias?

The question of the rarity of antler flint-knapping hammers in the Lower and Middle Palaeolithic archaeological record: reality or bias?

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Abstract

The use of soft (bone, antler, tooth and wood) hammers and retouchers is a key innovation in early stone tool technology, first appearing in the archaeological record with Lower Palaeolithic handaxe industries (e.g. Boxgrove, UK ~ 500 kya). Although organic knapping tools were undoubtedly a component of early human toolkits and are essential, for example, for the manufacture of finely-flaked handaxes, Mousterian scrapers and Upper Palaeolithic blades tools, such archaeological finds are exceptionally rare. In this study, we present qualitative and quantitative analyses (focus variation optical microscope, scanning electron microscope, micro-CT scanning and energy dispersive X-ray spectroscopy), to characterise use-damage on an antler base from Laugerie Haute (France). This specimen was originally identified as a waste-product from splinter manufacture, and the use-damage appears to have been missed. The new analysis shows that prior to being used as a flint-knapping percussor, the red deer antler had been further modified to reduce the length of its beam and to remove the tines. Although minimally used, characteristic use-damage includes attrition (pits and scores), compression of the antler matrix and flint chips embedded within some of the percussion features on the base of the burr. An AMS radiocarbon date of 12385 ± 55 BP (calibrated) confirms a Magdelanian context for the hammer. The fact that the Laugerie Haute knapping hammer went unrecognised in a well-studied and accessible collection for almost 200 years since its discovery, suggests that antler hammers may be more common than generally assumed. Only further re-examination of prehistoric antlers in museum collections will confirm whether the apparent rarity of antler hammers during the Lower and Middle Palaeolithic is real phenomenon or the result of analytical biases.

Keywords:

Knapping tools, CT-scanning, focus variation microscope, scanning electron microscope, energy dispersive X-ray spectroscopy, Laugerie Haute.

1. Introduction

The experimental reproduction of archaeological flint tools is an important source of information for understanding how prehistoric stone tools were manufactured and for investigating associated aspects of past human activities (e.g. Vincent, 1993; Armand and Delagnes, 1998; Bourguignon, 2001; Mallye et al., 2012; Bello et al., 2013c). Several popular books are now available that describe how to knap stone tools (e.g. Whittaker, 1994; Butler, 2005; Turner, 2013). Modern flint knapping kits generally include a range of hard hammers (hammer stones – often stream-rounded pebbles and cobbles) to prepare the piece, or to remove larger flakes, as well as softer organic hammers for more carefully contolled removals. Soft hammers are used, for example, to thin and shape bifacial tools (e.g. handaxes) by percussion, and antler tines can be used as pressure-flakers in the final stages of bifacial tool working. Modern knappers favour soft hammers made from the beam or basal part of deer antlers, usually red or fallow deer or even moose. Modern knappers use moose antler billets which are heavier and denser than deer antlers, however, as none has ever been found in the archaeological record, these are unlikely to be widely applicable in most archaeological experimentations. The natural shape (billet form) and physical and mechanical properties that combine strength with resilience, make antlers particularly suited for use as soft hammers. Despite the preference of modern knappers for antler hammers, evidence for the use of antler percussors in the Lower and Middle Palaeolithic is generally rare and restricted to very few sites. This paucity of data contrasts with evidence for the significant role of bone 'retouchers' in this period, a type of organic material rarely used or consider by modern knappers as suitable for knapping hammers or pressure-flakers (Wenban-Smith, 1989). In Europe and Asia, bones used as retouchers have been recovered from numerous Neanderthal sites (e.g. Henri-Martin, 1906; Chase, 1990; Auguste, 2002; Griggo, 2002; Veselski, 2008; Conard et al., 2012; Jéquier et al. 2012; Mallye et al., 2012; Abrams et al., 2014; Daujeard et al., 2014; Romandini et al., 2014) and, increasingly from Lower Palaeolithic sites (Rosell et al., 2011; Blasco et al., 2013; Rosell et al., 2015; van Kolfschoten et al., submitted). The limits of modern knapping experiments are highlighted by the much wider range of knapping tools found with Upper Palaeolithic and later lithic industries in Eurasia and North America; these include a various types of hammers, retouchers and punches made from a range of raw materials including bone, teeth (including ivory) and antler (Bourlon, 1907; Bordes, 1974; Saunders et al., 1991; Averbouch and Bodu, 2002; Haynes, 2002; Leroy-Prost, 2002; Castel et al., 2003; Steguweit and Trnka, 2008; Tartar, 2012; Évora, 2013). More recent (Neolithic) examples may include modified antlers from the ceremonial site of Durrington Walls (Wiltshire, UK) and flint mines at Grimes Graves (Norfolk, UK), some of which appear to have served a dual use as picks and hammers (Clutton-Brock, 1984, plate 12); whether any of these antlers were used for knapping is currently unclear.

Antler hammers are known only from a very few Palaeolithic sites in Europe (Girod and Massenat, 1906 pl. XCVI; Breuil and Barral, 1955; Bordes, 1974 fig.4; Bolus, 2003), occuring as single examples in often rich archaeological horizons that also include bone retouchers (Patou-Mathis and Schwab, 2002; Teyssandier and Liolios, 2003). Currently, the oldest antler knapping hammers are from Boxgrove (UK) and date to about 500, 000 years ago (Pitts and Roberts, 1997; Roberts and Parfitt, 1999; Pettit and White, 2012; Smith, 2013; Stout et al., 2014). It isn't until the end of the Palaeolithic that innovations in the use of organic raw materials incorporated antler working to a important degree (Vialou, 2004, Vitezović, 2014). Prior to this, there is little evidence for the use of antlers as raw material, other than rare examples of Lower and Middle Palaeolithic soft antler hammers. This may emerge from various factors including choice of raw material (Jaubert, 1999), techniques of debitage (Inizan et al., 1992), preservation and survival in the archaeological record, or Middle Palaeolithic site occupation and activity (Costamagno et al., 2006; Maureille, 2010; Niven et al., 2012).

The rarity of archaeological evidence for antler hammers remains to be adequately explained. A possibility is that antler percussors may not have been systematically recognised in archaeological collections or that they have been misidentified, either as naturally modified pieces or as waste products from antler working (Olsen, 1989; Jin and Shipman, 2010; Pétillon and Ducasse, 2012). Support for the latter suggestion comes from a previously unrecognised Palaeolithic knapping antler hammer from Laugerie Haute (France). This example was found during a survey of Pleistocene archaeological bone collections in the Natural History Museum (NHM), London, and identified as a possible flint-knapping hammer by one of us (S.A.P.) in April 2011. This knapping hammer had been overlooked because it was curated with other antlers that have been used to make antler-splinters.

In this his paper, we present a detailed description and analysis of the Laugerie Haute antler and evaluate the implications of this find for wider debates concerning the rarity of antler hammers in the archaeological record, particularly for Lower and Middle Palaeolithic.

2. Material and Methods

2.1. Laugerie Haute antler knapping hammer

In 2011 a survey of Upper Palaeolithic faunal remains and artefacts stored at the NHM was carried out in order to identify humanly modified specimens. Important specimens found during this survey included an engraved reindeer antler from the Magdalenian site of Neschers, France, (Bello et al., 2013a and 2013b) and the previously unrecongnized antler hammer from Laugerie Haute, described in this paper (Figure 1). The context and curatorial history of the Laugerie Haute antler hammer (NHMUK PA E 7605) is poorly documented. The antler is marked in black ink "*Laugerie Ht ou*". "Ht" and "*ou*" being the abbreviation of the French words "Haute" and "*ou(est)*" respectively, the antler was most certainly found during excavations at Laugerie Haute West (Figure 1B).

The site of Laugerie Haute (Dordogne, France) is located about 2 km northwest of the village of Eyzies-de-Tayac on the west bank of the river Vézère. It is a large rock shelter, about 180 m long and 35 m wide, with approximately 6 m of archaeological layers (Bordes, 1958), spanning the late Gravettian to the Magdalenian (Demars, 1995a). The site has been excavated from the 1860s by Peyrony and Peyrony (1938), Bordes (1958), Smith (1966) and Demars (1995b). Among the numerous finds, antler '*percuteurs*' were mentioned since 1900 (Girod and Massenat, 1900; Bourlon, 1907); these possibly represent the first prehistoric organic knapping hammers to have been recognised as such. Capitan and Breuil (1902), Peyrony and Peyrony (1938) and Bordes (1958, 1974, 1978, 1992) report an important bone and antler industry as raw material and various stages of manufacture in Upper Palaeolithic levels at Laugerie Haute East and Laugerie Haute West, as do Girod and Massenat (1900) and Maury (1925) at nearby Laugerie Basse.

New radio-carbon determination was undertaken at the the Research Laboratory for Archaeology and the History of Art (RLAH), University of Oxford (Oxford, UK). A radiocarbon determination of 12,385 ± 55 (corresponding to a calibrated date of about 12,647± 335 BC) confirms an Upper Palaeolithic (Magdalenian) age for the Laugerie Haute antler.

2.2. Analytical methods

The antler was examined following the protocol proposed by Bello et al. (2013c). Initial observations were conducted with a variable magnification binocular microscope to identify and record the distribution and extent of use-damage and to locate lithic chips embedded in the pedicle of the antler. Observations were aided by a fibre-optic light source. Under low-incidence illumination it was possible to observe embedded lithic chips, which were visible as translucent inclusions against the opaque and darker antler matrix.

Micro-computed tomography (micro-CT) was undertaken to record the surface topography and to gauge the extent of surface damage in relation to antler density. The specimen was scanned using a HMX-ST CT 225 System (Metris X-Tek, Tring, UK). The Laugerie Haute specimen was placed centrally in the CT scanner. In order to obtain the highest possible resolution only the basal part of the antler was scanned. This resulted in a truncated artefact, which, however, did not affect the analysis. The X-ray and scan parameters were: tungsten target 165 kV, 160 mA, 6284 projections with 0.354 second exposure and a voxel size of 0.0393 µm. The micro-CT data were reconstructed using CT-PRO software version 2.0 (Metris X-Tek) and rendered using VG Studio MAX 2.1 (Volume Graphics, Heidelberg, Germany).

To explore the micro-topography of the use-damage we employed focus variation microscopy (FVM). The Alicona Infinite Focus microscope (AIFM) used in this analysis provided a true-colour rendering of the pedicle surface in three dimensions (Bello and Soligo, 2008; Bello et al., 2011; Danzl et al., 2009). Images were captured using a 2.5x objective lens (magnification x 45.72) and a vertical and lateral resolution of 10 µm and 3.47 µm respectively; a 5x objective (magnification 91.44x, vertical resolution = 1.74 µm, lateral resolution = 1.49 µm) was used to record features of the embedded lithic fragments and morphology of the surface marks. The hammer was mounted vertically to expose its basal portion on a soft moulding support and the whole pedicle was scanned.

To record finer details of the use-damage, selected areas were examined with a LEO1455VP scanning electron microscope (SEM) equipped with an energy-dispersive X-ray microanalysis system (EDX). The SEM was operated in variable pressure mode (chamber pressure 15 Pa), enabling back-scattered electron (BES) images to be obtained without the application of a conducting layer on the specimen. Topographic BSE imaging mode was used to reduce elemental contrast between light element-rich silica (with a low BSE coefficient, hence dark) and bone, with calcium and phosphorus giving a higher BSE coefficient (bright). The operating parameters were: accelerating voltage of 15 kV; spot size 500; pole-piece to specimen working distance of 15 mm. The EDX microanalysis was carried out using an Oxford Instruments X-

Max 80 Silicon Drift Detector and INCA software. The working distance between the specimen and the EDX detector varied between 14 mm and 22 mm.

The identification of the antler as a knapping tool was based on comparisons with archaeological and experimental examples (Breuil and Barral, 1955, pl III; Bordes, 1974; Averbouch, 1999; Averbouch and Bodu, 2002; Bello et al., 2013c). The much more extensive literature on bone retouchers shows that the damage patterns are more-or-less analagous (e.g., Patou-Mathis and Schwab, 2002; Castel et al., 2003; Verna and d'Errico, 2011; Jéquier et al., 2012; Mallye et al., 2012; Abrams et al., 2014). For this reason we follow the terminology of Mallye et al. (2012), who defined 'used area' as the zone where the knapping-marks are concentrated. Their terminology identifies 'pits' as sub-triangular or ovoid depressions, and 'scores', which are depressions exhibiting a linear form.

3. Results

The Laugerie Haute hammer was made from a naturally shed antler of a red deer (*Cervus elaphus*), from which both basal tines have been removed, together with the entire beam and crown above the bez tine (Figure 1). The hammer is 150 mm long and the circumference around the burr is 207 mm. The antler is not exceptionally large and probably derives from a fully mature individual.

The beam displays clear modifications associated with the production of splinters. This is indicated by a set of at least six parallel grooves, some of which pentrate the cortical tissue and extend as shallower grooves as far as the coronet (Figures 1A, B and C). The longest grooves are found on the posterior face. These grooves penetrate the spongy tissue and breaks between the grooves show that the splinters had been snapped to separate them from the beam (Figures 1C-D). The terminations of the other grooves are well-defined, but superficial. After the removal of the splinters, the beam was chopped about its circumference to remove irregularities from the groove-and-splinter working. A similar technique was used to remove the brow and bez tines. Traces on the resulting bevelling include closely-spaced rectilinear facets. These features show that the tines and beam were removed by chopping with a straight-edge flint tool.

The short beam section thus created served as the hammer handle. The function of the hammer can be inferred from characteristic damage found on the base of the pedicle. Here, the modifications are consistent with battering marks produced during flint knapping, notably chop-like gouges and pits, some of which contain small lithic fragments. The intensity of use-wear is greateest in the centre of the pedicle. This area is more heavily flaked than the peripheral areas closer to the coronet. Differential attrition is also clearly visible on the CT sections, which show the central concavity (Figures 2A and C) where the densest area of pits, scores and gouges is located. Other types of microscopic modifications associated with the pits and scores include crushing and flaking (Figure 3). Pits and scores are distributed uniformly, but with a higher concentration on the medial side of the concavity. Overall the frequency of pits ($n = 24$) and scores ($n = 25$) is comparable. Measurements show that the pits are on average slightly longer (mean of maximal length 4.48 mm) than scores (mean of maximal length 4.21 mm), and that pits (mean depth 613.10 µm) are significantly deeper than scores (mean depth 424.39 µm; $t=3.06$, $df=47$, $p<0.004$; table 1). This suggests that pits were probably produced with a greater amount of force in the knapping action than that used to produce the scores.

Examination under the binocular and AIFM microscopes identified three lithic fragments, all embedded in scores (Figure 3). These are also visible in CT sections (Figure 4). The CT images show that the lithic fragments are rather deeply embedded at an oblique angle to the surface of the burr (Figure 4 B and C). EDX spectroscopy was performed to determine the elemental composition of the lithic inclusions. Elemental microanalysis of one of the fragments shows that it is composed of silicon, with an associated oxygen peak consistent with silicon dioxide (SiO_2), either as a crystalline material such as quartz or a cryptocrystalline material like flint or chert (Figure 5, spectra 1 to 3). Analyses of the surrounding matrix (Figure 5, spectra 4 and 5) showed the presence of calcium and phosphorus peaks typical of bone. Small peaks of carbon, aluminium and iron are probably associated with environmental contamination, either from sediment particles or from specimen handling (peaks of sulphur, carbon and potassium). The EDX maps (Figure 6) showing the surface distribution of diagnostic chemical elements clearly show the morphology of the flint chips (silicon-rich area) bounded by antler (calcium-rich area).

4. Discussion and conclusion

Little is presently known about the curatorial history of the Laugerie Haute antler hammer. It is not clear how and when the specimen was acquired by the British Museum (London) and there is no direct record of this specimen having been studied or displayed in the Museum's public galleries. In 1881, when the NHM became independent from the British Museum, the collections were split and the Laugerie Haute antler was among the specimens moved to the new building in South Kensington. At the time, it was assumed that the NHM kept exclusively what were then thought to be unmodified faunal remains or the waste products resulting from the manufacture of bone ans antler tools. Because evidence for groove-and-splinter working is clearly visible on the Laugerie Haute antler, it is likely that this specimen was regarded simply as a waste product from antler working. The present study, however, shows that the antler base was further worked to make a knapping hammer, and that the hammer was used to work flints. With respect to microscopic use-wear, our findings match those described in earlier studies (e.g.; Bordes 1974; Olsen 1989; Mallye et al. 2012; Bello et al., 2013c; Abrams et al. 2014). Characteristic use-wear features on the pedicle include attrition resulting in a 'hollowing' of the base, the result of numerous overlapping and inter-cutting pits and scores, some of which contain microscopic flint chips. These are the distinguishing features of knapping damage that are used to identify knapping tools and to distinguish them from natural taphonomic alterations (d'Errico and Villa, 1997; Jin and Shipman, 2010). When compared with experimental antler knapping hammers and other archaeological examples (e.g. Bordes, 1974), the comparatively low density of pits and scores observed on the Laugerie Haute hammer suggests that this hammer was not heavily used. The higher concentration of indentations on the medial side of the concavity may indicate that the hammer was used by a right handed person.

The discovery of a previously unrecognised antler knapping-hammer in the Laugerie Haute collection suggests that antler hammers may not have been recognised in museum collections or that other examples have been overlooked or misidentified, either as naturally modified pieces, or as waste products from tool manufacture (Jin and Shipman, 2010; Olsen, 1989; Pétillon and Ducasse, 2012). Despite the long history of research into the European Palaeolithic the paucity of evidence for the use of antler hammers in this period has been given surprisingly little consideration. The paucity of antler knapping hammers from the European Palaeolithic has allowed the view to persist that antler knapping tools played a insignificant, or undetectable, role in early knapping technologies. There are several reasons for these misconceptions and the failure to investigate the role and prevelance of different types of organic knapping hammers from early sites in Europe.

While it is true that antler knapping tools were a component of early human toolkits since at least the Lower Palaeolithic, the use of antler hammers may have occurred sporadically, perhaps emerging in different populations as a result of independent innovations. In this scenario, antler hammers use was not widespread and became prevelant only during the Upper Palaeolithic. This suggestion is supported by Rosell et al. (2015) who propose that although soft hammers were used by Acheulean knappers to shape large lithic tools (mainly bifaces), they were less suited to fashioning Middle Palaeolithic stone tools and that knapping during this period relied on more easily accesible bone retouchers. Moreover, Daujeard et al. (2014) have argued that Neanderthals preferred the physical properties of bone surfaces to the corrugated surface of antler beams, which made antlers less suitable for fine retouching tasks.

A further factor that may account for the rarity of antler hammers is the greater impact-resistance and elasticity of antlers when compared to bone knapping tools. For this reason, antler hammers are more likely to have been curated and used for a longer period of time than more easily availiable bones commonly used as retouchers. The more brittle bone retouchers, in contrast, would have had a shorter lifecycle (MacGregor and Currey, 1983; Jin and Shipman, 2010). This suggestion is supported by evidence from Geissenklösterle Cave, (Germany), for example, where rare lower Aurignacian antler hammers were found in association with a rich lithic industry (Bolus, 2003, Teyssandier and Liolios, 2003). The rarity of antler hammers at Geissenklösterle Cave can be contrasted with the abundance of stone, bone and other antler artefacts at the site, suggesting that antler hammers were more often re-used and curated tools (Teyssandier and Liolios, 2003 fig. 6). The manufacture of antler hammers would have required a more complex chain of actions that included procuring the necessary raw-materials (shed antler and chopping/cutting tools) and technological actions to reduce the length of the beam and remove the tines (Wenban-Smith, 1989). Long use-life can be inferred from the heavy damage observed on some archaeological antler hammers, supporting the suggestion that they were curated tools (Gál, 2011, Daujeard et al., 2014); for these reasons, antler hammers were less likely to have been lost or discarded than more easily procured bone retouchers. In contrast, bone retouchers are less resilient and more prone to breakage; they therefore had a much shorter use-life and probably functioned as *ad hoc* or expedient tools made on the spot to fulfil immediate needs (Rosell et al., 2015; van kolfschoten et al., submitted). For this reason, Middle Palaeolithic sites with over a hundred bone-fragments used as retouchers are not uncommon (e.g. Auguste, 2002; Auguste et al., 2005; Jéquier et al, 2012; Daujeard et al., 2014).

The scarcity of published archaeological antler knapping hammers may be accounted for by these factors alone, however, biases relating to the difficulties of identfying knapping damage on antlers should also be considered. This issue is part of a wider debate concerning the identification and interpretation of Palaeolithic bone, antler and tooth tools (Dart, 1957; Brain, 1981). A confounding factor is the problem of pseudo-tools created by natural taphonomic processes (e.g. Shipman and Phillips-Conroy, 1977; Shipman, 1981; Bromage, 1984; Behrensmeyer et al., 1986; Olsen and Shipman, 1988; d'Errico, 1993; Blumenschine et al. 1996; Backwell and d'Errico, 2004, 2008; Domínguez-Rodrigo et al., 2009). The study of knapping tools has greatly benefited from this debate, particularly in the case of bones used to shape, sharpen or retouch flint tools, where the study of this category of knapping tool has been beset by problems of misidentification and interpretation. The use of bones as knapping tools in the European Palaeolithic was first recognised and defined during the second half of the 19th century (Dupont, 1871, 39; Leguay, 1877; Daleau, 1883). This early work included detailed studies undertaken by Henri-Martin (1906, 1907), who illustrated and described Palaeolithic retouchers and hammers made from a range of different bone elements as well as antler knapping hammers. Subsequently, however, Binford (1981) questioned the interpretation of 'retouchers' as bone tools, suggesting that the modifications were the result of marrow breakage and carnivore chewing. Within the past few decades, new techniques of analysis and in-depth studies have re-examined the question of Palaeolithic bone retouchers, by highlighting the distinction between natural damage and knapping marks (Patou-Mathis, 2002; Mallye et al., 2012; Tartar, 2012; Abrams et al., 2014), with experimental studies demonstrating how these tools were used to work stone tools (Chase, 1990; Vincent, 1993; Armand and Delagnes, 1998; Karavanic and Sokec, 2003; Mallye et al., 2012). The recent resurgence in the study of retouchers is evident from the increase number of publications and research groups undertaking experimentation and systematic descriptions of bone retouchers. It is now apparent that such bone tools occur fairly frequently in Palaeolithic zooarchaeological assemblages, as illustrated by the growing number of sites from which bone retouchers have been identified (Figure 7). In part, this new phase of research was initiated by the work of 'La Commission de Nomenclature sur l'Industrie de l'Os Préhistorique' (2002). Similarly carefull and in-depth analyses have yet to be systematically applied to the study of Palaeolithic antler hammers, which remain poorly described and analysed (cf. Pitts and Roberts, 1997; Stout et al., 2014).

Our preliminary survey of Pleistocene faunal collections in the Natural History Museum (London) has resulted in the finding of a previously unidentified antler knapping hammer which, together with recent discovery of Lower Palaeolithic examples from Boxgrove, hints that the use of antler hammers was more widespread and certainly of longer duration than formerly believed. The application of high-resoluton imaging and analytical techniques has contributed to establishing criteria for idetifying knapping damage on antlers. Once applied to a broader range of sites, the consequences of such investigations may force a fundemental revision of the use of antler and other organic knapping hammers and of knapping techniques during the Eurpean Lower and Middle Palaeolithic. Only further careful re-examination of prehistoric antlers in museum collections will show whether the apparent rarity of antler hammers during the Lower and Middle Palaeolithic is real or the result of analytical biases.

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