Editorial: Chronology, palaeoenvironments and subsistence in the Acheulean of western Europe.

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1. Introduction

The handaxe is an iconic object in European prehistory. The first discovery (a flint handaxe) was in 1679 in the Grays Inn Road in central London, followed in the late 18th century by the pioneering work of John Frere at Hoxne (Suffolk, eastern England, Fig. 1; Frere, 1800). In the next century, Jacques Boucher de Perthes (1847) made important discoveries of handaxes in the gravels of the River Somme around Abbeville (northern France). His work inspired a distinguished group of British visitors, namely Hugh Falconer, Joseph Prestwich, John Evans and John Lubbock (later Lord Avebury), whom he convinced that these artefacts were manufactured by primitive humans who lived at the time when the gravels were being deposited (see Bridgland and White, this issue). This established an Anglo-French collaboration that continues to this day and is reflected in this Special Issue. Key contributions in the 19th and 20th centuries to the study and understanding of handaxes were made on both sides of the English Channel. In France, Gabriel de Mortillet (1883) was the first to establish nomenclature for these characteristic implements, followed by Victor Commont (1906, 1908), who established the importance of St Acheul, in the Somme valley, eventually the type locality for the handaxe industries. Subsequent work by François Bordes (1961) erected an influential typological classification of handaxe varieties. In England (see Bridgland and White, this issue), Derek Roe (1968a, 1968b) made an exhaustive study of handaxe occurrences and variability, while John Wymer (1968, 1985, 1999) also documented find-spots, particularly in fluvial contexts, and was responsible for his own typological classification.

Figure 1 about here please

There is no doubt that handaxes remain a source of fascination for Palaeolithic archaeologists and Quaternary scientists alike. They have been known by different names: in France as '*limande*', '*hache*', '*coup de poing*' and '*biface*', and in England as '*implement*', '*palaeolith*' (a term that must also be applied to cores and flakes) and '*biface*', the last being much favoured in recent decades as a descriptive term that made no reference to use and was applicable in both countries. However named, they nevertheless form part of a group of tools commonly referred to as Large Cutting Tools (LCTs) that are frequently (but not always) bifacially worked (Goren-

Inbar and Sharon, 2006). Furthermore, handaxes can be made on a wide range of raw materials, including numerous different rock types (for example, flint, quartz and quartzite and volcanic products such as basalt and andesite), as well as bone. Many questions remain as to the purpose of handaxes (e.g. Keeley, 1980; O'Brien, 1981), the reason for their variable morphologies and possible evolution of this material culture (e.g. Roe, 1968a; White, 1998; Hodgson, 2015 and references therein) and the technological and cognitive capacities of their makers (Gibson and Ingold, 1993 and references therein; McNabb and Ashton, 1995). The long-standing and generally accepted view, and one widely supported by modern experimental evidence, is that handaxes were general-purpose implements for skinning and butchering animal remains, as well as for cutting and shaping wood (Bordaz, 1970; Oakley, 1961; Ohel, 1987).

The collection of papers presented here stems from a conference organised in Paris (19–21 November 2014) on "*European Acheuleans. Northern v. Southern Europe: Hominins, technical behaviour, chronological and environmental contexts*", which aimed to address the key issues outlined in the title of the meeting. However, the purpose of the papers in this Special Issue is not to explore the handaxe from a techno-typological viewpoint (a topic to be explored in a forthcoming sister Special Issue in *Quaternary International*, presenting additional papers from the conference) but rather to provide a state-of-the-art view on the chronology and palaeoenvironments of the earliest handaxe makers in Europe, with a view to understanding key evolutionary trends in the hominin lineage, patterns of occupation and aspects of behaviour. Here, by way of an introduction, we summarise the origin and dispersal of the Acheulean, from its beginnings in Africa through its initial spread in India and western Asia, to its eventual arrival in Europe. The 'Movius Line' dichotomy between western and eastern Europe (the former with handaxes and the latter without) is still current but much debate and controversy surrounds the timing of the first appearance of handaxes in the west. The current chronological framework for the earliest Acheulean is then reviewed for western Europe, drawing largely on multiproxy evidence from long fluvial sequences. Finally, individual papers in the Special Issue are summarised with respect to the new contributions that they make to our understanding of Acheulean occupation, palaeoenvironments and behaviour.

2. The origin and dispersal of Acheulean industries

Handaxes appeared during the Early Pleistocene in Africa as early as ~1.75–2 Ma (Semaw *et al*., 2009; Beyene *et al*., 2013). This is a topic that is beyond the brief of both the conference in Paris and this Special Issue, although of course it remains one of enormous interest and is the subject of continued intense research.

There are also records of 'Early Acheulean' artefacts from Peninsular India, contrasting with later handaxe industries that are associated with low-level fluvial deposits and had long been regarded as of late Quaternary age (Mishra *et al.*, 2007). The recent recognition that areas of cratonic crust such as the Indian subcontinent have not experienced the progressive uplift experienced by younger continental crust elsewhere (cf. Westaway *et al.*, 2003; Bridgland and Westaway, 2014), means that fluvial incision has been minimal and low-level deposits can date back to the Middle or Early Pleistocene. There have been few opportunities to bring geochronological techniques to bear on the Indian record, but application of Th/U dating of a number of ‘Early Acheulean’ localities in India showed that all were beyond the range of the technique (>400 ka) (Mishra, 1992; Mishra *et al.*, 2007). Paddaya *et al.* (2002) dated bones associated with Early Acheulean artefacts at Isampur, Karnataka, and obtained Electron Spin Resonance (ESR) ages >1.2 Ma. The same technique was used to obtain a date of > 800 ka for calcretes in the Thar Desert of Rajasthan (Kailath *et al.*, 2001), from which ‘Late Acheulean’ artefacts have been obtained. Palaeomagnetic studies have suggested that the Acheulean contexts at Bori, Morgaon and Nevasa are of Matuyama age (Sangode *et al.*, 2007). Such data led Mishra *et al.* (2007) to conclude that the Indian ‘Early Acheulian’ probably dates from the Early Pleistocene. However, this remains a topic of debate, as indeed does the veracity of pre-Middle Pleistocene hominin occupation of the Indian subcontinent (cf. Dennell, 2007; Chauhan, 2009, 2010; Patnaik *et al.*, 2009; Dennell *et al.*, 2010; Gaillard *et al.*,2010; Mishra *et al.*, 2010; Chauhan and Patnaik, 2012).

Handaxes appear at the gates of Europe, in the Levant and southern Turkey, in Early Pleistocene contexts at Ubeidiya in the Jordan valley in Israel (e.g., Bar-Yosef and Goren-Inbar, 1993; Belmaker *et al.*, 2002), at Latamneh in the valley of the Orontes in Syria (Bar-Yosef and Belmaker, 2010; Bridgland *et al.*, 2012) and from Euphrates gravels both north and south of the border between Syria and Turkey (Demir *et al.*, 2007, 2008). Although these occurrences might be imagined to mark the spread of handaxe makers from Africa, this technology was apparently not shared by the earliest inhabitants of Europe, for example at the site of Dmanisi in the Lesser Caucasus Mountains of Georgia (Gabunia and Vekua, 1995; Gabunia *et al.*, 2000; de Lumley *et al.*, 2002). Hominin remains in fluvial and volcanogenic deposits at Dmanisi have been dated to 1.8 Ma by Argon-Argon, applied to underlying and overlying basalt flows. This date, which is supported by the normal polarity of the deposits, indicative of the Olduvai subchron, is apparently older than the spread of handaxe industries through the Levant and pre-dates the supposed ages of the Acheulean industries at Ubeidiya (~1.4 Ma: Tchernov, 1987, 1999) and Latamneh (1.2–1.0 Ma: Bar-Yosef and Belmaker, 2010). The Levantine corridor is therefore of great potential significance as the pathway for hominin migration and population exchange between SW Asia and Europe, as well as from Africa (cf. Dennell *et al.*, 2010).

Twenty years ago, the appearance of handaxes on the European continent was widely viewed as delayed until the Middle Pleistocene (the “short chronology” of Roebroeks and van Kolfschoten, 1994), with a series of stringent criteria to be met by sites put forward for early occupation; even then, the Acheulean was widely thought to be restricted to western and southern Europe. Many sites “failed” these criteria on various grounds but in recent years, there has been a resurgence in claims for pre-Middle Pleistocene Acheulean occupation at Solana del Zamborino and at Estrecho del Quípar, in Spain, at ~900 ka (Scott and Gibert, 2009; see, however, Jiménez-Arenas *et al.*, 2011, and Bridgland and White, this volume), at Barranc de la Boella, also in Spain, around 1 Ma (Vallverdú *et al.*, 2014; Mosquera *et al.*, this volume) and >700ka at La Noira, central France (Despriée *et al.*, 2010, 2011; Moncel *et al.*, 2013). Although controversial in some cases, if the dates of these oldest sites can be verified, then handaxe making in southern Europe might not be so very much later than in areas further to the south.

The question remains as to how the Acheulean dispersed. Several scenarios may be envisaged, for example either (1) rapid and ancient dispersal throughout Western Europe of one (or several) new hominins, (2) separate dispersals of new technical habits through a Levantine corridor or across the Gibraltar Strait from Morocco (cf. Bridgland *et al.*, 2006), where the earliest Acheulean assemblages around Casablanca have been dated by magnetostratigraphy to the latest part of the Matuyama chron (~850 ka, or MIS 21: Raynal and Texier, 1989; Raynal *et al.*, 1995, 2002), or (3) a local origination in some areas due to an increase in skills of established populations.

3. The current chronological framework for Acheulean occupation in western Europe

In western Europe (as indeed in other regions), the record from river terrace 'staircases' has provided some of the best-preserved evidence for understanding the timing of the appearance of the Acheulean (Bridgland, 1994; Bridgland *et al*., 2006; Westaway *et al.*, 2006; Mishra *et al.*, 2007). Within a number of long fluvial sequences, the earliest occurrence of the Acheulean has been consistently estimated at around 500 ka, within the latter part of the early Middle Pleistocene. This is equally the case between Britain and northern France, although given the peninsular status of Britain in the early Middle Pleistocene, this is to be expected. Nevertheless, absolute age estimates for this period have been few from fluvial sequences (e.g. Voinchet *et al*., 2010; Hérisson *et al.*, 2012; Antoine *et al.*, 2015) and the preponderance of dating information comes from other techniques, such as the relative position of the deposits within the river terrace succession (e.g. Bridgland 1994; Antoine, 1994; Antoine *et al*., 2007, 2010, 2015), from mammalian and molluscan biostratigraphy (Keen, 1990, 2001; Preece, 1995, 2001; Schreve, 2001; Bridgland and Schreve, 2004; Schreve *et al.*, 2007) and from aminostratigraphy (Penkman *et al*., 2013).

The majority of Acheulean sites from northern France have been recovered from the terraces of the Somme (Antoine, 1994; Antoine *et al.*, 2000), with the oldest known from the vicinity of Abbeville, from the quarries of Carpentier and Champ de Mars (Tuffreau *et al.*, 2008), and from the Rue du Manège site at Amiens. Although the Champ de Mars site is no longer available for reinvestigation, recent re-dating of the Carpentier site using a combination of terrace stratigraphy, biostratigraphy and ESR suggests an age for the handaxe assemblage within MIS 14 (Voinchet *et al*., this volume). The same ESR technique at the Rue du Manège site has yielded an age of around 550 ka for the handaxe assemblage, although the artefacts are not in primary context. An age within MIS 15 or MIS 14 is therefore indicated (Antoine *et al.*, 2015).

The Thames terrace sequence dates back to the Early Pleistocene (c. 1.9 Ma) (e.g., Gibbard, 1988; Whiteman and Rose, 1992; Bridgland, 1994; Westaway *et al.*, 2002). However, despite the substantial number of Cromerian Complex sites in Britain, not a single primary context archaeological site of definitive pre-MIS 12 age has been identified in the Thames Valley (Wymer, 1999). Further information comes from the terrace staircases of the Solent River and its tributaries in southern England and interdigitating raised beach sequence, best expressed at the site of Boxgrove (West Sussex). There, an abundance of handaxes (and hominin remains) has been found in association with lagoonal silts and freshwater spring deposits and a late early

Middle Pleistocene mammalian faunal assemblage (Roberts and Parfitt, 1999). Again, although absolute dates are limited, the available evidence tentatively highlights the appearance of the Acheulean prior to MIS 12 in southern England (Ashton and Hosfield, 2010).

In Iberia, the fluvial record also provides a potential dating framework for the Lower Palaeolithic record, although better dating control of the Spanish and Portuguese river-terrace sequences is required (cf. Raposo and Santonja, 1995; Bridgland *et al*., 2006; Santisteban and Schulte, 2007). Palaeomagnetic criteria have allowed the Matuyama–Brunhes boundary to be defined in several Iberian systems, including the Ebro, Tagus and Guadalquivir, as reviewed by Santisteban and Schulte (2007); they noted, however, that the archaeological record was being used as an indication of the Middle Pleistocene in some systems, based on the occurrence of Acheulean material at particular stratigraphical levels, such as in Terrace 7 in the Guadiana basin. Similarly, non-handaxe (Mode 1 flake and core) archaeology was taken as evidence for a Jaramillo age for high-level Tagus terrace deposits with normal magnetic polarity (Santonja and Pérez-González, 2000–2001; Santisteban and Schulte, 2007), although given the younger occurrence of Mode 1 assemblages in other parts of Europe (e.g. at Pakefield, UK, in the early Middle Pleistocene; Parfitt *et al*., 2006), this cannot be taken as a reliable indicator of age. Clearly an independent dating system is desirable if the transition into the Acheulean is to be charted in this important region, given that immigration from Africa may have occurred across the Gibraltar Strait. Although a proliferation of open air sites in Italy have been put forward as documenting hominin occupation in the Early Pleistocene and first half of the early Middle Pleistocene (Mussi, 1995; Arzarello *et al*., 2007), the best evidence for pinpointing the appearance of the Acheulean within a fluvial sequence comes from Notarchirico (see Pereira *et al*., this volume).

In the cases of the Lower Thames in south-east England and the Somme in northern France, both river systems are apparently responding on a 100 ka climate cycle, for the last 450 ka in the case of the former (Bridgland, 1994, 2006), and for over 1 Ma for the latter (Antoine *et al.*, 2015). It is not yet unequivocally established whether terrace formation in the Bytham River of the English Midlands, which was obliterated by the MIS 12 glaciation (Rose, 1994), is responding on the same timescale, although a similar MI3 13 age is inferred for the appearance of the Acheulean at sites such as Waverley Wood in Warwickshire (Shotton *et al*., 1993), Brooksby (Stephens *et al*., 2008) and Warren Hill in Norfolk (Wymer *et al*., 1991; see Bridgland and White, this issue) on the basis of their altitudinal position (Westaway 2009a, 2009b, but see Lee *et al*., 2004 for a contrasting age model).

The combination of biostratigraphy and aminostratigraphy also allows for correlations to be made with other Acheulean sites that occur outside the main fluvial sequences, for example those within the Cromer Forest-bed Formation of eastern England, such as Happisburgh I in Norfolk (Ashton *et al.*, 2008), where deposits of multiple ages within the early Middle Pleistocene Cromerian Complex crop out at sea level and individual finds of handaxes are often made. A small number of cave sequences have yielded Acheulean assemblages, dated through a combination of mammalian biostratigraphy and absolute methods (notably Uranium-series dating), including Kents Cavern (south-west England; Campbell and Sampson, 1971), the basal levels of Aragó and Montmaurin in southern France (Falguères *et al*., 2004; Lumley and

Barsky, 2004), the Gruta de Aroeira in central Portugal (Hoffman *et al*., 2010) and Galería at Atapuerca (northern Spain; Berger *et al*., 2008; García-Medrano *et al.*, 2014).

4. Contributions within the special issue

As highlighted in McNabb and Cole's (2015) recent evaluation of handaxe symmetry and refinement, there is an urgent need for a robust chronological underpinning, if any evolution of material culture is to be genuinely identified. Without better dating, the recognition of such patterns and any linkage to biological or behavioural change will be forever obscured (*contra* Hodgson, 2015).

Two papers in the Special Issue tackle the problems of chronology. **Voinchet *et al.*** document the recent application of geochronological techniques to date the earliest Acheulean sites of northwestern Europe. These authors have applied ESR dating of sedimentary quartz and ESR/U-series dating of fossil tooth enamel to obtain new age estimates from a range of key sites age, albeit with large associated uncertainties in many cases. By and large the resultant data fit well with previous evidence, largely based on biostratigraphy and the framework control of river-terrace sequences. For Britain, the arrival of Acheulean technologies in late MIS 15 through to MIS 9 is reinforced, with a similar pattern in northern France. Although there is evidence from La Noira in the Cher valley to suggest that the Acheulean was present in central France as early as MIS 17, it remains clear that handaxe-making first appeared in NW Europe significantly later than in the southern parts of the continent.

The second paper on chronology, by **Pereira *et al.***, concerns the dating of Notarchirico, the oldest hominin fossil site in Italy. The site preserves a series of fluvial deposits interbedded with volcaniclastic materials, which have yielded a series of handaxes and a femur of *Homo heidelbergensis*. The authors present new combined Argon-Argon and ESR dates that place both the archaeological assemblage and the hominin specimen within MIS 16. Not only does the new chronological attribution affirm the *H. heidelbergensis* femur as the oldest Middle Pleistocene hominin fossil known from Italy, but the study demonstrates the importance of the Italian peninsula for hominin populations during this stage. Despite the aforementioned MIS 17 ages from La Noira (Voinchet *et al*., 2010 and this volume), there is no evidence from either this site or any further north that hominins withstood the subsequent severe cold-climates of MIS 16 *in situ*. The Italian peninsula may therefore have acted as a refugium for hominin populations and as a source for subsequent re-colonisation during interglacials or interstadials.

With a robust chronological framework in place, even a relative one, the possibility to investigate patterns within the archaeological data then becomes realistic. The paper by **Bridgland and White** explores the extent to which differing handaxe forms can have chronological relevance, using river terrace sequences in Britain as a chrono-stratigraphical template. This builds on work done many years ago by Derek Roe (1968a), who recognized statistically meaningful handaxe groups in Britain, with differences in form; however, given the inadequate Quaternary chronostratigraphy of the time, he could make little sense of their distribution. There are now clear indications of patterns, with two of Roe's groups characterizing early Middle Pleistocene assemblages, another, with high incidence of twisted handaxes, representing MIS 11–10 and a group in which cleavers and ficrons are common seeming to be associated with MIS 9 contexts. The extent to which these patterns can be extended into France is touched upon, although the emphasis is on a requirement for future research aimed in this direction. Similarly, the available chronological frameworks also set the scene for exploring differences in the archaeological repertoires of northern and southern Europe, for example, the use or otherwise of large flakes for bifacial manufacture, or the presence or otherwise of cleavers made on flakes. This diversity continues through time, even if assemblages dated to 500–350 ka are sometimes considered to be more standardized in terms of their bifacial tools.

Of equal importance is the role of climate, environment and biogeography in the spread of the Acheulean, in particular the occurrence of periods of favourable climatic conditions, biogeographical barriers, competition from large carnivores and changing availability of prey. The youngest interglacial in the early Middle Pleistocene, MIS 13, has been highlighted above as a significant period for hominin occupation in northern Europe. The paper by **Candy *et al*.** accordingly explores the palaeoclimatic and palaeoenvironmental context of the earliest Acheulean in Britain during this interglacial. The palaeoclimatic record from Britain and the north Atlantic for MIS 13 indicates enhanced warmth, contrasting markedly with evidence for cooler conditions at this time in the Iberian peninsula and in both ice and marine core records (e.g. Lang and Wolff, 2011). However, the authors conclude that, although there is evidence for occupation under temperate climate conditions in MIS 13, the wealth of multiproxy palaeoenvironmental data from the majority of handaxe sites point to cool to “post-temperate” climates, with winter temperatures at or below freezing, and boreal landscapes. These findings have significant implications for early hominin behavioural adaptations and coping strategies in sub-optimal environmental conditions, such as subsistence practices, use of fire or clothing (see also Leroy *et al*., 2011). In this respect, the extinction of a number of large carnivores during MIS 12 (Turner, 1992) may have enhanced resource availability for later hominin populations, as well as reducing competition for shelter in caves.

The need for quantifiable palaeotemperature and palaeoprecipitation estimates in order to appreciate fully the hominin environment is highlighted by the paper by **Blain *et al***. These authors apply Mutual Climatic Range and habitat weighting methods to herpetofaunal (amphibian and reptile) assemblages from key MIS 11 archaeological deposits in northern and central Spain, including level TD10 at Gran Dolina (Atapuerca), Áridos-1 (Madrid) and Ambrona (Soria) in order to establish past climatic and environmental parameters at these sites. The results not only allow the observation of climatic evolution through the MIS 11 interglacial, with a decline in termperatures and precipitation, combined with a decrease in woodland cover through time, but also emphasise the importance of such records for depositional environments where other climatically-sensitive proxies such as pollen or beetles may not be preserved.

The contribution to the Special Issue by **Limondin-Lozouet *et al*.** underlines the value of molluscan faunas in determining the palaeo-environmental conditions during the MIS 11 (Holsteinian/Hoxnian) interglacial in NW Europe, where this is recognized as an usually long interglacial, important as a period during which hominin populations exploited the varying landscapes, with evidence that they pursued different tool-making strategies, with both handaxe and non-handaxe traditions represented (cf. White, 2000; White and Schreve, 2000; Bridgland, 2006). Once again there is emphasis on fluvial contexts, with tufa deposits proving especially significant; in France, these authors report on six MIS 11 tufa sites, five with Acheulean assemblages (from north to south, Rue Boileau, St Acheul, St Pierre-les-Elbeuf, Vernon and La Celle), whereas Britain has just two tufa sites dating from this interglacial, at Hitchin and Beeches Pit, West Stow, with only the latter yielding archaeology (Gowlett *et al.*, 2005; Preece *et al.*, 2007). The authors pay particular attention to the unusually long malacological record obtained from the tufa at La Celle, in the Seine system, which provides a precise environmental and chronological framework for Acheulean occupation. Importantly, they are able to demonstrate continued occupation by Palaeolithic populations during the entire optimum phase of the interglacial, showing adaptation by these hominin groups both to fully temperate conditions and to closed forest environments.

Having established a testable chronological framework and elaborated key elements of the palaeoenvironmental context of the earliest Acheuleans in western Europe, it is equally timely to explore in more depth aspects of behaviour such as subsistence practices. The evidence from the flagship site of Boxgrove in southern England has previously demonstrated beyond reasonable doubt that by at least MIS 13, hominins were hunting megafauna such as rhinoceroses, deer and horses, likely using the topography of the landscape to their advantage in terms of trapping and dispatching the animals (Roberts, 1996; Roberts and Parfitt, 1999). The paper of **Mosquera *et al***., however, presents evidence for the oldest elephant butchery site in Europe, from Barranc de la Boella in north-east Spain. Here, a lithic assemblage including several hammerstones, multiple flakes (some refitting) and cores and a large cutting tool (a pick) has been recovered from a palaeo-landsurface, around the disarticulated carcass of a sub-adult mammoth, *Mammuthus meridionalis*. The appearance of large cutting tools in the archaeological record marks the onset of the Acheulean and Barranc de la Boella therefore witnesses the apparent first occurrence of this industry in Europe. Although the cause of death of the animal is unknown, the presence of cutmarks on the mammoth ribs points to exploitation of the carcass shortly after the death of the animal, thereby providing a more complete picture of Early Pleistocene hominin foraging opportunities at a time when megafaunal exploitation is rare but nevertheless present in both Europe and Africa.

The paper by **Rodríguez-Hidalgo *et al*.** continues the theme of analysing subsistence behaviour by reviewing the origins of the prime-age ungulate hunting niche that comes to the fore in the Middle Palaeolithic (Stiner, 2013). Drawing on the evidence from the celebrated TD10.1 bone bed at Gran Dolina (Atapuerca, Spain), dated to around 300 ka, these authors reveal that the site was used extensively by hominins as a long-term residential base camp, where a diversity of domestic activities were undertaken. In particular, the characteristics of the animal bone assemblage indicate a predominance of prime-age ungulate carcasses (mostly of red and fallow deer, with smaller numbers of bison, equids and rhinoceros). These have been systematically butchered, showing signs of skinning, removal of the guts, disarticulation and defleshing, human tooth marks from chewing, and frequent cracking of long bones and mandibles for marrow access. Together, these lines of evidence present an important overview of subsistence behaviour during the Lower Paleolithic at this key site for the European Middle Pleistocene and lays the foundation for our understanding of selective prey exploitation by hominins in the subsequent Middle Palaeolithic.

The identity of the handaxe makers must also be discussed, with *Homo ergaster* or *erectus* (e.g. Rightmire *et al*., 2006), or *H. antecessor* (e.g. Bermúdez de Castro *et al*., 1997) inferred for any Early Pleistocene Acheulean localities and *Homo heidelbergensis* for the Middle Pleistocene (e.g. Roberts *et al*., 1994; Pérez *et al*., 1999). However, handaxe manufacture (and therefore the Acheulean) persists into the Middle Palaeolithic under the Neanderthals. The final paper in the Special Issue, by **Compton and Stringer**, examines an important series of late Middle Pleistocene hominin teeth from the site of Pontnewydd Cave in north Wales, dated to around 225 ka and found in association with both handaxes (the furthest north-west extent of any hominin to be associated with these tools) and Levallois artefacts. Based on the characteristics of the Pontnewydd teeth, the authors classify them as "pre Neanderthal", drawing particular comparisons with the morphology and size of specimens from the Sima de los Huesos at Atapuerca, and grouping them with other hominin fossils such as Swanscombe (UK) and Bilzingsleben (Germany), which show a similar stage of "neanderthalization". The authors further refute the view that the Pontnewydd and Sima de los Huesos individuals should be regarded as *H. heidelbergensis* (*contra*, for example, Martinón-Torres *et al*., 2007) and highlight the diversity in degree of Neanderthal affinities that are present within apparently contemporary European Middle Pleistocene specimens.

To conclude, the papers presented in this Special Issue address core problems in our understanding of the Acheulean in western Europe, related principally to chronology, environment, behaviour and identity. These papers not only pinpoint the first occurrence of the Acheulean in northern Spain during the Early Pleistocene but also present new dating evidence for hominin fossil material and key archaeological sequences in Italy, northern France and England. In turn, the establishment of a more robust chronology, developed through a multiproxy lithostratigraphic, biostratigraphic, aminostratigraphic and geochronological approach, allows for a more nuanced interpretation of patterns in the archaeological record, as well as direct comparison of variability within the hominin fossils, subsistence practices and detailed palaeoenvironmental records of this region.

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Figure 1: John Frere's "Flint Weapon found at Hoxne in Suffolk" (Frere, 1800).

References

Antoine P. 1994. The Somme Valley terrace system (northern France); a model of river response to Quaternary climatic variations since 800 000 BP. *Terra Nova* **6**: 453–464.

Antoine P, Lautridou J-P, Laurent M. 2000. Long-term fluvial archives in NW France: response of the Seine and Somme rivers to tectonic movements, climate variations and sea-level changes. *Geomorphology* **33**: 183–207.

Antoine P, Limondin-Lozouet N, Chaussé C, Lautridou J-P, Pastre J-F, Auguste P, Bahain J-J, Falgueres C, Ghaleb B. 2007. Pleistocene fluvial terraces from northern France (Seine, Yonne, Somme): synthesis, and new results from interglacial deposits. *Quaternary Science Reviews* **26**: 2701–2723.

Antoine P, Auguste P, Bahain J-J, Chaussé C, Falguères C, Ghaleb B, Limondin-Lozouet N, Locht J-L, Voinchet P. 2010. Chronostratigraphy and palaeoenvironments of Acheulean occupations in Northern France (Somme, Seine and Yonne valleys). *Quaternary International* **223–224**: 456–461.

Antoine P, Moncel M-H, Locht J-L, Limondin-Lozouet N, Auguste P, Stoetzel E, Dabkowski J, Voinchet P, Bahain J-J, Falguères C. 2015. Dating the earliest human occupation of Western Europe: new evidence from the fluvial terrace system of the Somme basin (Northern France). *Quaternary International* **370**: 77-99.

Arzarello M, Marcolini F, Pavia G, Pavia M, Petronio C., Petrucci M, Rook L, Sardella R. 2007. Evidence of earliest human occurrence in Europe: the site of Pirro Nord (Southern Italy). *Naturwissenschaften* **94**: 107-112.

Ashton N, Hosfield R. 2010. Mapping the human record in the British early Palaeolithic: evidence from the Solent River system. *Journal of Quaternary Science* **25**: 737-753.

Ashton, N.M., Parfitt, S.A., Lewis, S.G., Coope, G.R., Larkin, N.R. 2008. Happisburgh Site 1 (TG388307). In *The Quaternary of Northern East Anglia. Field Guide*, Candy I, Lee JR, Harrison AM (eds). Quaternary Research Association: London; 151–156.

Bar-Yosef O, Goren-Inbar N. 1993. The lithic assemblage of 'Ubeidiya, a Lower Paleolithic site in the Jordan valley. *The Institute of Archaeology* **34**. The Hebrew University of Jerusalem, Jerusalem.

Bar-Yosef O, Belmaker M. 2010. Early and Middle Pleistocene Faunal and hominin dispersals through Southwestern Asia. *Quaternary Science Reviews* **30**: 1318–1337.

Belmaker M, Tchernov E, Condemi S, Bar-Yosef O. 2002. New evidence of Hominid presence in the Lower Pleistocene of the southern Levant. *Journal of Human Evolution* **43**: 43–56.

Berger GW, Pérez-González A, Carbonell E, Arsuaga JL, Bermúdez de Castro JM, Ku TL. 2008. Luminescence chronology of cave sediments at the Atapuerca paleoanthropological site, Spain. *Journal of Human Evolution* **55**: 300–311.

Bermúdez de Castro JM, Arsuaga JL, Carbonell E, Rosas A, Martínez I, Mosquera M. 1997. A Hominid from the Lower Pleistocene of Atapuerca, Spain: Possible Ancestor to Neandertals and Modern Humans. *Science* **276**: 1392-1395.

Beyene Y, Katoh S, WoldeGabriel G, Hart WK, Uto K, Sudo M, Kondo M, Hyodo M, Renne PR, Suwa G, Asfaw B. 2013. The characteristics and chronology of the earliest Acheulean at Konso, Ethiopia. *Proceedings of the National Academy of Science* **201**: 1584–1591.

Blain H-A, Lozano-Fernández I, Ollé A, Rodríguez J, Santonja M, Pérez-González A. 2015. The continental record of Marine Isotope Stage 11 (Middle Pleistocene) on the Iberian Peninsula characterized by herpetofaunal assemblages. *Journal of Quaternary Science*. This volume.

Bordaz, J. 1970. *Tools of the Old and New Stone Age*. Natural History Press; Garden City.

Bordes F. 1961. *Typologie du Paléolithique ancien et moyen*. Publications de l'Institut de Préhistoire de l'Université de Bordeaux, Mémoire n° 1.

Boucher de Perthes J. 1847. *Antiquités celtiques et antédiluviennes : Mémoire sur l'industrie primitive et les arts à leur origine*. Treuttel et Wurtz; Paris.

Bridgland DR. 1994. *Quaternary of the Thames*. Geological Conservation Review Series 7, Chapman & Hall; London.

Bridgland DR. 2006. The Middle and Upper Pleistocene sequence in the Lower Thames; a record of Milankovitch climatic fluctuation and early human occupation of southern Britain. Henry Stopes Memorial Lecture. *Proceedings of the Geologists' Association* **117**: 281–305.

Bridgland DR, Schreve DC. 2004. Quaternary lithostratigraphy and mammalian biostratigraphy of the Lower Thames terrace system, south-east England. *Quaternaire* **15**: 29–40.

Bridgland DR, Westaway R. 2014. Quaternary fluvial archives and landscape evolution: a global synthesis. *Proceedings of the Geologists' Association* **125**: 600–629.

Bridgland DR, White MJ. 2015. Chronological variations in handaxes: patterns detected from fluvial archives in north-west Europe. *Journal of Quaternary Science* This volume.

Bridgland DR, Antoine P, Limondin-Lozouet N, Santisteban JI, Westaway R, White MJ. 2006. The Palaeolithic occupation of Europe as revealed by evidence from the rivers: data from IGCP 449. *Journal of Quaternary Science* **21**: 437–455.

Bridgland DR, Westaway R, Abou Romieh M, Candy I, Daoud M, Demir T, Galiatsatos N, Schreve DC, Seyrek A, Shaw A, White TS, Whittaker J. 2012. The River Orontes in Syria and Turkey: downstream variation of fluvial archives in different crustal blocks. *Geomorphology* **165–166**: 25–49.

Campbell, JB, Sampson, CG. 1971. A new analysis of Kents Cavern, Devonshire, England. *University of Oregon Anthropological Papers* **3**: 1-40.

Candy I, Schreve D, White, T. 2015. MIS 13 to 12 in Britain and the north Atlantic: understanding the palaeoenvironmental context of the earliest Acheulean. *Journal of Quaternary Science*. This volume.

Chauhan PR. 2009. The Lower Paleolithic of the Indian subcontinent. *Evolutionary Anthropology* **18**: 62–78.

Chauhan PR. 2010. Comment on 'Lower and Early Middle Pleistocene Acheulian in the Indian Sub-Continent' by Gaillard *et al.* 2009 (Quaternary International). *Quaternary International* **223–224**: 248–259.

Chauhan PR, Patnaik R. 2012. Inter-disciplinary perspectives on Indian paleoanthropology and prehistory. *Quaternary International* **269**: 1–8

Commont V. 1906. Les découvertes récentes à Saint-Acheul: L'Acheuléen. *Revue de l'école d'Anthropologie de Paris* **16**: 228–241.

Commont V. 1908. Les industries ancien Saint-Acheul. L'anthropologie 19: 527–572.

Compton T, Stringer C. 2015. The morphological affinities of the Middle Pleistocene hominin teeth from Pontnewydd Cave, Wales. *Journal of Quaternary Science*. This volume.

de Lumley H, Lordkipanidze D, Féraud G, Garcia T, Perrenoud C, Falguères C, Gagnepain J, Saos T, Voinchet P. 2002. Datation par la méthode $^{40}Ar/^{39}Ar$ de la couche de cendres volcaniques (couche VI) de Dmanissi (Géorgie) qui a livré des restes d'hominidés fossiles de 1,81 Ma. *Comptes Rendus Palevol* **1**: 181–189.

de Mortillet G. 1883. *Le Préhistorique. Antiquité de l'homme*. Bibliothèque des Sciences Contemporaines, Paris.

Demir T, Westaway R, Seyrek A, Bridgland D. 2007. Terrace staircases of the River Euphrates in southeast Turkey, northern Syria and western Iraq: evidence for regional surface uplift. *Quaternary Science Reviews* **26**: 2844–2863.

Demir T, Seyrek A, Westaway R, Bridgland D, Beck A. 2008. Late Cenozoic surface uplift revealed by incision by the River Euphrates at Birecik, southeast Turkey. *Quaternary International* **186**: 132–163.

Dennell R. 2007. *“Resource-rich, stone-poor”: early hominin land use in large river systems of northern India and Pakistan.* In *The Evolution and History of Human Populations in South Asia–Interdisciplinary studies in Archaeology*, Petraglia MD, Allchin B (eds). Biological Anthropology, Linguistics and Genetics. Vertebrate Paleobiology and Paleoanthropology Series, Springer Press, New York.

Dennell RW, Martinón-Torres M, Bermúdez de Castro JM. 2010. Out of Asia: The initial colonisation of Europe in the Early and Middle Pleistocene. *Quaternary International* **223–224**: 439.

Despriée J, Voinchet P, Tissoux H, Moncel M-H, Arzarello M, Robin S, Bahain J-J, Falguères C, Courcimault G, Dépont J, Gageonnet R, Marquer L, Messager E, Abdessadok S, Puaud S. 2010. Lower and middle Pleistocene human settlements in the Middle Loire River Basin, Centre Region, France. *Quaternary International* **223–224**: 345–359

Despriée J, Voinchet P, Tissoux H, Bahain J-J, Falguères C, Courcimault G, Dépont J, Moncel M-H, Robin S, Arzarello M, Sala R, Marquer L, Messager E, Puaud S, Abdessadok S. 2011. Lower and Middle Pleistocene human settlements recorded in fluvial deposits of the middle Loire River Basin, Centre Region, France. *Quaternary Science Reviews* **30**: 1474-1485.

Falguères C, Yokoyama Y, Shen G, Bischoff JL, Ku TL, Lumley H de, 2004. New U-series dates at the Caune de l’Arago, France. *Journal of Archaeological Science* **31**: 941–952.

Frere J. 1800. Account of Flint Weapons discovered at Hoxne in Suffolk. *Archaeologia* **XIII**: 204-205.

Gabunia L, Vekua A. 1995. A Plio-Pleistocene hominid from Dmanisi, east Georgia. *Nature* **373**: 509–512.

Gabunia L, Vekua A, Lorkidpanidze D, Swisher CC, Ferring R, Justus A, Nioradze M, Tvalchrelidze M, Anton SC, Bosinski G, Jöris O, de Lumley MA, Masuradze G, Mouskhelishvili A, 2000. Earliest Pleistocene hominid cranial remains from Dmanisi, Republic of Georgia: taxonomy, geological setting, and age. *Science* **288**: 1019–1025.

Gaillard C, Mishra S, Singh M, Deo S, Abbas R. 2010. Lower and Early Middle Pleistocene Acheulian in the Indian sub-Continent. *Quaternary International* **223–224**: 234–241.

García-Medrano P, Ollé A, Mosquera M, Cáceres I, Díez C, Carbonell E. 2014. The earliest Acheulean technology at Atapuerca (Burgos, Spain): Oldest levels of the Galería site (GII Unit). *Quaternary International* **353**: 170-194.

Gibbard PL. 1988. The history of the great northwest European rivers during the past three million years. *Philosophical Transactions of the Royal Society of London* **B318**: 559–602.

Gibson KR, Ingold T. 1993 (eds) *Tools, language and cognition in human evolution*. New York: Cambridge University Press, pp 230-250.

Goren-Inbar, N. and Sharon, G. (eds) 2006. *Axe Age: Acheulian Toolmaking from Quarry to Discard*. Equinox, London.

Gowlett JAJ, Hallos J, Hounsell S, Brant V, Debenham NC. 2005. Beeches Pit – archaeology, assemblage dynamics and early fire history of a Middle Pleistocene site in East Anglia, UK. *Eurasian Prehistory* **3**: 3-38.

Hodgson, D. 2015. The symmetry of Acheulean handaxes and cognitive evolution. *Journal of Archaeological Science Reports* **2**: 204–208.

Hoffmann, D.L., Pike, A.W.G., Wainer, K., Zilhao, J., 2013. New U-series results for speleogenesis and the Palaeolithic archaeology of the Almonda karstic system (Torres Novas, Portugal). *Quaternary International* **294**: 168–182.

Jiménez-Arenas JM, Santonja M, Botella M, Palmqvist P. 2011. The oldest handaxes in Europe: fact or artefact? *Journal of Archaeological Science* **38**: 3340–3349.

Kailath AJ, Rao TKG, Dhir RP, Nambi KSV, Gogte VD, Singhvi AK. 2001. ESR characterization of Calcretes from Thar Desert for dating applications. *Radiation Measurements* **32**: 371–383.

Keeley, L.H. 1980. *The Uses of Hand axes. Experimental Determination of Stone Tool Uses*. The University of Chicago Press, London.

Keen DH. 1990. Significance of the record provided by Pleistocene fluvial deposits and their included molluscan faunas for palaeoenvironmental reconstruction and stratigraphy: case study from the English Midlands. *Palaeogeography, Palaeoclimatology, Palaeoecology* **80**: 25–34.

Keen DH. 2001. Towards a Late Middle Pleistocene non-marine molluscan biostratigraphy for the British Isles. *Quaternary Science Reviews* **20**: 1657–1665.

Lang N, Wolff, EW. 2011. Interglacial and glacial variability from the last 800ka in marine, ice and terrestrial archives. *Climates of the Past* **7**: 361-380.

Lee JR, Booth SJ, Hamblin RJO, Jarrow AM, Kessler H, Moorlock BSP, Morigi AN, Palmer A, Riding JB, Rose J. 2004. A new stratigraphy for the glacial deposits around Lowestoft, Great Yarmouth, North Walsingham and Cromer, East Anglia, UK. *Bulletin of the Geological Society of Norfolk* **53**: 3-60.

Leroy SAG, Arpe K, Mikolajewicz U. 2011. Vegetation context and climatic limits of the Early Pleistocene hominin dispersal in Europe. *Quaternary Science Reviews* **30**: 1448-1463.

Limondin-Lozouet N, Antoine P, Bahain J-J, Cliquet D, Coutard S, Dabkowski J, Ghaleb B, Locht J-L, Nicoud E, Voinchet P. 2015. Northwest European MIS 11 malacological successions : a framework for the timing of Acheulean settlements. *Journal of Quaternary Science*. This volume.

Lumley H. de, Barsky D 2004. Évolution des caractères technologiques et typologiques des industries lithiques dans la stratigraphie de la Caune de l'Arágó. *L'Anthropologie* **108**: 185–237.

Martinón-Torres M, De Castro JB, Gómez-Robles A, Arsuaga JL, Carbonell E, Lordkipanidze D, Manzi G, Margvelashvili A. 2007. Dental evidence on the hominin dispersals during the Pleistocene. *Proceedings of the National Academy of Sciences* **104**: 13279–13282.

McNabb J, Cole, J. 2015. The mirror cracked: Symmetry and refinement in the Acheulean handaxe. *Journal of Archaeological Science Reports* **3**: 100–111.

Mishra S. 1992. The age of the Acheulian in India: some new evidence. *Current Anthropology* **33**: 325–327.

Mishra S, White MJ, Beaumont P, Antoine P, Bridgland DR, Limondin-Lozouet N, Santisteban JI, Schreve DC, Shaw AD, Wenban-Smith FF, Westaway RWC, White TS. 2007. Fluvial deposits as an archive of early human activity, *Quaternary Science Reviews* **26**: 2996–3016.

Mishra S, Gaillard C, Deo S, Singh M, Abbas R, Agrawal N. 2010. Large flake Acheulian in India: Implications for understanding lower Pleistocene human dispersals. *Quaternary International* **223–224**: 271–272.

Mithen, S. 2005. *The Singing Neanderthals*. Weidenfeld and Nicolson, London.

Moncel M-H, Despriée J, Voinchet P, Tissoux H, Moreno D, Bahain J-J, Courcimault G, Falguères C. 2013. Early Evidence of Acheulean Settlement in Northwestern Europe - La Noira Site, a 700 000 Year-Old Occupation in the Center of France. *PLoS ONE* **8**: e75529. doi:10.1371/journal.pone.0075529.

Mosquera M, Saladié P, Ollé A, Cáceres I, Huguet R, Villalaín JJ, Carrancho A, Bourlès D, Braucher R, Vallverdú J. 2015. Barranc de la Boella (Catalonia, Spain): an Acheulean elephant butchering site from the European late Early Pleistocene *Journal of Quaternary Science*. This volume.

Mussi, M. 1995. The earliest occupation of Europe: Italy. In *The Earliest Occupation of Europe*, Roebroeks W, van Kolfschoten T (eds), Leiden, Leiden University, 27-51.

Oakley, K.P. 1961. *Man the tool maker.* University of Chicago Press, Chicago.

O'Brien EM. 1981. The projectile capabilities of an Acheulean handaxe from Olorgesailie. *Current Anthropology* **22**: 76-79.

Ohel MY. 1987. The Acheulean handaxe: A maintainable multifunctional tool. *Lithic Technology* **16**: 54-55.

Paddayya K, Blackwell BAB, Jhaldiyal R, Petraglia MD, Fevrier S, Chaderton II DA, Blickstein JIB, Skinner AR. 2002. Recent findings on the Acheulian of the Hunsgi and Baichbal valleys, Karnataka, with special reference to the Isampur excavation and its dating. *Current Science* **83**: 641-647.

Parfitt SA, Barendregt RW, Breda M, Candy I, Collins MJ, Coope GR, Durbidge P, Field MH, Lee JR, Lister AM, Mutch R, Penkman KEH, Preece RC, Rose J, Stringer CB, Symmons R, Whittaker JE, Wymer JJ, Stuart AJ. 2005. The earliest record of human activity in northern Europe. *Nature* **438**: 1008-1012.

Patnaik R, Chauhan PR, Rao MR, Blackwell BAB, Skinner AR, Sahni A, Chauhan MS, Khan HS. 2009. New geochronological, palaeoclimatological and archaeological data from the Narmada Valley hominin locality, central India. *Journal of Human Evolution* **56**: 114–133.

Penkman KEH, Preece RC, Bridgland DR, Keen DH, Meijer T, Parfitt SA, White TS, Collins MJ. 2013. An aminostratigraphy for the British Quaternary based on *Bithynia* opercula. *Quaternary Science Reviews* **61**: 111-134.

Pereira A, Nomade S, Voinchet P, Bahain J-J, Falguères C, Garon H, Lefèvre D, Raynal J-P, Scao V, Piperno M. 2015. The earliest securely dated hominin fossil in Italy: Evidence of Acheulian human occupations during glacial MIS 16 at Notarchirico (Venosa, Basilicata, Italy). *Journal of Quaternary Science*. This volume.

Pérez-Pérez A, Bermúdez de Castro JM, Arsuaga JL. 1999. Nonoclusal dental microwear analysis of 300.000 years-old Homo heidelbergensis teeth from Sima de los Huesos (Sierra de Atapuerca, Spain). *American Journal of Physical Anthropology* **108**: 433-457.

Preece RC. 1995. Mollusca from interglacial sediments at three critical sites in the Lower Thames. In *The Quaternary of the lower reaches of the Thames. Field Guide*; Bridgland DR, Allen P, Haggart BA (eds), Quaternary Research Association, Durham; 55–60.

Preece RC. 2001. Molluscan evidence for differentiation of interglacials within the 'Cromerian Complex'. *Quaternary Science Reviews* **20**: 1643–1656.

Preece RC, Parfitt SA, Bridgland DR, Lewis SG, Rowe PJ, Atkinson TC, Candy I, Debenham NC, Penkman KEH, Rhodes EJ, Schwenninger JL, Griffiths HI, Whittaker JE, Gleed-Owen C. 2007. Terrestrial environments during MIS 11: evidence from the Palaeolithic site at West Stow, Suffolk, UK. *Quaternary Science Reviews* **26**: 1236–1300.

Raposo L, Santonja M. 1995. The earliest occupation of Europe: the Iberian Penisula. In The Earliest Occupation of Europe, Roebroeks W, van Kolfschoten T (eds). University of Leiden Press: Leiden; 7–25.

Raynal J-P, Texier J-P. 1989. Découverte d'Acheuléen ancien dans la carrière Thomas I à Casablanca et problème de l'ancienneté de la présence humaine au Maroc. Comptes *Rendus de l'Academie des Sciences de Paris* **Series II 308**: 1743–1749.

Raynal J-P, Magoga L, Sbihi-Alaoui F-Z, Geraads D. 1995. The earliest occupation of Atlantic Morocco: the Casablanca evidence. In *The Earliest Occupation of Europe*, Roebroeks W, van Kolfschoten T (eds). University of Leiden Press: Leiden; 255–268.

Raynal J-P, Sbihi-Alaoui F-Z, Magoga L, Mohib A, Zouak M. 2002. Casablanca and the earliest occupation of north Atlantic Morocco. *Quaternaire* **13**: 65–77.

Rightmire GP, Lordkipanidze D, Vekua A. 2006. Anatomical descriptions, comparative studies and evolutionary significance of the hominin skulls from Dmanisi, Republic of Georgia. *Journal of Human Evolution* **50**: 115–141.

Roberts M. 1996. `Man the Hunter' returns at Boxgrove. *British Archaeology* **18** (retrieved online at http://www.archaeologyuk.org/ba/ba18/BA18FEAT.HTML).

Roberts MB, Parfitt SA. (eds), 1999. Boxgrove: a Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex. English Heritage, London.

Roberts MB, Stringer CB, Parfitt SA. 1994. A hominid tibia from Middle Pleistocene sediments at Boxgrove, UK. *Nature* **369**: 311-313.

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

Roe DA. 1968a. British Lower and Middle Palaeolithic hand axe groups. *Proceedings of the Prehistoric Society* **34**: 1–82.

Roe DA. 1968b. *A Gazetteer of British Lower and Middle Palaeolithic Sites*. Council for British Archaeology, Research Report No 8: London.

Rose J. 1994. Major river systems of central and southern Britain during the Early and Middle Pleistocene. *Terra Nova* **6**: 435–443.

Sangode SJ, Mishra S, Naik S. Deo S. 2007. Magnetostratigraphy of the Quaternary sediments associated with some Toba Tephra and Acheulian artefact bearing localities in the Western and Central India. *Gondwana Magazine* Special Volume **10**: 111–121.

Santisteban JI, Schulte L. 2007. Fluvial networks of the Iberian Peninsula: a chronological framework. *Quaternary Science Reviews* **26**: 2738–2757.

Santonja M, Pérez-González A. 2000–2001. El Paleolítico inferior en el interior de la Península Ibérica. Un punto de vista desde la geoarqueología. *Zephyrus* **53–54**: 27–77.

Schreve DC, 2001. Differentiation of the British late Middle Pleistocene interglacials: the evidence from mammalian biostratigraphy. *Quaternary Science Reviews* **20**: 1693–1705.

Scott GR, Gibert L. 2009. The oldest handaxes in Europe. *Nature* **461**: 82–85.

Semaw S, Rogers M, Stout D. 2009. The Oldowan–Acheulian transition: is there a “Developed Oldowan” artifact tradition? In *Sourcebook of Paleolithic Transitions* Camps M, Chauhan P (eds). Springer, New York; 173–192.

Shotton FW, Keen DH, Coope GR, Currant AP, Gibbard PL, Aalto M, Peglar SM, Robinson JE. 1993. The Middle Pleistocene Deposits of Waverley Wood Pit, Warwickshire, England. *Journal of Quaternary Science* **8**: 293-325.

Stephens M, Challis K, Graf A, Howard AJ, Rose J, Schreve DC 2008. New exposures of Bytham River deposits at Brooksby, Leicestershire, UK: context and importance. *Quaternary Newsletter* **115**: 14-27.

Stiner MC. 2013. An unshakable Middle Paleolithic? Trends versus conservatism in the predatory niche and their social ramifications. *Current Anthropology* **54**: 288-304.

Tchernov E. 1987. The age of the ‘Ubeidiya Formation, an Early Pleistocene hominid site in the Jordan Valley, Israel. *Israel Journal of Earth Sciences* **36**, 3–30.

Tchernov E. 1999. The earliest hominids in the southern Levant. *Proceedings of the International Conference of Human Palaeontology, Orce, Spain, 1995*. Museo de Prehistoria y Paleontologia, Orce, Spain; 389–406.

Turner A. 1992. Large carnivores and earliest European hominids: changing determinants of resource availability during the Lower and Middle Pleistocene. *Journal of Human Evolution* **22** : 109-126.

Vallverdú J, Saladié P, Rosas A, Huguet R, Cáceres I, Mosquera M, Garcia-Tabernero A, Estalrrich A, Lozano-Fernández I, Pineda-Alcalá A, Carrancho A, Villalaín JJ, Bourlès D, Braucher R, Lebatard A, Vilalta J, Esteban-Nadal M, Bennàsar ML, Bastir M, López-Polín L, Ollé A, Vergés JM, Ros-Montoya S, Martínez-Navarro B, García A, Martinell J, Expósito I, Burjachs F, Agustí J, Carbonell E. 2014. Age and Date for Early Arrival of the Acheulian in Europe (Barranc de la Boella, la Canonja, Spain). *PLoS ONE* **9**: e103634. doi:10.1371/journal.pone.0103634.

Voinchet P, Despriée J, Tissoux H, Falguères C, Bahain J-J, Gageonnet R, Dolo J-M, Dépont J. 2010. ESR chronology of alluvial deposits and first human settlements of the Middle Loire Basin (Region Centre, France). *Quaternary Geochronology* **5**: 381-384.

Voinchet P, Moreno D, Bahain J-J, Tissoux H, Tombret O, Falguères C, Moncel M-H, Schreve D, Candy I, Antoine P, Ashton N, Beamish M, Cliquet D, Despriée J, Lewis S, Limondin-Lozouet N, Locht J-L, Parfitt S, Pope M. 2015. New chronological data (ESR and ESR/U-series) for the earliest Acheulian sites of northwestern Europe. *Journal of Quaternary Science*. This volume.

Westaway R. 2009a. Quaternary uplift of northern England. *Global and Planetary Change* **68**: 357–382.

Westaway R. 2009b. Quaternary vertical crustal motion and drainage evolution in East Anglia and adjoining parts of southern England: chronology of the Ingham River terrace deposits. *Boreas* **38**: 261–284.

Westaway R, Maddy D, Bridgland D. 2002. Flow in the lower continental crust as a mechanism for the Quaternary uplift of southeast England: constraints from the Thames terrace record. *Quaternary Science Reviews* **21**: 559–603.

Westaway R, Bridgland D, Mishra S. 2003. Rheological differences between Archaean and younger crust can determine rates of Quaternary vertical motions revealed by fluvial geomorphology. *Terra Nova* **15**: 287–298.

Westaway R, Bridgland DR, White MJ. 2006. The Quaternary uplift history of central southern England: evidence from the terraces of the Solent River system and nearby raised beaches. *Quaternary Science Reviews* **25**: 2212-2250.

White, MJ 1998. On the significance of Acheulean biface variability in Southern Britain. *Proceedings of the Prehistoric Society* **64**: 15-45

White MJ. 2000. The Clactonian Question: On the interpretation of core-and-flake assemblages in the British Lower Palaeolithic. *Journal of World Prehistory* **14**: 1–63.

White MJ, Schreve DC. 2000. Island Britain – peninsular Britain: palaeogeography, colonisation and the Earlier Palaeolithic settlement of the British Isles. *Proceedings of the Prehistoric Society* **66**: 1–28.

Whiteman CA, Rose J. 1992. Thames river sediments of the British early and Middle Pleistocene. *Quaternary Science Reviews* **11**: 363–375.

Wymer JJ. 1968. *Lower Palaeolithic Archaeology in Britain, as represented by the Thames Valley*. John Baker, London.

Wymer JJ. 1985. *The Palaeolithic sites of East Anglia*. Geobooks, Norwich.

Wymer JJ. 1999. *The Lower Palaeolithic Occupation of Britain*. Wessex Archaeology and English Heritage, Salisbury.

Figure 1