A Middle Pleistocene Butchery Site at Great Yeldham, Essex, UK: Identifying Butchery Strategies and Implications for Mammalian Faunal History

Simon A. Parfitt[1,2]

Abstract

This paper discusses the evidence relating to an assemblage of Pleistocene bones and teeth discovered in a brick pit at Great Yeldham, Essex, in the late nineteenth century. Surviving elements from this collection, which include a bison foot bone with cut-marks, are now in the British Geological Survey Museum, Keyworth. A re-examination of this collection suggests that humans were present at the site during a temperate period in the earlier part of the late Middle Pleistocene. The cut-marks suggest that the hind foot was detached and discarded as butchery waste at the death site. Finally, the paper discusses the implications of humanly modified bones for understanding aspects of early human behaviour and distribution in Britain, which have hitherto largely centred around the study of stone tools.

Keywords Lower Palaeolithic · Biostratigraphy · Marine Isotope Stage 9 · Butchery · Cut-marks

Introduction

During the latter part of the nineteenth century, Pleistocene bones were recovered from a small brick pit at Great Yeldham, Essex. A selection of these finds was given to the eminent Victorian palaeontologist E.T. Newton by a Mr. Wade of Spayne's Hall, Great Yeldham, when he visited the site with T.V. Holmes of the Geological Survey in 1896 (Holmes, 1896). The site was evidently a rich source of bones, but sadly the much larger collection retained by Wade cannot be traced and Holmes commented that other bones collected before the intervention of Mr. Wade had been lost. Newton (quoted in Holmes, 1896) commented on the exceptional preservation

✉ Simon A. Parfitt
s.parfitt@ucl.ac.uk

[1] Institute of Archaeology, University College London, 31-34 Gordon Square, London WC1H 0PY, UK

[2] Centre for Human Evolution Research (CHER), Natural History Museum, Cromwell Road, London SW7 5BD, UK

of the bones: 'The four upper grinding teeth of … bear, which have been found here are in a perfect condition, and make one hopeful that more complete specimens of Pleistocene mammals will yet be met with at Great Yeldham, p. 117'. Tantalisingly, Whitaker (Whitaker et al., 1878) speculated that some of the bones had been broken open to extract bone marrow. No artefacts were found at the time, and the pit has long been infilled (Wymer, 1985).

The purpose of the present paper is to describe the assemblage of animal bones from Great Yeldham preserved in the British Geological Survey Museum, Keyworth. As well as providing valuable information on the age of the site and environmental conditions, the principal importance of this collection arises from the identification of a bison foot bone with cut-marks made with a flint tool. This previously unrecognised cut-marked specimen adds a new site to the meagre list of Middle Pleistocene localities in Northern Europe with evidence for human modification of animal bones (Binford, 1985; Gaudzinski & Turner, 1996).

The Site

The bones were recovered from a brickearth layer in a small clay pit (UK Grid Reference TL 756378) at Great Yeldham, Essex. The site occupies a position to the west of the River Colne, at an elevation of approximately 58 m OD. It overlooks a small tributary stream to the south, which has a floodplain at about 50 m OD (Fig. 1).

Whitaker first described the geological sequence, noting that the bones came from a thin (0.6 m) layer of light-coloured brickearth overlying 'a black sandy peaty earth with land and fresh-water shells' and sealed beneath a sequence of up to 2.7 m of brickearth and clay (Whitaker et al., 1878). Holmes (1896) suggested that these fossiliferous deposits were contained within a slight hollow on the surface of the 'Boulder Clay'. The relationship of the fossiliferous deposits to the modern drainage system is unclear, although the sediments may represent a terrace remnant associated with the Colne or one of its tributaries.

The Mammal Remains

The Great Yeldham faunal assemblage bears all the hallmarks of extreme collector and curatorial selection, with a strong bias towards easily identifiable specimens, particularly limb-bone epiphyses and teeth. Virtually all the bones have been broken, but the large-scale disposal of fragmented bone means that it is not possible to determine whether this is the result of breaking to obtain marrow, as suspected by the Victorian scientists, rather than damage inflicted when they were uncovered.

Indications of the taphonomic history of the bones can be derived from examining the surface modifications. Overall, the surfaces of the bones are well preserved and in fresh condition, an indication of rapid burial and recovery in a primary context. Bones with light polishing of raised areas and breaks and associated random fine striations were observed on several bones (e.g. bovid proximal femur heads GSM115545, GSM 115546); these features are indicative of trampling. Whereas
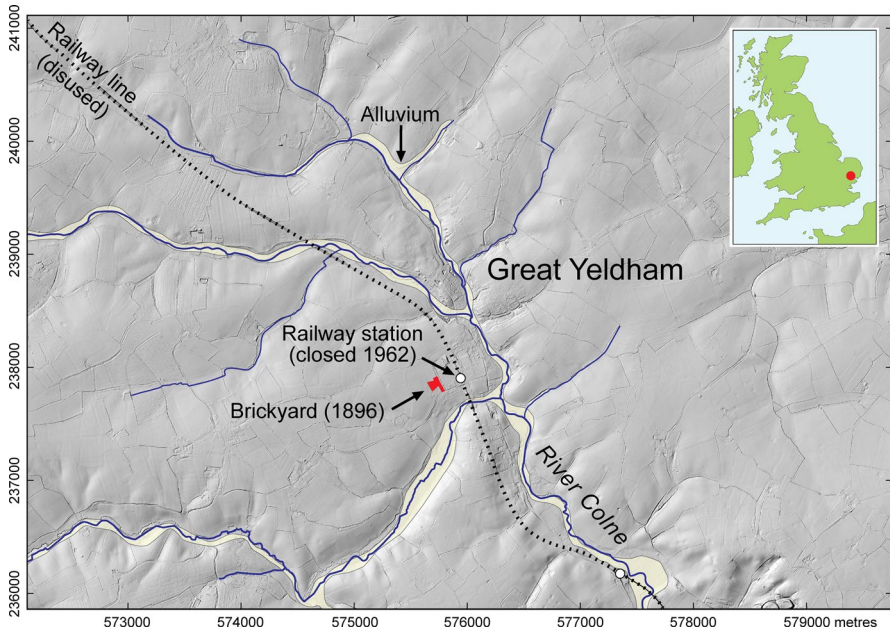
Fig. 1 Map showing the location of Great Yeldham, Essex (inset), and a digital terrain model (DTM) showing the position of the brickyard in relation to the local topography. The DTM is constructed from Environment Agency National LIDAR data at 1 m spatial resolution

most of the bones are unweathered, the cut-marked bison astragalus (GSM 115547) has localised weathering on the ridges on the anterior face and on the high points on the distal articular surface. The extent of the weathering suggests that the astragalus was resting on the ground or was partly exposed to the elements for long enough to allow weathering degradation of the exposed surface. Finally, rootlet marks were observed on the enamel of two bovid molars (GSM 115548, GSM 115549). No traces of carnivore chewing were observed.

The small size of the sample (Table 1) and the unknown proportion of material that was selectively discarded make it impossible to estimate the relative proportions of animals in the living population. One can merely remark that the range of mammalian taxa (8 taxa identified from 28 specimens) includes selected elements from a more diverse interglacial community.

Newton (quoted in Holmes, 1896) recognised six taxa comprising mammoth *Elephas primigenius* (=*Mammuthus primigenius*), narrow-nosed rhinoceros *Rhinoceros leptorhinus* (=*Stephanorhinus hemitoechus*), aurochs *Bos taurus* var. *primigenius* (=*Bos primigenius*), red deer *Cervus elaphus*, roe deer *Capreolus caprea* (=*Capreolus capreolus*) and brown bear *Ursus arctos*. Curiously, horse (represented by a lower cheek tooth in the collection donated by Wade) is not included in Newton's list. The only other study of the bones was undertaken by Schreve (1997), who updated Newton's taxonomy. Further work on the collection has shown that some of these records are erroneous, most notably that of mammoth, which is based on a small piece of a cheek tooth that is too fragmentary to identify with certainty (A.M.

Table 1 Large mammal remains from Great Yeldham in the British Geological Survey Museum. NISP = number of identified specimens

Taxon	NISP	Specimen
Carnivora		
Ursus arctos L., brown bear	3	GSM 11558, right upper canine, GSM 115560, left maxilla fragment with M^1 and M^2, GSM 115559, right maxilla fragment with M^1 and M^2 (GSM 115560 and GSM 115559 from same individual)
Proboscidea		
Elephantidae gen. et sp. indet., elephant	1	GSM 115527, cheek tooth fragment (identified as probably *Mammuthus primigenius* by E.T. Newton and cf. *Mammuthus primigenius* by Schreve, 1997)
Perissodactyla		
Equus ferus Boddaert, horse	1	GSM 115532, left P_4 or M_1
Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros	4	GSM 115530, left $M_{1 or 2}$; *Stephanorhinus* cf. *hemitoechus*: GSM 115529, upper cheek tooth fragment (probably M^1 or M^2); GSM 115531, lower cheek tooth fragment; GSM 115528, lower cheek tooth fragment
Artiodactyla		
Dama dama (L.), fallow deer	1	GSM 115541, left astragalus (identified as *Cervus elaphus* by Newton (quoted in Holmes, 1896) and Schreve, 1997)
Cervus elaphus L., red deer	4	GSM 115552, antler base (shed); GSM 115555, left $M_{1 or 2}$; GSM 115556, left M_3; GSM 115540, right scapula fragment (distal end)
Capreolus capreolus L., roe deer	1	GSM 115543, antler
Cervidae gen. et sp. indet	5	GSM 115553 and 115554, antler tines of medium-large cervid; GSM 115534, vertebra fragment (?cervid); GSM 115533, acetabulum fragment; GSM 115542, metapodial distal epiphysis (unfused)
Bison priscus Bojanus, bison	4	GSM 115547, left astragalus (cut-marked. Identified as *Bos primigenius* by E.T. Newton (quoted in Holmes, 1896) and Schreve, 1997). cf. *Bison*: GSM 115549, right $M^{1 or 2}$, GSM 115544, $M_{1 or 2}$; GSM 115548, right M_3
Bovidae gen. et sp. indet	4	GSM 115550, upper molar fragment; GSM 115545 and 115546, left and right femur proximal epiphyses (identified as *Bos primigenius* by E.T. Newton); GSM 115539 first phalanx fragment

Lister, pers. comm.). Fallow deer (*Dama dama*) and bison (*Bison priscus*) are new additions (Table 1). The astragalus of the fallow deer can be distinguished from that of red deer based on its smaller size (cf. Stuart et al., 1993) and on the morphological features described by Lister (1986, 1996). The bovid astragalus (identified as aurochs by Newton) has morphological features that align it with bison (Fernandez, 2006; Gee, 1993; Jaubert et al., 1990; Olsen, 1960), whereas the identity of the other bovid specimens is less certain.

The addition of fallow deer and bison and the removal of mammoth from the fauna list impact on both the environmental interpretation and the biostratigraphical arguments for the age of the site.

Environmental Context

The mammals from the brickearth at Great Yeldham provide valuable environmental evidence. The condition of the bones suggests that the fauna forms a coherent assemblage with no evidence for mixing or any obvious derived elements and probably is all the same age. Moreover, the preservation of the fine surface details and anatomical features suggests that the bones were buried relatively rapidly by fine-grained sediments in a low-energy depositional environment. Only one specimen has broad areas of weathering, which suggest that it was lying on the ground for a period of no more than a few years (Andrews & Fernández-Jalvo, 2019); the other bones are well preserved suggesting that they could not have been exposed to the elements for very long and were presumably buried rapidly. Sediment adhering to the pelvis GSM 115551 was sampled for pollen, but the samples were barren (P.L. Gibbard, pers. comm.).

Overall, the fauna comprises a temperate assemblage, dominated by cervids and bovids. Ecologically, the presence of fallow deer is particularly significant as an indicator of temperate open-woodland conditions. Important limiting factors influencing the distribution of fallow deer are deep snow and low winter temperatures that restrict winter food supply. Accordingly, the main range of fallow deer nowadays encompasses parts of Europe with a moderate maritime climate. British Pleistocene records of fallow deer are invariably associated with temperate conditions and regional vegetation dominated by deciduous or mixed woodland (Stuart et al., 1993). A similar environment is indicated by roe deer, a species that shows a strong preference for woodland interspersed with areas supporting open herbaceous vegetation. Species likely to have favoured more open conditions are narrow-nosed rhinoceros, horse and bison. During wooded interglacial periods, these species would have frequented grassy clearings in the forest or along rivers (Stuart, 1982). Red deer is tolerant of a wider range of conditions from open deciduous woodland, conifer forest, moorland, parkland and grassland. Finally, brown bear is also adaptable and until recently occurred widely throughout the Palaearctic and North America, both in coniferous and deciduous woodland and extending into adjacent areas of steppe and tundra in both regions. From the mammalian evidence, it is possible to envisage a landscape of deciduous forest with glades, and perhaps more extensive areas of grassland in the vicinity of a waterbody.

Age of the Butchery Site

The Great Yeldham fauna includes a combination of extinct and extant mammals that provide information on the age of the site. The distribution of mammal species throughout the British Middle Pleistocene shows the cyclical changes from cold to warm faunas that are known to have occurred in this interval. Correlating British Pleistocene faunas has focused on the better-known interglacial stages with the recognition that distinctive combinations of mammal species occur in different temperate episodes (Sutcliffe, 1976, 1995; Stuart, 1982; Currant, 1989; Schreve, 1997, 2001a, b). These changes in faunal composition through time reflect patterns of immigration, evolution and extinction in successive faunal assemblages, which provide the basis for using mammalian fossils as biostratigraphical indicators (Lister, 1992).

The framework of mammalian history and the succession of Mammal Assemblage Zones (MAZs) developed by Schreve (1997, 577–8) led her to conclude, on the basis of species composition, that the Great Yeldham 'assemblage was most closely comparable with faunas assigned to the second temperate peak of the Stage 7 interglacial, such as from the upper part of the sequence at Aveley and Uphall Pit, Ilford'. Schreve highlights the importance of cf. *M. primigenius*, together with *E. ferus*, *S. hemitoechus* and a large form of *Bos primigenius*, as the key elements in this argument (Schreve, 1997, 2001a, b).

The revised faunal list for Great Yeldham differs in important details from that of Schreve (1997, 2001a, b), necessitating a reappraisal of the age of the site. Some of the arguments remain unchanged, but recent work on key sites has resulted in a reinterpretation of the biostratigraphical groups and their relation to the marine oxygen isotope record (Penkman et al., 2011, 2013). An updated framework for mammalian history for the British late Middle Pleistocene is summarised in Fig. 2.

The revised scheme identifies additional temperate stages with mammalian faunas that can now be assigned to marine isotope substages with varying degrees of confidence (Penkman et al., 2011, 2013). The scheme includes major modifications to previous models with the recognition that an intervening cold stage separates the main faunal horizon at Hoxne from the underlying Hoxnian lake sediments assigned to MIS 11c (Ashton et al., 2008; Wenban-Smith, 2013). Both temperate episodes at Hoxne can be shown to fall within MIS 11 (424–374 thousand years (ka) ago), with the bulk of the vertebrate remains being assigned to the younger temperate episode correlated with MIS 11a (Horne et al., 2022). Further complexity is shown by recent work in the Ebbsfleet Valley, which has identified three distinct temperate episodes that can be assigned to substages of MIS 7 (Wenban-Smith et al., 2020). This marine isotope stage has a distinctive climatic record (Past Interglacials Working Group of PAGES, 2016) of an early warm peak during MIS 7e (~240 ka years ago) followed by a sustained cold episode (MIS 7d), which is followed in turn by a double warm peak, pertaining to MIS 7c (~210 ka years ago) and MIS 7a (~190 ka years ago). The temperate deposits assigned to MIS 7a appear to be associated with a cooler climate and an open grassland fauna that preceded the onset of glacial conditions of MIS 6.
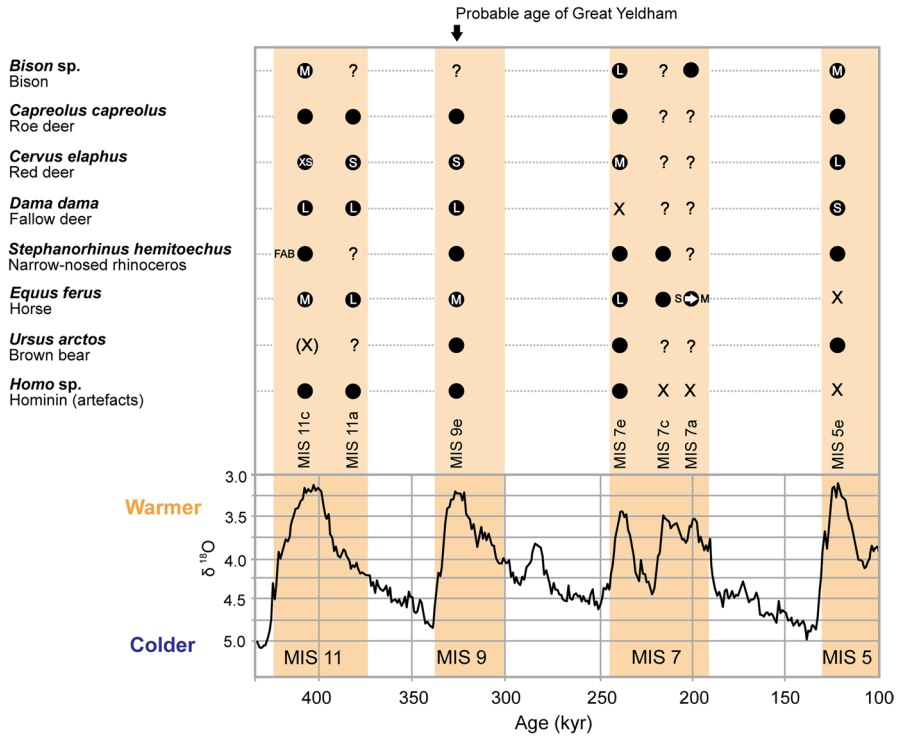
Fig. 2 Mammalian faunal change during late Middle and Late Pleistocene temperate episodes in Britain, with a focus on species found at Great Yeldham. Key: ● = Taxon present; ? = status uncertain due to small sample size; X = absence in Britain; (X) = possible absence in Britain; FAB = first appearance in Britain. Changes in body-size for red deer, fallow deer and horse follow Stuart et al. (1993) and Collinge (2001). Body-size categories: L = large; M = medium, S = small; XS = extra small

The allocation of sites to substages of MIS 7 is based primarily on aminostratigraphy and the succession of faunas identified in the Ebbsfleet Valley (Penkman et al., 2011, 2013; Wenban-Smith et al., 2020). Key sites in this revision are Selsey (Lifeboat Station Channel), Aveley, West Thurrock (Lion Pit) and Ebbsfleet (bed 2a), which are now correlated with MIS 7e, Ebbsfleet 3776 TP (D-E) which is assigned to MIS 7c and Ebbsfleet site B (Temperate Bed) and the Brighton-Norton sequence that spans the MIS 7–6 transition. Significantly, mammoths (*Mammuthus trogontherii* steppe mammoth and/or *M. primigenius* woolly mammoth) appear to have been present episodically in Britain throughout this period (Wenban-Smith et al., 2020). This redating of key sites has necessitated a significant re-ordering of sites previously assigned to Schreve's (2001a, b) Ponds Farm and Sandy Lane MAZs, some of which are now known to date to the Ipswichian (Briant et al., 2018; Penkman et al., 2011, 2013).

Although the succession of late Middle Pleistocene temperate faunas has been clarified by the new work, significant sampling issues are also apparent. Whereas some temperate stages have been comprehensively sampled (e.g. Hoxnian MIS 11c

and Ipswichian MIS 5e), those of the later substages of MIS 7 are currently very poorly known, and currently there are no faunas that can be assigned with certainty to substages MIS 9c and 9a. With these limitations in mind, it is nevertheless possible to constrain the age of the Great Yeldham fauna based on the presence of key 'indicator' species and information from biometrical comparisons (Stuart et al., 1993; Collinge, 2001).

Firstly, the Great Yeldham mammal assemblage is incompatible with a last interglacial age (Ipswichian, MIS 5e, 123–109 ka years ago). This highly characteristic large mammal fauna is known from a large array of British sites, which are notable for the absence of horse and humans (Lewis et al., 2011; Sutcliffe, 1995), both of which are present at Great Yeldham. Secondly, the presence of fallow deer at Great Yeldham may exclude correlation with MIS 7 (243–191 ka years ago). Sites with fallow deer that have previously been assigned to MIS 7 (e.g. Itteringham, Norfolk (Schreve, 1997) and Stone Point, Hampshire) are now known to date to the Ipswichian (Briant et al., 2018; Penkman et al., 2011, 2013). Removing these records of fallow deer from MIS 7 supports the conclusion of Sutcliffe (1995), who suggested that fallow deer was absent in Britain throughout this stage.

Excluding these stages from consideration leaves MIS 11 and MIS 9 as the strongest options for the age of the Great Yeldham fauna. Biometric comparisons of skeletal elements from Great Yeldham with material recovered from better dated sites allow further constraints on the dating. The relatively large size of the horse tooth and fallow deer astragalus, combined with the small size of the red deer specimens from Great Yeldham, is consistent with assemblages assigned to 11c, 11a and 9e (Collinge, 2001). According to Schreve (1997; 2001a, b), the presence of brown bear is biostratigraphically significant in that it first appears in Britain during MIS 9 (337–300 ka years ago). Although it is tempting to use this record to constrain the age of the Great Yeldham fauna, it is important to note that bear remains are extremely rare in the British late Middle Pleistocene. This is illustrated by the Hoxnian record for which the only specimens identified to species are a skull/cranium and mandible from Swanscombe, both of which are assigned to cave bear *Ursus spelaeus* (Kurtén, 1959). Elsewhere in Europe, cave bear occurs together with brown bear in broadly contemporary sites. It is not yet possible to determine whether brown bear was genuinely absent in Britain at this time or if its apparent absence merely relates to small sample size. Similarly, inadequate sampling may also explain the absence of bison from British sites equated with MIS 9.

The Butchered Bison Bone

The cut-marks on the bison astragalus (GSM 115547) were discovered during a search for butchery traces on Pleistocene faunal remains in the British Geological Survey Museum. The bones were inspected with a magnifying glass and an intense, unidirectional light source was used to highlight fine details. The cut-marks on the Great Yeldham astragalus can be observed without magnification (Fig. 3) as they consist of deeply incised, parallel incisions located on the medial face of the bone. Moreover, the distribution of the cuts is consistent with butchery marks found in

experimental and ethnoarchaeological assemblages (Abe, 2005; Binford, 1981, 1984; Nilssen, 2000; Soulier & Costamagno, 2017) in which the foot bones and the distal tibia were marked during the detachment of the foot, a process that requires the severing of the complex arrangement of ligaments, tendons and capsules that hold this joint together.

The context for interpreting the marks on the Great Yeldham astragalus is provided by comparisons with cut-marks recorded for ethnographic and experimental butchery studies. These reveal interesting patterns that link the position of cuts on the astragalus to specific butchery actions resulting from the different techniques used to dismember the tibia-tarsal joint. Factors governing the strategy employed include the number and size of animals killed, the physical state of the carcass (whether freshly killed or desiccated), numbers of hunters and bearers, distance from kill site to processing camp or home base, the skill of the butcher and differences in tool technology. Similarly, the influence of processing intensity and aspects of food preparation (e.g. extraction of bone grease and marrow), as well as whether the hind-limb is used to hang the leg or carcass for further butchering or drying in the sun, are other factors that contribute to decisions made during the butchery process (Binford, 1981, 1984; Lyman, 1995; Egeland, 2003; Merritt, 2017; Soulier & Costamagno, 2017; Pobiner et al., 2018). In one of these studies, Binford (1981) observed the results of Nunamiut butchery of reindeer and sheep. He recorded the location of cut-marks inflicted on the lower leg bones during the disarticulation of the tibia from the tarsals and he defined two common sets of cut-marks inflicted on the astragalus during this process:

TA-1. Transverse marks on the margins of the anterior face, midway on the astragalus.

Fig. 3 **a–c** Middle Pleistocene bison (*Bison priscus*) astragalus from Great Yeldham bearing cut-marks. **a** Posterior view; **b** medial view; **c** close-up of cut-marks. Scales = 50 mm

TA-2. Marks across the medial face midway on the astragalus.

Both sets of marks may result from the same slicing action when the leg is out-stretched or flexed (Binford, 1981, 119) and when the carcass is fresh and supple (Strategy 1 (Fig. 4a, b) of Binford, 1984). Binford observed that the cut usually starts across the anterior face of the distal tibia and continues to the medial side of the leg. This action leaves cut-marks that extend across the anterior face of the astragalus at essentially its midpoint (TA-1) to the medial face of the astragalus (TA-2). A sweeping cut may then be required to fully separate the tibia from the tarsals, which remain attached to the metatarsal. This action may leave further marks on the articular surfaces of the astragalus that are in contact with the tibia.

Binford (1981, p. 199; 1984) describes an alternative method (Strategy 2, Fig. 4c) of disarticulating the tibia from the foot by making transverse cuts where the tarsals attach to the proximal metatarsal. This action is responsible for transverse cut-marks that encircle the proximal metatarsal, navicular-cuboid and the distal part of the astragalus. The calcaneus and astragalus remain attached to the distal tibia. Binford noted that this strategy is commonly employed when the meat is to be dried and the 'ham' hung as a unit, using the calcaneal tendon as a hanging hook.

Binford does not allocate a code to marks inflicted on the astragalus by this process, but Nilssen (2000) recorded transverse marks across the distal end of the astragalus as the predominant cut-marks on the astragali during his experimental butchery of South African bovids. Nilssen (2000) defined a new code to incorporate this type of mark:

TA-3 (PJN). Transverse marks on medial, anterior and lateral faces, on the distal half of the astragalus.

The disarticulation of the ankle joint described by Nilssen (2000) matches Binford's Strategy 2 with the division of the tarsal bones that split the calcaneum, astragalus and lateral malleolus which remain attached to the distal tibia from the remainder of the tarsals that are attached to the proximal metatarsal. Although Binford (1984) suggested that this strategy is more commonly employed when the joint is immobile or otherwise difficult to manipulate, this was not the case with the fresh carcasses butchered in Nilssen's experiments. Here, the general practice involved the removal of the feet early in the butchery sequence, often at the skinning stage. In these experiments, severing the lower hind-limb above the metatarsal joint was undertaken to make the carcass easier to manipulate during the butchery process (Nilssen, 2000, p. 49).

Binford (1984) observed a further strategy (Strategy 3, Fig. 4d) for butchering the lower hind-limb. This involved making cuts that circle the articulation between the proximal metatarsal and the navicular-cuboid and ectocuneiform. In this process, the metatarsal is detached from the tarsal bones, which remain in articulation with the distal tibia, and a characteristic pattern of cut-marks can be seen in the clustering of transverse marks across the proximal metatarsal, navicular-cuboid and ectocuneiform. Because these incisions are located mostly below the level of the astragalus, Strategy 3 is unlikely to leave any marks on this bone. Binford (1984, p. 141) observed that this strategy is commonly employed when the joint is totally immobile
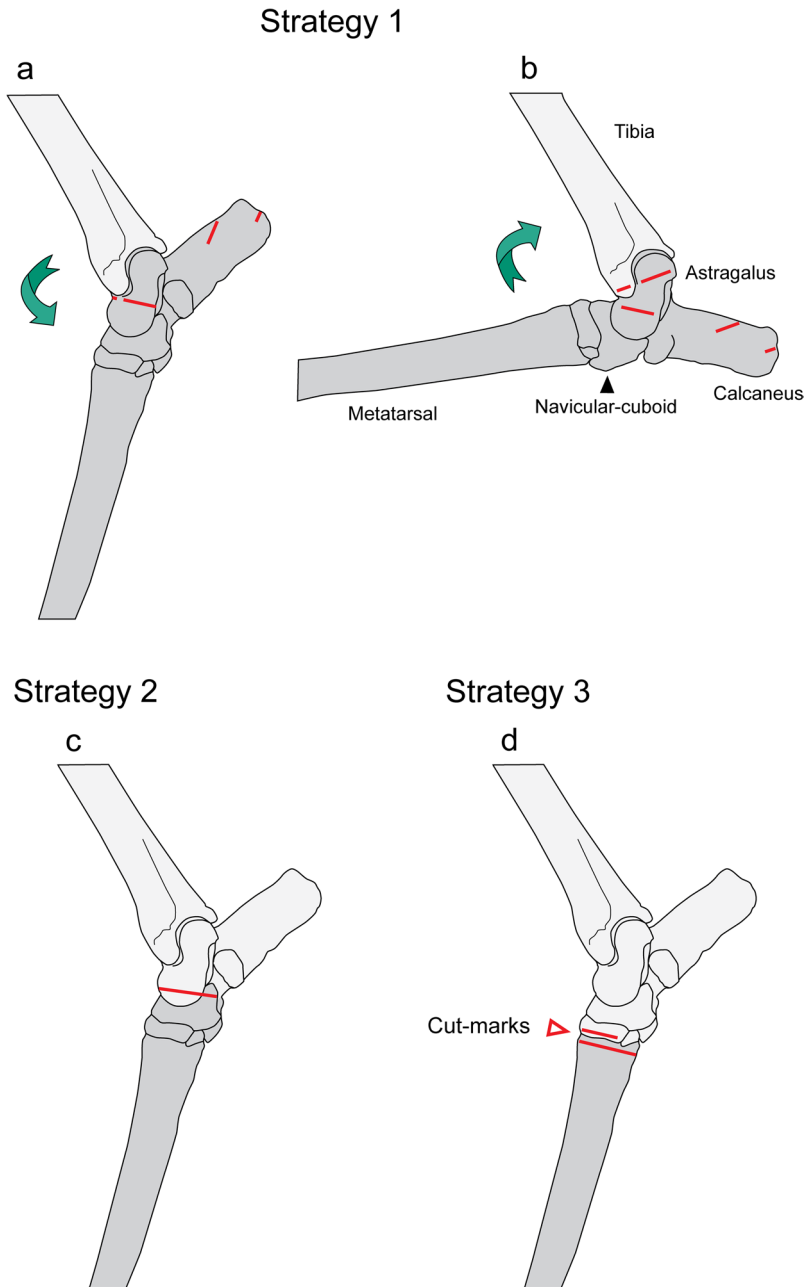
Fig. 4 Three strategies commonly employed to disarticulate the lower limb of artiodactyls (Binford, 1984). In Strategy 1 (**a** dorsoflexion; **b** plantarflexion), the joint is supple and flexible and can be manipulated with cuts that sever the tibia from the lower part of the limb. In Strategy 2 (**c**), cuts across the distal end of the astragalus leave the calcaneus and astragalus attached to the tibia. In Strategy 3 (**d**), disjointing of the metatarsal is achieved by making circling cuts at the junction of the navicular-cuboid and proximal metatarsal. Cut-marks are indicated by red lines; shading shows the division of bone elements resulting from the different butchery strategies

(e.g. frozen, desiccated), and/or when the metatarsal is being specifically disarticulated for purposes of marrow cracking.

Figure 5 shows how the distribution of cut-marks on the astragalus can be linked to the different strategies observed by Binford (1981). This was tested against an ethnographic example of reindeer butchered by Evenki hunters in Northern Transbaikalia, Russia (Abe, 2005).

Abe (2005) described in detail the butchery of reindeer lower limbs for leg fur (*kamus*). This study is particularly useful as cut-marks resulting from the complete disarticulation prior to marrow extraction are illustrated for several hind-limbs. The distribution of the marks summarised in Fig. 5 are those resulting from *Kamus* butchery, which involved the removal of the lower limb fur (*kamus*) and the disarticulation of the lower limb bones in preparation for marrow cracking. The procedure starts with the careful removal of the skin, followed by the extraction of the tendons and hooves and the disarticulation of the tibia from the metatarsal. The cut-marks on the astragalus were inflicted during the final stage in this process.

Abe noted that the disarticulation of the tibia-metatarsal joint was particularly difficult resulting in 'many gouging movements with the knife into the joint surface' (Abe, 2005, p. 132). Considering this effort, it is notable that four of the ten astragali in this series do not appear to have been marked during this process. Ultimately, the tarsal bones ended up either with the tibia or the metatarsal, although Abe noted that 'tarsals-attached-to-metatarsal result seems to have been more preferred, as it was harder to subsequently separate the tarsals from the tibia without the leverage supplied by the attachment of two leg bones.' (Abe, 2005, p. 132). Finally, the tarsal bones were then removed from the long bone that they were attached to, and the long bones were then cracked for marrow. Abe commented that there is no functional reason for removing the tarsal bones as they did not impede marrow cracking. Instead, she suggested that cultural/ritual motivations were the reason for the care taken to clean the lower limb bones of these extraneous parts (Abe, 2005, p. 116). This complex butchery process, which results in the complete disarticulation of the tarsal 'block', may account for the presence on several astragali of cut-marks on both the medial and lateral ridges of the trochlea as well as the distal articular surface of the bone. It is also notable that there are no cut-marks recorded on the medial face, which is a location where cuts are most commonly found on the astragalus (Binford, 1981).

These ethnoarchaeological studies provide a basis for interpreting cut-marks on astragali from Palaeolithic sites. This comparison was first applied to a sample of late Middle Pleistocene bovid astragali from Grays Thurrock, Essex. In the Grays Thurrock sample, the distribution of cut-marks on the astragalus differs from the Evanki example (Figs. 5 and 6), suggesting that a different procedure was used to disarticulate the lower hind limb. At Grays Thurrock, the cuts were focused higher on the anterior face and across the medial surface. Cuts in these locations would have separated the tarsal bones from the distal tibia, leaving the tarsal bones attached to the metatarsal (cf. Strategy1). As with the Evenki example, the Grays Thurrock assemblage includes a proportion of unmarked bovid astragali; in this case, however, it is not possible to determine whether these represent elements in the Grays
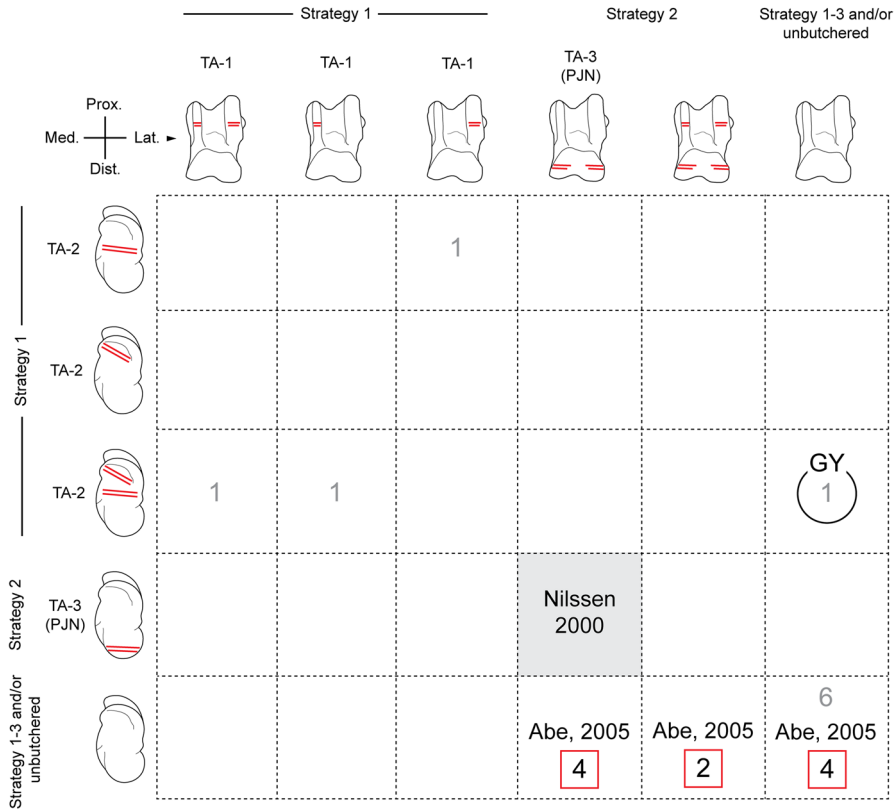
Fig. 5 Configuration of cut-marks observed on late Middle Pleistocene astragali from Great Yeldham (circle) and Grays Thurrock, Essex (grey numbers), compared with the distribution of cut-marks recorded by Nilssen (2000) in large and small bovids butchered by traditional butchers in South Africa (grey-tone cell) and Abe (2005) for astragali of reindeer butchered by Evenki hunters in Northern Transbaikalia, Russia (red squares). The cut-marks are arranged according to the strategies and codes defined by Binford (1981, 1984) with the addition of TA-3 (PJN) of Nilssen (2000). Binford's cut-mark coding system has been updated by Soulier and Costamagno (2017): TA-1=TA-a; TA-c=TA-2; TA-3 (PJN)=TA-b and TA-d. Numbers refer to counts of individual astragali with specific cut-mark configurations. Note, although there are no cut-marks on anterior face of the Great Yeldham astragalus (GY, circle), the cuts on the medial face are indicative of Strategy 1 (a similar distribution of cut-marks is exhibited by the astragalus from Grays Thurrock illustrated in Fig. 6)

Thurrock assemblage that came from unbutchered carcasses or if these bones are from limbs that were butchered without leaving cut-marks on the astragalus.

Returning to the Great Yeldham astragalus, it is possible to discern two distinct sets of incisions (Fig. 3c). Most of the cuts with a transverse orientation are located midway across the medial face of the bone, whereas the second set is aligned obliquely, extending from the middle of the medial face to the proximal tip of the astragalus. The location of the cuts and the presence of two sets of cut-marks with different orientations indicate that it was possible for the butcher to manipulate the joint during the cutting process; this implies that the carcass was supple (not frozen)

Fig. 6 Cut-marks on rearticulated foot bones of a late Middle Pleistocene aurochs (*Bos primigenius*) from Grays Thurrock, Essex, UK (NHMUK PV M 103305a-c). Cut-marks on the astragalus (NHMUK PV M 103305b) are shown in close-up in the inset. This specimen is part of a heavily butchered assemblage, purchased by the NHM in 1847. Scale = 50 mm
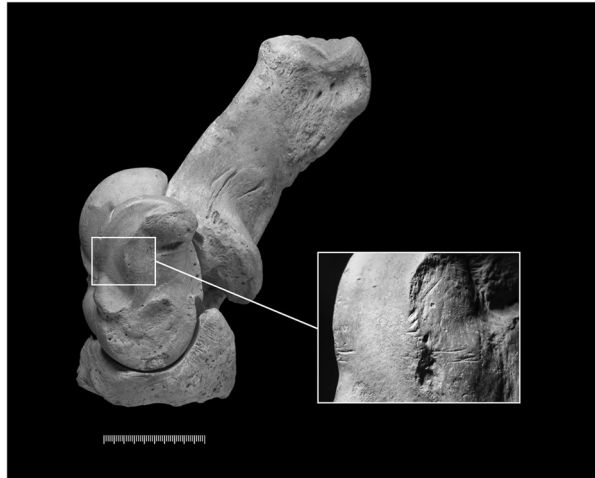
and fresh (prior to *rigour mortis* or desiccation) when butchered and that the incisions could be made with the joint in flexion and extension. This pattern of cut-marks appears to have been inflicted when the upper part of the hind limb was separated from the lower part using a strategy that left the tarsal bones attached to the metatarsal (Strategy 1). This strategy is commonly employed at kill sites when low-value parts, notably the head and feet, were discarded on the spot (Binford, 1981).

The nutritional value of bovid feet is limited, and ethnographic and archaeological studies show that the foot bones of large bovids are often discarded at kill sites (Binford, 1981; Helmer & Monchot, 2006; Kenady et al., 2011; Prummel & Niekus, 2011; Prummel et al., 2002; Rowley-Conwy, 2017; Street, 1991; Todd et al., 1997). Bone marrow from the metapodials may, however, be extracted by cracking the bones at the butchery site, a further 'snack' can be obtained by splitting the compact tarsal bones to recover bone grease. Leaving these elements behind at the kill site reduces substantially the weight of the carcass when transported for consumption elsewhere. However, this is not a universal practice as there are many ethnographic and archaeological examples where the lower limbs of large herbivores were removed from the kill site for processing elsewhere (Binford, 1984; Bunn, 2004; Gustavs, 1987). Such processing tasks may include the extraction of marrow and bone grease (Karr et al., 2015) or the manufacture of bone tools. Bovid metapodials provide a useful source of raw material as they have long, straight shafts and thick cortical bone that makes them amenable for fashioning into a variety of tools (e.g. Legge & Rowley-Conwy, 1988). Bovid metapodials are also naturally shaped like a baton. Lower Palaeolithic examples where unmodified metapodials have been used in this way include a bison metatarsal from Clacton (Essex, UK) that was used to knap Clactonian flint tools (S.A.Parfitt, S. Bello and M.L Lewis in prep.) and horse and bovid metapodials that were used as hammers to break marrow bones at Schöningen, Germany (van Kolfschoten et al., 2015). With only a single butchered astragalus from Great Yeldham, it is not possible to take the interpretation further.

Discussion

Great Yeldham is one of the few sites in Britain where butchered bones have been found in a Middle Pleistocene context. No artefacts were found and consequently the human occupation cannot be assigned to any particular lithic industry. Although the small size of the mammal assemblage makes it difficult to draw precise conclusions about the age of the site, human occupation at Great Yeldham is likely to have occurred in a period of temperate climatic conditions, possibly during MIS 9. Marine Isotope Stage 9 spans the period 328–301 ka and consists of three pronounced warm peaks (MIS 9e, 9c and 9a) separated by two cold intervals (MIS 9d and 9b). This interglacial has only been recently recognised in the British chronostratigraphical scheme, which is now coming into sharper focus with improved dating methods (e.g. Penkman et al., 2011, 2013; Roe et al., 2009). Evidence from the Thames terraces is critical to the recognition of the archaeological and paleoenvironmental context of this interglacial stage, informally named the 'Purfleet Interglacial' (Bridgland et al., 2013). In Britain, MIS 9 also corresponds to a dynamic phase in the history of human occupation with the successive replacement of a non-handaxe, core-and-flake (Mode 1) industry by an Acheulean handaxe industry (Mode 2) and later by the first appearance of an early Levalloisian (Mode 3) technology; these successive lithic industries occurred over a period spanning perhaps no more than 50,000 years from the end of MIS 10 to the early part of MIS 8 (Rawlinson, 2021; Rawlinson et al., 2022; White & Bridgland, 2018; White & Ashton, 2003; White et al., 2011). White et al. (2018) have suggested that these represent different occupation phases, likely the result of different waves of colonisation. It is currently unclear whether these changes in lithic tool industries were also accompanied by significant differences in human behaviour, such as in hunting, planning depth and resource use and organisation within the landscape, reflecting different cognitive abilities in the colonising groups.

The handaxe industry assigned to MIS 9 is particularly notable with some of the largest handaxes known from Britain and a dominance of pointed handaxes and significant proportions of cleavers and elegantly shaped ficrons (Bridgland & White, 2015; White et al., 2018). In the Upper Thames, the site of Wovercote has another distinctive handaxe type typified by well-made plano-convex forms with a characteristic 'slipper-shaped' outline (Rawlinson, 2021; White et al., 2018).

Whilst the British sequence provides 'snapshots' in time, more continuous sequences are known from continental cave successions, such as Orgnac 3 in southern France (Moncel et al., 2011; Bahain et al., 2022) and Atapuerca in Spain (de Lombera-Hermida et al., 2002), and from a lacustrine context at Schöningen in Germany (Conard et al., 2015); these sites serve to illustrate similarities and contrasts with the British record and perhaps suggest a phased appearance of Mode 3 technologies occurred in western Europe (Moncel et al., 2022). Significant differences in hunting behaviour can also be recognised with different butchery patterns reflecting varying activities undertaken at 'base camps' and kill/butchery sites.

At Orgnac 3, handaxes are present throughout the sequence with the industries in the basal levels showing a variety of non-Levallois methods; a 'fully-fledged

Levallois' technology developed in the middle part of the sequence and become increasingly important in the upper levels at the site (Moncel et al., 2011, 2022). These deposits span MIS 9 and part of MIS 8, and the associated faunal assemblage provides clear evidence for provisioning with horse and bovids which provided the main source of large mammal food.

At Atapuerca, the Gran Dolina TD10 sequence records a local transformation to the Middle Palaeolithic with radiometric dates suggesting this transition occurred during the period covered by MIS 11 to MIS 8. Two contrasting bone-rich horizons are found within the TD10 sequence (Rodríguez-Hidalgo et al., 2015a, b, 2017). At the top of the sequence is the TD10.1 'bone-bed level'. This is the richest archaeological horizon at Atapuerca with more than 22,000 late Acheulean lithic artefacts (including a rare Levallosian component) and 50,300 faunal remains. The faunal assemblage shows clear traces for human accumulation and modification of the bones, which are primarily represented by prime-age deer, bison and horse (de Lombera-Hermida et al., 2002; Rodríguez-Hidalgo et al., 2015b). The site appears to have functioned as a base camp with repeated occupations of generally short duration. Somewhat earlier is the bison bone bed (TD10.2), which has yielded an exceptional accumulation of bison bones (NISP= ~40,000). Taphonomic results indicate the site was a kill-butchery locale, which was the focus of seasonal bison communal hunts (Rodríguez-Hidalgo et al., 2015a, 2017).

At Schöningen, the lake-margin deposits include the famous 'Spear Horizon', where the remains of at least 25 horses occur together with wooden spears and a variety of flake tools and bones that were used for knapping and hammering activities (Conard et al., 2015). This level is located within the upper part of a series of deposits filling Channel II that includes the climatic optimum of the Reinsdorf Interglacial (=MIS 9e) and two later temperate episodes (Reinsdorf interstadials A and B – the 'Spear Horizon') sandwiched between cold periods (Reinsdorf stadial A, B and C). Unlike broadly contemporary sites in western Europe, there is no evidence for the use of Levallois knapping techniques and the assemblage appears to represent a purely Lower Palaeolithic non-handaxe industry with scrapers, denticulates and borers. At Schöningen, this industry occurred throughout the different climatic substages of MIS 9 and into the early part of MIS 8. Current consensus suggests that multiple hunting events at the Schöningen lakeside site (Schöningen 13 II-4) targeted herds of horses. The butchery pattern is somewhat atypical with a focus on skinning and marrow extraction combined with the selective removal of horse metapodials; some metapodials were removed from the site, but others were used during the butchery stage as anvils/retouchers for resharpening stone tools, and as hammers used to break marrow bones (van Kolfschoten et al., 2015; Hutson et al., 2018; Bonhoff & van Kolfschoten, 2021).

In Britain, the extensively butchered MIS 9 large mammal assemblage from Grays Thurrock (Lower Thames) is currently under study (Parfitt and Bello). The Grays assemblage offers rare insights into butchery practices and human behaviour at this time with notable evidence for specialised skinning of brown bears (which were probably killed when the animals were hibernating) and a focus on prime-aged individuals of horse, red deer, fallow deer and two species of rhinoceros (*Stephanorhinus hemitoechus* and *S. kirchbergensis*). Significantly, the presence of humans at the site was only recognised from butchery evidence as no artefacts were found when bones were being recovered from the Grays brickearth pits in the first half of the nineteenth century.

These selected case studies serve to illustrate the variability of MIS 9 archaeological assemblages. Moreover, they show that the Middle Pleistocene hominins who accumulated the bones at these sites were efficient hunters who based their subsistence on large ungulates and acquired other animal resources for specific tasks (e.g. bear skins and sinews).

Whilst the vast majority of Palaeolithic butchery sites are associated with stone tools (Type C sites of Issac, 1978, 1984), cut-marks have also been found on bones which come from other excavated sites where no stone tools were present. Bunn (1994) defined a new type of stone age site to accommodate such occurrences. His landscape study of bones from Early Pleistocene deposits in the Omo Valley identified butchered bones at locations where hominins had used stone tools in butchery but rarely discarding them at these sites. Evidently, stone tools had been carried to these butchery sites and removed after the tasks had been completed. Bunn also noted that the sites in question are typically situated in locations where there is no immediate source of lithic raw material suitable for tool manufacture. We can speculate as to why no stone tools were found with the bones at sites such as Grays Thurrock and Great Yeldham. Alternative, although mutually not exclusive, explanations include the possibility that stone tools occurred at a low density at the site or they were not recognised as tools and thus considered unimportant by the labourers who recovered the animal bones.

Finally, this study exemplifies the potential of examining faunal collections discovered and studied decades ago for traces of human modification. Not only do such studies contribute information to regional Palaeolithic archaeology, but archived collections are also a rich source and largely untapped resource that can reveal important insights regarding early human behaviour and adaptation that are unreachable from the study of stone tools alone (Bello et al., 2021; Charles & Jacobi, 1994; Lord et al., 2007; Parfitt, 2004; Parkin et al., 1986).

Declarations

References

Abe, Y. (2005). *Hunting and butchering patterns of the Evenki in the Northern Transbaikalia Russia*. PhD Thesis, Stony Brook University.

Ashton, N., Lewis, S. G., Parfitt, S. A., Penkman, K. E. H., & Coope, G. R. (2008). New evidence for complex climate change in MIS 11 from Hoxne, Suffolk, UK. *Quaternary Science Reviews, 27*, 652–668.

Andrews, P., & Fernández-Jalvo, Y. (2019). *Understanding time in taphonomy. A 30-year field study in Wales*. Nova Science Publishers Inc.

Bahain, J. J., Mercier, N., Valladas, H., Falgueres, C., Masaoudi, H., Joron, J. L., Froget, L., Moigne, A.-M., Combier, J., & Moncel, M.-H. (2022). Reappraisal of the chronology of Orgnac 3 Lower-to-Middle Paleolithic site (Ardeche, France), a regional key sequence for the Middle Pleistocene of southern France. *Journal of Human Evolution, 162*, 103092. https://doi.org/10.1016/j.jhevol.2021.103092

Bello, S. M., Crété, L., Galway-Witham, J., & Parfitt, S. A. (2021). Knapping tools in Magdalenian contexts: New evidence from Gough's Cave (Somerset, UK). *PLoS ONE, 16*(12), e0261031. https://doi.org/10.1371/journal.pone.0261031

Binford, L. R. (1981). *Bones, ancient men and modern myths*. Academic Press.

Binford, L. R. (1984). *Faunal remains from Klaises River Mouth*. Academic Press.

Binford, L. R. (1985). Human ancestors: Changing views of their behaviour. *Journal of Anthropological Archaeology, 4*, 292–327.

Bonhof, W. J., & van Kolfschoten, T. (2021). The metapodial hammers from the Lower Palaeolithic site of Schöningen 13 II-4 (Germany): The results of experimental research. *Journal of Archaeological Science: Reports, 35*, 102685.

Briant, R., Bates, M. R., Boreham, S., Cameron, N. G., Coope, G. R., Field, M. H., Hatch, B. M., Holmes, J. A., Keen, D. H., Kilfeather, A. A., Penkman, K. E. H., Simons, R. M. J., Schwenninger, J.-L., Wenban-Smith, F. F., Whitehouse, N. J., & Whittaker, J. E. (2018). Early Ipswichian (last interglacial) sea level rise in the Channel region: Stone point site of special scientific interest, Hampshire, England. *Proceedings of the Geologists Association, 130*, 1–26.

Bridgland, D. R., & White, M. J. (2015). Chronological variations in handaxes: Patterns detected from fluvial archives in north-west Europe. *Journal of Quaternary Science, 30*, 623–638.

Bridgland, D. R., Harding, P., Allen, P., Candy, I., Cherry, C., Gerorge, W., Horne, D. J., Keen, D. H., Penkman, K. E. H., Rhodes, E. J., Scaife, R., Schreve, D. C., Schwenninger, J., Slipper, I., Ward, G. R., White, M. J., White, T. S., & Whittaker, J. E. (2013). An enhanced record of MIS 9 environments, geochronology and geoarchaeology: Data from construction of the High Speed 1 (London-Channel Tunnel) rail-link and other recent investigations at Purfleet, Essex, UK. *Proceedings of the Geologist's Association, 124*, 417–476.

Bunn, H. T. (1994). Early Pleistocene hominid foraging strategies along the ancestral Omo River at Koobi Fora, Kenya. *Journal of Human Evolution, 27*, 247–266.

Bunn, H. T. (2004). Butchering backstraps and bearing backbones: Insights from Hadza foragers and implications for Paleolithic archeology. In T. R. Pickering, K. Schick, & N. Toth (Eds.), *Breathing life into fossils: Taphonomic studies in honor of C.K. (Bob) Brain* (pp. 269–279). Stone Age Institute Press.

Charles, R., & Jacobi, R. M. (1994). The Lateglacial fauna from the Robin Hood Cave, Creswell Crags: A re-assessment. *Oxford Journal of Archaeology, 13*, 1–32.

Collinge, S. E. (2001). *Size and community structure in British Pleistocene mammals*. PhD Thesis, University College London.

Conard, N. J., Serangeli, J., Bohner, U., Starkovich, B. M., Miller, C. E., Urban, B., & Van Kolfschoten, T. (2015). Excavations at Schöningen and paradigm shifts in human evolution. *Journal of Human Evolution, 89*, 1–17.

Currant, A. J. (1989). The Quaternary origins of the modern British mammal fauna. *Biological Journal of the Linnean Society, 38*, 23–30.

de Lombera-Hermida, A., Rodríguez-Álvarez, X., Mosquera, M., Ollé, A., García-Medrano, P., Pedergnana, A., Terradillos-Bernal, M., Lopez-Ortega, M., Bargalló, A., Rodríguez-Hidalgo, A., Saladié, P., Bermúdez de Castro, J. M., & Carbonell, E. (2002). The dawn of the Middle Paleolithic in Atapuerca: The lithic assemblage of TD10.1 from Gran Dolina. *Journal of Human Evolution, 145*, 102812. https://doi.org/10.1016/j.jhevol.2020.102812

Egeland, C. P. (2003). Carcass processing and cutmark creation: An experimental approach. *Plains Anthropologist, 48*, 38–51.

Fernandez, P. (2006). Etude paléontologique des ongules du gisement moustérien du Bau de l'Aubesier (Vaucluse, France): Morphométrie et contexts biochronologique. *Documents des Laboratoires de Geologie de Lyon, 161*.

Gaudzinski, S., & Turner, E. (1996). The role of early humans in accumulating European Lower and Middle Palaeolithic bone assemblages. *Current Anthropology, 37*, 153–156.

Gee, H. (1993). The distinction between postcranial bones of *Bos primigenius* Bojanus, 1827 and *Bison priscus* Bojanus, 1827 from the British Pleistocene and the taxonomic status of *Bos* and *Bison*. *Journal of Quaternary Science, 8*, 79–92.

Gustavs, S. (1987). Das Ur-Skelett von Potsdam-Schaaltz. *Der Archäolgische Befund, Veröffentlichungen des Museums für Ur-Und Frühgeschichte, Potsdam, 21*, 3–31.

Helmer, D., & Monchot, H. (2006). Un site mésolithique de chasse à l'aurochs (La Montagne, Sénas, Bouches-du-Rhône). *Anthropozoologica, 41*, 215–228.

Holmes, T. V. (1896). Discovery of mammalian remains at Great Yeldham, Essex. *Essex Naturalist, 9*, 115–118.

Horne, D. J., Ashton, N., Benardout, G., Brooks, S. J., Coope, G. R., Holmes, J. A., Lewis, S. G., Parfitt, S. A., White, T. S., Whitehouse, N. J., & Whittaker, J. E. (2022). A terrestrial record of climate variation during MIS 11 through multiproxy palaeotemperature reconstructions from Hoxne. *UK. Quaternary Research, 2022*, 1–32. https://doi.org/10.1017/qua.2022.20

Hutson, J. M., Villaluenga, A., García Moreno, A., Turner, E., & Gaudzinski-Windheuser, S. (2018). On the use of metapodials as tools at Schöningen 13II-4. In J. M. Hutson, A. García Moreno, E. S. Noack, E. Turner, M. Villaluenga, A. Martínez, & S. Gaudzinski (Eds.), *The origins of bone tool technologies: "Retouching the Palaeolithic: Becoming human and the origins of bone tool technology" conference at Schloss Herrenhausen in Hannover, Germany, 21–23. October 2015* (pp. 53–91). Römisch-Germanisches Zentralmuseum.

Issac, G. L. (1978). The food-sharing behaviour of proto-human hominids. *Scientific American, 238*, 90–108.

Issac, G. L. (1984). The archaeology of human origins: Studies of the Lower Pleistocene in East Africa. *Advances in World Archaeology, 3*, 1–87.

Jaubert, J., Lorblanchet, M., Laville, H., Slott-Moller, R., Turq, A., & Brugal, J.-P. (1990). Les chassuers d'Aurochs de La Borde: Un site du Paléolithique moyen (Livernon, Lot). *Documents d'Archéologie Français, No. 27*.

Karr, L. P., Short, A. E. G., Hannus, L. A., & Outram, A. K. (2015). A bone grease processing station at the Mitchells Prehistoric Indian Village; Archaeological evidence for the exploitation of bone fat. *Environmental Archaeology, 20*, 1–12.

Kenady, S. M., Wilson, M. C., Schalk, R. F., & Mierendorf, R. R. (2011). Late Pleistocene butchered *Bison antiquus* from Ayer Pond, Orcas Island, Pacific Northwest: Age confirmation and taphonomy. *Quaternary International, 233*, 130–141.

Kurtén, B. (1959). On the bears of the Holsteinian interglacial. *Stockholm Contributions in Geology, 2*, 73–102.

Legge, A. J., & Rowley-Conwy, P. (1988). *Star Carr revisited: A reanalysis of the large mammals*. London University.

Lewis, S. G., Ashton, N., & Jacobi, R. (2011). Testing human presence during the Last Interglacial (MIS 5e): A review of the British evidence. In N. Ashton, S. G. Lewis, & C. Stringer (Eds.), *The ancient human occupation of Britain* (pp. 125–164). Developments in Quaternary Science 14.

Lister, A. M. (1986). New results on deer from Swanscombe, and the stratigraphical significance of deer in the Middle and Upper Pleistocene of Europe. *Journal of Archaeological Science, 13*, 319–338.

Lister, A. M. (1992). Mammalian fossils and Quaternary biostratigraphy. *Quaternary Science Reviews, 11*, 329–344.

Lister, A. M. (1996). The morphological distinction between bone and teeth of fallow deer (*Dama dama*) and red deer (*Cervus elaphus*). *International Journal of Osteoarchaeology, 6*, 119–143.

Lord, T. C., O'Connor, T., Siebrandt, D., & Jacobi, R. (2007). People and large carnivores as biostratinomic agents in Lateglacial cave assemblages. *Journal of Quaternary Science, 22*, 681–694.

Lyman, R. L. (1995). A study of variation in the prehistoric processing of large artiodactyls. In E. Johnson (Ed.), *Ancient peoples and landscapes* (pp. 233–253). Museum of Texas Tech University.

Merritt, S. R. (2017). Investigating hominin carnivory in the Okote Member of Koobi Fora, Kenya with an actualistic model of carcass consumption and traces of butchery on the elbow. *Journal of Human Evolution, 112*, 105–133.

Moncel, M.-H., Ashton, N., Arzarello, M., Fontana, F., Lamotte, A., Scott, B., Muttillo, B., Berruti, G., Nenzioni, G., Tuffreau, A., & Peretto, C. (2022). Early Levallois core technology between Marine Isotope Stage 12 and 9 in Western Europe. *Journal of Human Evolution, 139*, 102735.

Moncel, M.-H., Moigne, A.-M., Sam, Y., & Combier, J. (2011). The emergence of Neanderthal technical behavior: New evidence from Orgnac 3 (Level 1, MIS 8), Southeastern France. *Current Anthropology, 52*, 37–75.

Nilssen, P. J. (2000). *An actualistic butchery study in South Africa and its implications for reconstructing hominid strategies of carcass acquisition and butchery in the Upper Pleistocene and Plio-Pleistocene*. PhD Thesis, University of Cape Town.

Olsen, S. (1960). Post-cranial skeletal characters of *Bison* and *Bos*. *Papers of the Peabody Museum of Archaeology and Ethnography, 35*.

Past Interglacials Working Group of PAGES. (2016). Interglacials of the last 800,000 years. *Review of Geophysics, 54*, 162–219. https://doi.org/10.1002/2015RG000482

Parfitt, S. (2004). A butchered bone from Norfolk: Evidence for a very early human presence in Britain. *Archaeology International, 8*, 14–17.

Parkin, R. A., Rowley-Conwy, P., & Serjeantson, D. (1986). Late Palaeolithic exploitation of horse and red deer at Gough's Cave, Cheddar, Somerset. *University of Bristol Spelaeological Society, 17*, 311–330.

Penkman, K. E., Preece, R. C., Bridgland, D. R., Keen, D. H., Meijer, T., Parfitt, S. A., & White, T. S. (2011). A chronological framework for the British Quaternary based on *Bithynia* opercula. *Nature, 476*, 446–449.

Penkman, K. E., Preece, R. C., Bridgland, D. R., Keen, D. H., Meijer, T., Parfitt, S. A., White, T., & Collins, M. (2013). An aminostratigraphy for the British Quaternary based on *Bithynia* opercula. *Quaternary Science Reviews, 61*, 111–134.

Pobiner, B. L., Higson, C. P., Kovarovic, K., Kaplan, R. S., Rogers, J., & Schindler, W. (2018). Experimental butchery study investigating the influence of timing of access and butcher expertise on cut mark variables. *International Journal of Osteoarchaeology, 28*, 377–387.

Prummel, W., & Niekus, M. (2011). Late Mesolithic hunting of a small female aurochs in the valley of the River Tjonger (the Netherlands) in the light of Mesolithic aurochs hunting in NW Europe. *Journal of Archaeological Science, 38*, 1456–1467.

Prummel, W., Th. Niekus, M. J. L., van Gijn, A. L., & Cappers, R. T. J. (2002). A Late Mesolithic kill site of aurochs at Jardinga, Netherlands. *Antiquity, 76*, 413–424.

Rawlinson, A. A. (2021). *The Purfleet Interglacial: An examination of change and complexity in core and flake technology during the final Lower Palaeolithic.* PhD thesis, Durham University.

Rawlinson, A., Dale, L., Ashton, N., Bridgland, D., & White, M. (2022). Flake tools in the European Lower Paleolithic: A case study from MIS 9 Britain. *Journal of Human Evolution, 165*, 103153. https://doi.org/10.1016/j.jhevol.2022.103153

Rodríguez-Hidalgo, A., Rivals, F., Palmira Saladié, P., & Carbonell, E. (2015a). Season of bison mortality in TD10.2 bone bed at Gran Dolina (Atapuerca); Integrating tooth eruption, wear and microwear methods. *Journal of Archaeological Science: Reports, 6*, 780–789.

Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., & Carbonell, E. (2015b). Hominin subsistence and site function of TD10.1 bone bed level at Gran Dolina site (Atapuerca) during the late Acheulean. *Journal of Quaternary Science, 30*, 679–701.

Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., Arsuaga, J. L., Bermúdez de Castro, J. M., & Carbonell, E. (2017). Human predatory behavior and the social implications of communal hunting based on evidence from the TD10.2 bison bone bed at Gran Dolina (Atapuerca, Spain). *Journal of Human Evolution, 105*, 89–112.

Roe, H. M., Coope, G. R., Devoy, R. J., Harrison, C. J., Penkman, K. E., Preece, R. C., & Shcreve, D. C. (2009). Differentiation of MIS 9 and MIS 11 in the continental record: Vegetational, faunal, aminostratigraphic and sea-level evidence from coastal sites in Essex, UK. *Quaternary Science Reviews, 28*, 2342–2373.

Rowley-Conwy, P. (2017). To the Upper Lake: Star Carr revisited – By birchbark canoe. In P. Rowley-Conwy, D. Serjeantson, & P. Halstead (Eds.), *Economic zooarchaeology: Studies in hunting, herding and early agriculture* (pp. 197–207). Oxbow Books.

Schreve, D. C. (1997). *Mammalian biostratigraphy of the later Middle Pleistocene in Britain*. University College London, PhD thesis.

Schreve, D. C. (2001a). Differentiation of the British Middle Pleistocene interglacials; The evidence from mammalian biostratigraphy. *Quaternary Science Reviews, 20*, 1693–1705.

Schreve, D. C. (2001b). Mammalian evidence from Middle Pleistocene fluvial sequences for complex environmental change at the oxygen isotope substage level. *Quaternary International, 79*, 65–74.

Soulier, M.-C., & Costamagno, S. (2017). Let the cutmarks speak! Experimental butchery to reconstruct carcass processing. *Journal of Archaeological Science: Reports, 11*, 782–802.

Stuart, A. J. (1982). *Pleistocene vertebrates in the British Isles*. Longman.

Stuart, A. J., Wolff, R. G., Lister, A. M., & Eggington, J. M. (1993). Fossil vertebrates. In R. Singer, B. G. Gladfelter, & J. J. Wymer (Eds.), *The Lower Paleolithic site at Hoxne, England* (pp. 163–206). University of Chicago Press.

Sutcliffe, A. J. (1976). The British Glacial-Interglacial Sequence. *Quaternary Newsletter, 18*, 1–7.

Sutcliffe, A. J. (1995). Insularity of the British Isles 250 000–30 000 years ago: The mammalian, including human, evidence. In R. C. Preece (Ed.), *Island Britain: A Quaternary perspective* (pp. 127–140). Geological Society Special Publication No. 96.

Street, M. (1991). Bedburg-Königshoven: A pre-boreal Mesolithic site in the Lower Rhineland, Germany. In N. Barton, A. J. Roberts, & D. A. Roe (Eds.), *The late-glacial in north-west Europe: Human adaptation and environmental change at the end of the Pleistocene* (pp. 256–270). *CBA Research Report 77*.

Todd, L., Hill, M. G., Rapson, D., & Frison G. C. (1997). Cutmarks, impacts, and carnivores at Casper site bison bonebed. In L. A. Hannus, L. Rossum, & R. P Winham (Eds.), *Proceedings of the 1993 Bone Modification Conference, Hot Springs, South Dakota* (pp. 136–157). Occasional Publication No. 1, Archeology Laboratory, Augusta College.

Van Kolfschoten, T., Parfitt, S. A., Serangeli, J., & Bello, S. M. (2015). Lower Paleolithic bone tools from the 'Spear Horizon' at Schöningen (Germany). *Journal of Human Evolution, 89*, 226–263.

Wenban-Smith, F. (2013). The Ebbsfleet Elephant: Excavations at Southfleet Road, Swanscombe in advance of High Speed 1, 2003–4. *Oxford Archaeology Monograph* 20.

Wenban-Smith, F., Stafford, E., Bates, M., & Parfitt, S. A. (2020). Prehistoric Ebbsfleet: Excavations and research in advance of High Speed 1 and South Thameside Development Route 4, 1989–2003. *Oxford Wessex Archaeology Monograph 7*.

Whitaker, W., Penning, W. H., Dalton, W. H., & Bennett, F. J. (1878). *Geology of the N.W. part of Essex and the N.E. part of Herts. with parts of Cambridgeshire and Suffolk*. Memoir of the Geological Survey of Great Britain.

White, M., & Ashton, N. (2003). Lower Palaeolithic core technology and the origins of the Levallois method in north-western Europe. *Current Anthropology, 44*, 598–609.

White, M., Ashton, N., & Scott, B. (2011). The emergence, diversity and significance of Mode 3 1269 (Prepared Core) technologies. In: N. Ashton, S. G. Lewis, & C. Stringer (Eds.), *The ancient human occupation of Britain* (pp. 67–91). Developments in Quaternary Science, 14.

White, M. J., & Bridgland, D. R. (2018). Thresholds in lithic technology and human behaviour in MIS 9 Britain. In M. Pope, J. McNabb, & C. Gamble (Eds.), *Crossing the human threshold: Dynamic transformations and persistent places during the Middle Pleistocene* (pp. 165–192). Routledge.

White, M. J., Bridgland, D. R., Schreve, D. C., White, T. E., & Penkman, K. E. H. (2018). Well-dated fluvial sequences as templates for patterns of handaxe distribution: Understanding the record of Acheulean activity in the Thames and its correlatives. *Quaternary International, 480*, 118–131.

Wymer, J. J. (1985). *Palaeolithic sites of East Anglia*. Geo Books.