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Humans in the Hoxnian: habitat, context and fire use at Beeches Pit, West Stow, Suffolk, UK

R. C. PREECE,[1]* J. A. J. GOWLETT,[2] S. A. PARFITT,[3,4] D. R. BRIDGLAND[5] and S. G. LEWIS[6]
[1] Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK
[2] SACE, The Hartley Building, University of Liverpool, Liverpool L69 3GS, UK
[3] Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK
[4] Institute of Archaeology, University College London, 31–34 Gordon Square, London WC1H 0PY, UK
[5] Department of Geography, University of Durham, South Road, Durham DH1 3LE, UK
[6] Department of Geography, Queen Mary, University of London, Mile End Road, London E1 4NS, UK

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ABSTRACT: A Lower Palaeolithic industry at Beeches Pit, West Stow, Suffolk, occurs within an interglacial sequence that immediately overlies glacial deposits, referable to the Anglian Lowestoft Formation. There is strong biostratigraphical evidence from both vertebrates and molluscs that the interglacial represented is the Hoxnian (MIS 11). This conclusion is supported by uranium series dates from carbonate nodules (>400 kyr), TL dates from burnt flint (414 ± 30 kyr) and a range of amino acid racemisation data. The archaeology consists of flint artefacts of Acheulian character, including many refitting examples. Charred material is abundant in three stratigraphical units and many bones and flints have been burnt, indicating repeated occurrence of fire. Several discrete areas of burnt sediment appear to be hearths. This interpretation is supported by: (1) the intensity of burning (600–800°C) implied by the charred and calcined bones; (2) the intersection of two of the burnt areas, implying separate burning events at slightly different, overlapping locations; (3) the discovery of two burnt flakes that refit onto an adjacent group that are unburnt, indicating that the burning was highly localised; and (4) the spatial distribution of artefacts respects the features interpreted as hearths, suggesting fireside knapping. Fossils associated with the archaeology indicate occupation within closed deciduous forest in a fully temperate climate. Attractions to this unusual environment would have included the fresh water provided by springs, a rich supply of potential food and a prolific source of good quality flint for tool manufacture. The archaeological evidence therefore suggests that the site repeatedly served as an area of focused activities (perhaps a 'home-base') during much of the interglacial. The upper levels of the sequence provide clear faunal evidence of climatic deterioration during which human occupation and fire use persisted. Biostratigraphical correlations with other Lower Palaeolithic sites lend support to the suggestion that Acheulian and Clactonian industries occurred in Britain during the same substage of the Hoxnian, although not necessarily at precisely the same time. Copyright © 2006 John Wiley & Sons, Ltd.

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KEYWORDS: Lower Palaeolithic; fire use, hearths; 'home-base'; Hoxnian; Acheulian; Clactonian.

Introduction

It has been suggested that during interglacial forest phases in Europe, human activity became focused on the relatively restricted areas of open country that remained (e.g. Gamble, 1986). Not only would hunting game have been much harder in woodland (Bradley *et al.*, 1989) but dispersal itself would have been particularly difficult in closed forest environments. Indeed, it is currently argued that most movement of human populations took place along the narrow open corridors provided by the floodplains of large rivers (Ashton *et al.*, this issue, pp. 497–505). The concentration of artefacts in fluvial contexts might be seen to reinforce this view, even though most such archaeological sites have furnished little or no evidence of *in situ* occupation. Indeed, fluvial sediments provide one of very few opportunities for the preservation of artefacts and other evidence of Pleistocene human activity. Other parts of the landscape in which such people lived are largely unrepresented in the sedimentary record, nor are Pleistocene land surfaces commonly preserved. Thus the concentration of archaeological evidence in fluvial contexts (cf. Wymer, 1999) might give an entirely false impression of the distribution of early human populations and the range of their activities (but see Ashton *et al.*, this issue, pp. 497–505). For this reason Beeches Pit is of particular value, since it provides a rare glimpse of an

*Correspondence to: R. C. Preece, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ UK.
E-mail: rcp1001@cam.ac.uk

interglacial area of focused activities (perhaps a 'home-base' *sensu* Rolland, 2004) that was not in the bottom of a large river valley.

There is evidence at sites such as Highlands Farm Pit near Henley-on-Thames, in the so-called 'Caversham Ancient Channel' (Wymer, 1999) and knapping scatters in the upper solifluction levels at Boxgrove (Roberts and Parfitt, 1999), for human occupation in southern England during the Anglian but the frequency of archaeological remains increases dramatically in early Hoxnian contexts (Fig. 1; Wymer, 1999). Based on annually laminated sediments at Marks Tey (Turner, 1970), the Hoxnian Stage would seem to be broadly equivalent to just the early part of MIS 11. Other Hoxnian localities, such as the cluster of archaeological sites near Hitchin, Hertfordshire (Wymer, 1985; Boreham and Gibbard, 1995), are associated with lakes that have formed on the surface of Anglian till. Such lacustrine archaeological contexts, perhaps originating as kettle-holes, are surprisingly rare and even the Palaeolithic industry at the Hoxne type-site has recently been shown to occur above, rather than within, the lake deposits at that site (Ashton *et al.*, this issue, pp. 497–505). One possible explanation for the failure to find archaeological evidence from lacustrine contexts is that quarries exploiting lake deposits, and researchers studying them, will have tended to concentrate on the thicker sequences away from the lake edges, whereas any evidence for human activity would be concentrated near the former margins (but see Ashton *et al.*, this issue, pp. 497–505).

At other sites, such as Barnham, Suffolk, the archaeology occurs in channels, rather than basins, the contexts being described as 'fluvio-lacustrine' (Ashton *et al.*, 1998). This implies some flow, perhaps at times of flood, alternating with quieter periods of stagnation. Such conditions were probably widespread in the immediate aftermath of the Anglian glaciation, which obliterated earlier drainage systems, leading to the formation of many small lakes connected by a network of channels on the newly deglaciated terrain (cf. Preece and Penkman, 2005). Most archaeological sites of Hoxnian age, however, occur in valleys, usually in river terrace deposits. Examples include the famous sites at Swanscombe, Kent (Ovey, 1964; Bridgland, 1994; Conway *et al.*, 1996), and Clacton-on-Sea, Essex (Warren, 1955; Bridgland, 1994; Bridgland *et al.*, 1999), both of which are beyond the limits of the Anglian glaciation.

Despite the wealth of the archaeological record, only a small part of the Hoxnian landscape has been sampled. Virtually nothing is known about occupation of upland interfluve areas, coastal regions or indeed caves. This paper concerns a site representing another poorly known context, namely closed forest, which would have covered extensive tracts of the landscape during the early part of the interglacial. It draws on recent multidisciplinary investigations at Beeches Pit, integrating evidence so as to work towards a reconstruction of human ecology in the Hoxnian. A full account of the geology of the site will appear elsewhere (Preece *et al.*, in preparation) and a detailed account of the archaeology has already been published (Gowlett *et al.*, 2005), hence only a general review of these aspects is provided in order to give context to the environmental and socio-ecological issues.

Location and geological succession

Beeches Pit, in the parish of West Stow, Suffolk (TL 798 719), is a disused brickpit at the edge of Thetford Forest. It is 2.5 km from the larger village of Icklingham, with which name it has also been associated. It is one of a number of important Lower

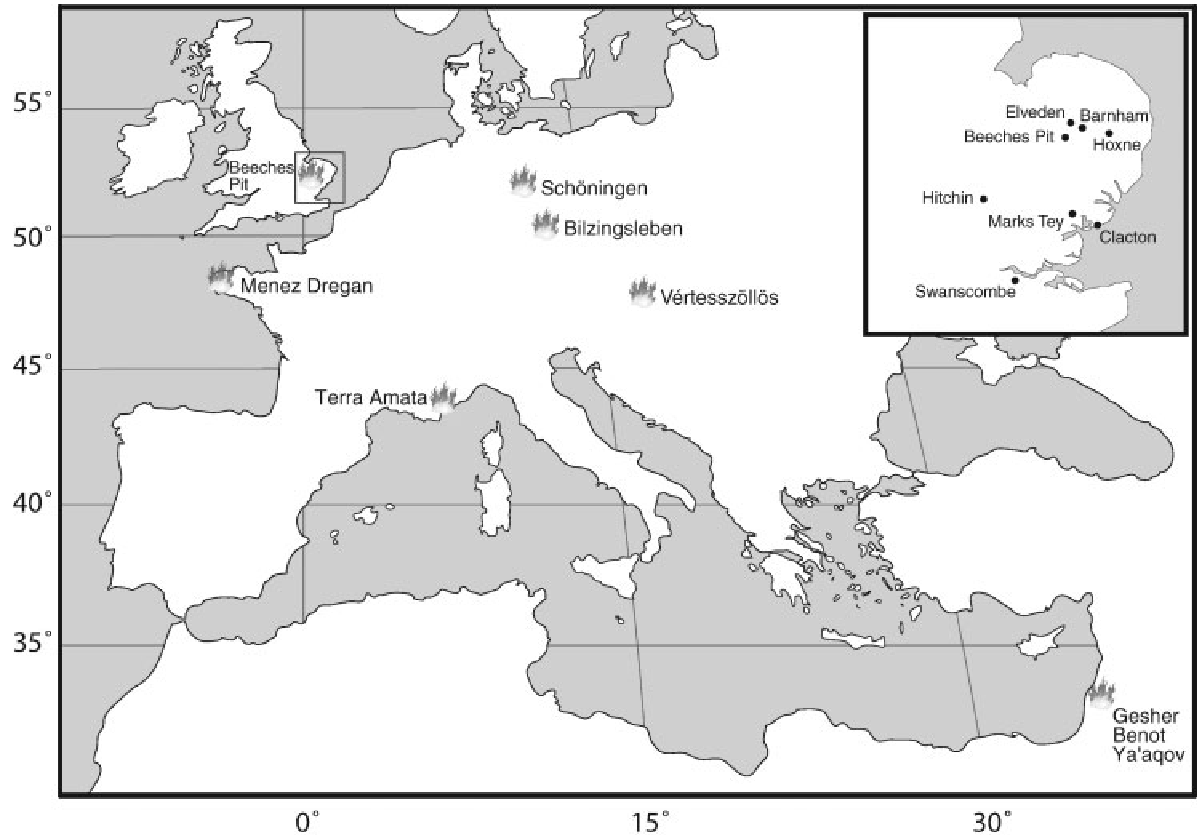

Figure 1 Map showing the location of the earliest Palaeolithic sites in Europe and Israel with evidence of burning attributed to human use of fire. Inset shows the location of the Beeches Pit site in relation to other Hoxnian (MIS 11) sites in southeast England mentioned in the text

Palaeolithic sites in this part of central East Anglia (Fig. 1; Lewis, 1998), the others including High Lodge (Ashton *et al.*, 1992), Warren Hill (Bridgland *et al.*, 1995; Wymer, 1999), Elveden (Ashton *et al.*, 2005) and Barnham (Ashton *et al.*, 1994, 1998). It is also one of several sites in East Anglia where Middle Pleistocene interglacial sediments overlie Anglian glacial deposits, a feature that it again shares with Barnham and Elveden, as well as the Hoxnian type locality at Hoxne, Suffolk (West, 1956), and the parastratotype at Marks Tey, Essex (Turner, 1970).

The sections at Beeches Pit were first described in the 1870s by S. B. J. Skertchly and reported in the Geological Survey Memoir (Whitaker *et al.*, 1891). Recent excavations (Fig. 2) have re-exposed some of the sediments seen by Skertchly and, together with new borehole data, have added further information about the sequence (Fig. 3) and the three-dimensional disposition of beds (Preece *et al.*, 1991, 2000).

The bedrock at Beeches Pit is Middle Chalk, which can be observed at a few points at or near the ground surface along the southern margin of the pit. The Middle–Upper Chalk boundary occurs <100 m upslope to the north. The basal part of the Upper Chalk in this area contains prominent bands of flint nodules known as the Brandon Series (Bristow, 1990), highly regarded as a raw material for flint-knapping. The Pleistocene succession fills a depression in the Chalk, which is 100 m wide and at least 15 m in depth (Fig. 2(A)) and has been interpreted as a subglacial channel.

The Pleistocene sequence has been divided into eight beds (Fig. 3). In places, the upper surface of the Chalk is strongly brecciated, which appears to represent periglacial weathering *in situ*, although some disturbance is apparent towards the top of this unit (Bed 1). A silty diamicton-rich unit (Bed 2) represents the most extensive deposit surviving at Beeches Pit. It is generally olive yellow (Munsell colour 2.5Y 6/6) to brownish yellow (10YR 6/6) and contains chalk clasts of all sizes, as well as flints and exotic rocks, including a striated clast of Carboniferous Limestone. Two lithologically distinct subunits are also recognised: a gravel (Bed 2a) that occurs in the northeast part of the pit and laminated silts and fine sands (Bed 2b) that rarely exceed 0.5 m in thickness. Bed 2 is interpreted as a glacial, probably subglacial deposit. The composition of the gravel provides a clear indication of a glacial origin; it contains non-durable material derived far from the catchments of any local rivers as well as *Rhaxella* chert, a notable durable rock that was brought from north of the Humber by the Pleistocene glaciations (Bridgland *et al.*, 1995). This gravel reinforces the interpretation of the glacial sequence as filling a channel; similar glacial gravel, with characteristic 'exotic' clasts, occurs

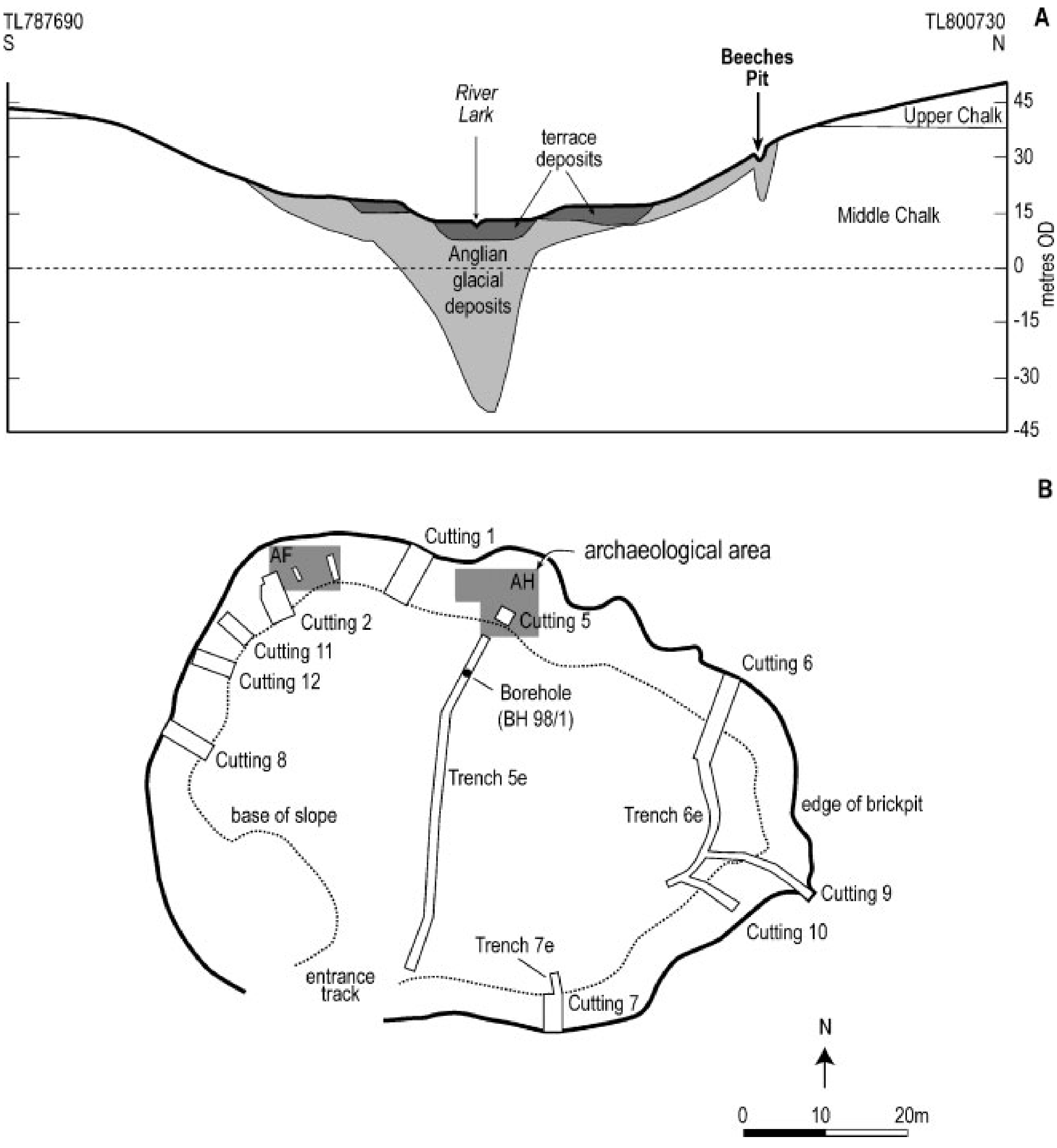

Figure 2 (A) Generalised geological section across the Lark valley showing the geomorphological context of Beeches Pit. (B) Plan of Beeches Pit showing the locations of archaeological excavations (shaded), cuttings, trenches and the borehole

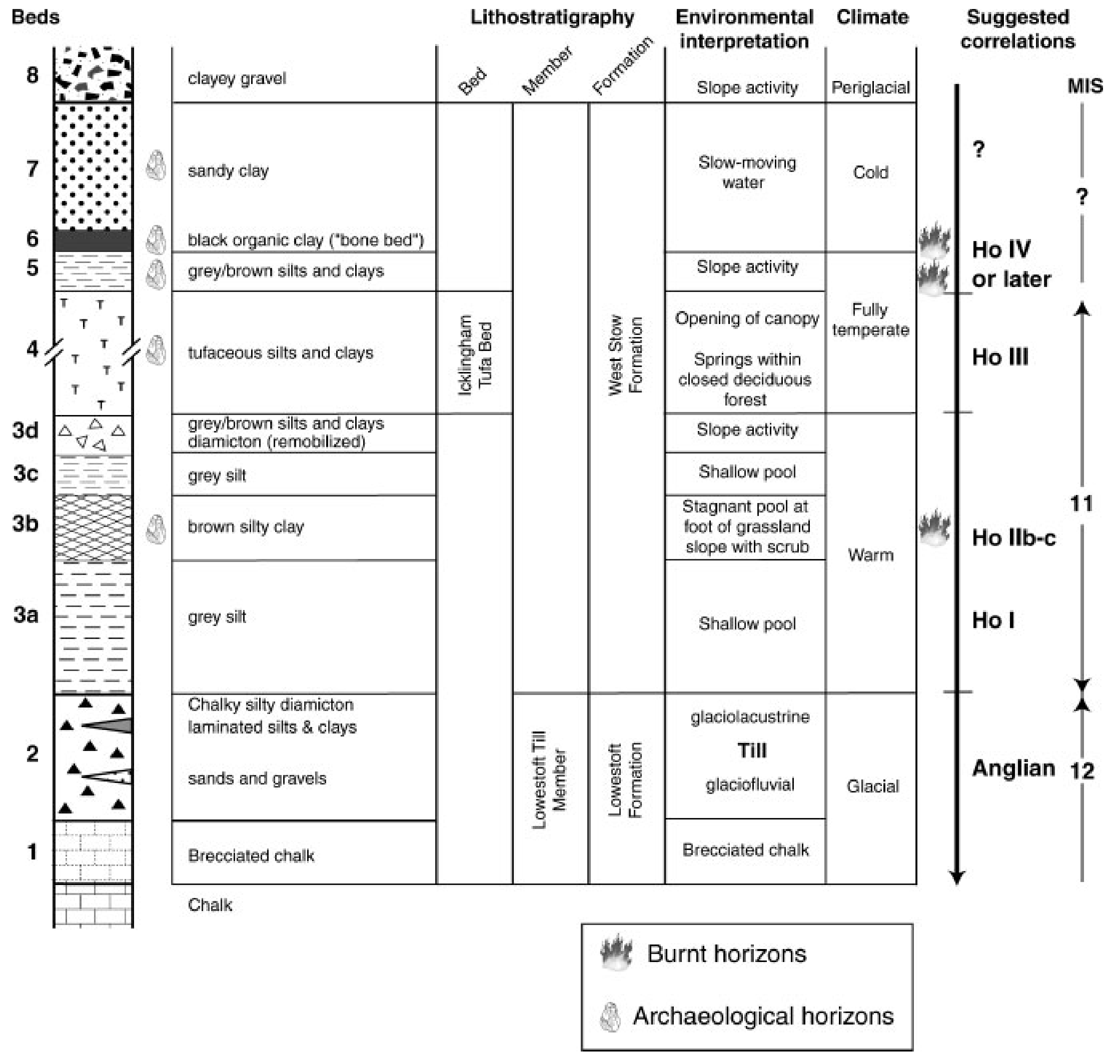

Figure 3 Schematic succession at Beeches Pit showing the location of artefacts and burnt horizons together with the environmental history and suggested correlations

at sites to the west, including Weatherhill Farm Pit (Bridgland *et al.*, 1995). The alignment of these sites is suggestive of a channel that may well have been part of the local subglacial drainage, which was centred on a 'tunnel valley' now drained by the Lark (Bridgland and Lewis, 1991), but which originated as the course of the Bytham-Ingham River (Rose, 1989, 1994; Rose *et al.*, 2001).

The interglacial sediments (Beds 3–7) have been defined as the West Stow Formation (Lewis, 1999) and are restricted to the northwest corner of the pit, where they appear to occupy a depression in the top of the glacial sequence. The glacial deposits pass upwards into Bed 3, which consists of light grey (2.5Y 7/2) silts and clays, rich in aquatic molluscs and ostracods, indicating deposition in shallow pools. In places this bed is separated into lower (3a) and upper (3c) units by a prominent very dark brown (10YR 2/2) horizon (3b) that is less calcareous but nevertheless contains land snails and small vertebrate remains, as well as aquatic molluscs indicative of stagnant water. Above these shallow lacustrine sediments is the Icklingham Tufa (Bed 4), which is separated from them by the products of slope erosion, in the form of a colluvial diamicton (Bed 3d). The Icklingham Tufa, first discovered by Kerney (1976), consists of light yellowish brown (2.5Y 6/4) to olive yellow (2.5Y 6/6) silts and clays with a concretionary tufaceous component. Notwithstanding previous descriptions, it is not a pure homogeneous tufa, as it contains a significant clastic component (small flints and belemnite fragments). Moreover, stable isotope analyses suggest that many of the carbonate concretions were formed as the result of post-depositional groundwater processes (I. Candy, unpublished data). Bed 4 is extremely fossiliferous and has yielded a diverse molluscan fauna dominated by land snails.

The upper levels of the sequence (Beds 5–8) are best exposed in the western faces of the pit (cuttings 2 and 11; Area AF; Fig. 2(B)). Bed 5 consists of grey/brown silts and clays that in places rest on a surface sloping to the southwest. The occurrence of large flint clasts (up to 20 cm) in an otherwise fine-grained sediment, together with faults and folds resulting from slumping, all suggest emplacement by colluvial processes. Shells are rare in this bed but vertebrate remains are frequent. Overlying Bed 5 is a prominent black (10YR 2/1) organic clay (Bed 6), up to 0.75 m thick, rich in charcoal and bone fragments, including those of the rhinoceros *Stephanorhinus hemitoechus*. It has also yielded a few aquatic molluscs, suggesting deposition in a shallow body of water. The yellowish brown (10YR 5/4) clayey sands of Bed 7, rich in ostracods and freshwater molluscs in their lower part (the upper part is decalcified), also indicates subaqueous deposition. Mantling the entire sequence is a poorly sorted and decalcified clayey gravel (Bed 8), which has clearly been strongly affected by periglacial disturbance (cf. vertical orientation of clasts). It is this bed that earlier authors might have regarded as a possible glacial 'boulder clay' or till (Whitaker *et al.*, 1891).

Dating

Several biostratigraphically important species occur at Beeches Pit. The molluscan fauna of the Icklingham Tufa (Bed 4) contains *Lyrodiscus* (indeed it is the type locality for *Retinella* (*Lyrodiscus*) *skertchlyi*) and other taxa typical of the '*Lyrodiscus* biome', thought to characterise MIS 11 (Rousseau *et al.*, 1992). Likewise, the mammalian fauna from the interglacial horizons (Beds 3–5) includes the voles *Arvicola terrestris cantiana* and *Microtus (Terricola) subterraneus*, the extinct mole *Talpa minor*, extinct beaver *Trogontherium cuvieri*, aurochs *Bos primigenius* and rabbit *Oryctolagus* cf. *cuniculus*, a combination also indicative of a Hoxnian (MIS 11) age (Parfitt, 1998; Schreve, 2001).

Three geochronological techniques have been used to date the sequence from Beeches Pit. Full details are given elsewhere, so only brief summaries are presented here. All techniques give support to the view that the interglacial sediments at Beeches Pit accumulated during MIS 11.

Uranium series dating (by Dr P. Rowe and Professor T.C. Atkinson) of carbonate concretions from the base of Bed 4 in Cutting 1 have yielded data with a mean age of ca. 455 kyr, which is very close to the limit of Th^{230}/U method and, as a consequence, carries a very large uncertainty. The stable isotope data suggest that the carbonate precipitated during an interglacial period. Since it postdates its host sediment, it is theoretically possible that it might relate to a later interglacial period than the site as a whole. This seems unlikely because it would require the maintenance of a high water table on the margins of an actively eroding valley through a least one cold stage. From detailed statistical arguments, it is estimated that the probability of the deposit being of MIS 7 age or younger is $<5\%$, of MIS 9 age 19–25% and of MIS 11 age 20–32%. An older age, which would imply a pre-Anglian interglacial, is equally compatible with the U/Th data, although it can be ruled out from other evidence.

Thermoluminescence dating has been undertaken by Dr N. C. Debenham on five burnt flints from the archaeological horizons in Bed 6 in Cutting 2 and Area AF and in Cutting 11 (Fig. 2(B)). Within their uncertainties, the TL dates of the five flints are not significantly different. If it is assumed that all the samples were heated contemporaneously, the best estimate for the date of the event is 414 ± 30 kyr (Gowlett *et al.*, 2005). This is fully compatible with attributions to MIS 11 made on the basis of other lines of evidence.

Finally amino acid dating has been undertaken by Dr K. Penkman on the calcitic opercula of *Bithynia*, which were chosen because they have been found to provide good quality data and therefore have potential for comparison with the large database being assembled from such material (Penkman, 2005). The opercula analysed were recovered from Bed 7 in Cutting 2. The data fall within a large cluster that represents MIS 11 sites (Penkman, 2005), corroborating that age attribution.

Evidence of human occupation

Archaeological excavations have been undertaken in two areas of the pit, Area AF, in the west, and Area AH, about 20 m to the east (Fig. 2(B); Gowlett *et al.*, 1998, 2005). Most of the artefacts in Area AH came from Bed 3b and in sediments immediately overlying it. These represent the oldest archaeology at Beeches Pit and include four Acheulian handaxes and a roughout. They were associated with a concentration of nodular flint forming an alignment at the bottom of the south-facing slope (Gowlett and Hallos, 2000: fig. 55; Gowlett *et al.*, 2005; Fig. 4). Whether this flint, which would have provided a ready supply of good quality raw material for tool manufacture, was derived from a chalk cliff to the north, now buried, or from glacial deposits such as were revealed in the trial pits to the northwest remains to be determined. The rich lithic assemblage suggests that

Figure 4 (a) Hearths in Area AH viewed from the west. (b) Burnt flint refit showing its provenance

knapping of locally obtained flint nodules was one of the activities carried out at the site. The nodules were first tested for suitability, then reduced to produce handaxes and flakes (including simple flake tools). This interpretation is supported by the recovery of many cores with fewer than three flake removals and by the refitting of several flakes onto the roughout, and other instances of conjoinable material. The occurrence of refits indicates that this is a primary-context locality that preserves an *in situ* knapping site. Other handaxes in the assemblage appear to be isolated from their manufacturing debitage, however, raising the possibility that they were imported and then discarded in their final form. The low numbers of flakes from the latter stages of handaxe manufacture, and the absence of refits relating to resharpening and retouching, supports this interpretation (Gowlett and Hallos, 2000; Hallos, 2005). The lack of long sequences of flaking, other than in one key specimen mentioned below, suggests that humans were also removing partly reduced cores from the site for use at other locations (Hallos, 2004, 2005).

Human occupation persisted into the ensuing cold phase represented by Beds 6 and 7. Bed 6 was uncovered over a restricted area of several square metres, as it is on a steep slope and also lenses out to the east. Its archaeological assemblage, however, includes two small handaxes found towards the base. They are in fresh condition and do not have the appearance of being burnt. Nearby, at the edge of some sand-filled 'pipes', small debitage was found. These finds may represent the fringe of a larger occupation on a flatter area beyond the channel bank, but this cannot be verified as soundings showed that the Pleistocene sediments do not continue in this direction. The small assemblage is sufficient, however, to indicate that knapping took place in the area during formation of Bed 6, and to show that it was of Acheulian character. The two handaxes (lengths 72 and 73 mm) are smaller than others from the site, and may hint that relatively delicate tasks were being performed nearby, but the sample is far too small to suggest that smaller handaxes were preferred in general.

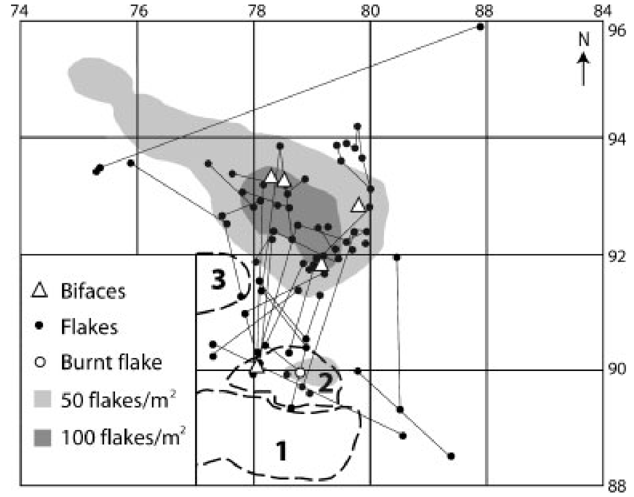

Figure 5 Plan of Area AH showing locations of hearths (1–3), the distribution of refitting artefacts and handaxes in relation to high concentrations of flint debitage

Evidence of fire use

Clear evidence of burning was present in both archaeological areas. There are scatters of burnt flints, sometimes deeply reddened and crazed (Figs. 4(b) and 6), across the AH excavation and at more than one level in Area AF. In addition, there are sharply delimited features (about 1 m^2) interpreted as hearths (Gowlett *et al.*, 2005; Gowlett, 2006). These generally have dark fills and are characterised by reddening of adjacent sediments (Figs. 4(a) and 5). Moreover, the most striking aspect of the vertebrate assemblage is that many of the bones are charred or calcined by burning (Fig. 6); about 13% of the small mammal teeth from Cutting 1 show unequivocal evidence, together with 9.2% of the amphibian bones. The bones from Beeches Pit and burnt modern bones show identical patterns of modification, notably splitting and mosaic cracking, as well as exhibiting similarities in colour, ranging from red to blue-black and grey-white, individual bones often showing variegated hues (Fig. 6). The colours reflect the degree of burning, which is a function of the prior state of the bone (weathered or 'green'), exposure (whether lying on the surface or buried) and the intensity and duration of the fire (Shipman *et al.*, 1984). Burning is also indicated by calcined shell, charcoal (some up to 2 cm across), 'clinker' (Fig. 6), and heat-fused sediment, which, with fire-crazed flint, are dispersed throughout Bed 3b in Area AH, Cutting 1 and Trench 5e.

A priori, these burnt remains could represent either natural forest fires or human occupation and fire use. In recent years, general arguments have inclined towards earlier human fire use in the light of new general models about diet in the Plio-Pleistocene, particularly the human digestive requirements for cooking in preparation of roots and tubers (Wrangham *et al.*, 1999; O'Connell *et al.*, 1999), and the need for high-grade foods as required by the expensive tissue hypothesis (Aiello and Wheeler, 1995; Wrangham and Conklin-Brittain, 2003). Supporting evidence for early fire comes mainly from Africa, at Swartkrans (>1 Ma), Chesowanja (ca. 1.5 Ma) and Koobi Fora (ca. 1.6 Ma), and remains controversial for some of the reasons explained below (Brain and Sillen, 1988; Gowlett *et al.*, 1981; Bellomo and Kean, 1997; Clark and Harris, 1985). Additional archaeological discoveries, however, as at Gesher Benot Ya'aqov in Israel, give further indications of a long timescale for fire use (Goren-Inbar *et al.*, 2004).

At Beeches Pit, evidence in favour of natural fires is the fact that large numbers of small rodent, insectivore and amphibian bones are burnt, an assortment suggestive of random burning. Burnt patches and 'depressions' representing burnt-out roots of trees have been observed in the aftermath of modern forest fires (Connor *et al.*, 1989). Bellomo has also noted that in rare cases where stump fires burn back into the roots they follow the distinctive root shapes (Bellomo, 1993). Alternative anthropogenic explanations are plausible but human use of fire during the Lower and Middle Palaeolithic is difficult to demonstrate for the simple reason that fire itself is transient (Perlès, 1975). James (1989) examined the claims for fire use in the Lower Palaeolithic and concluded that, although evidence of burning was present at many sites, it could not be securely linked to a human origin. Furthermore he found no evidence for definite hearth structures before the appearance of Neanderthals towards the end of the Middle Palaeolithic. Roebroeks and Tuffreau (1999: 129) came to a similar conclusion, noting that 'although burnt flints are very common at Middle Palaeolithic sites (yet more striking, in view of their virtual absence in Lower Palaeolithic contexts), hearth structures are conspicuously absent'. It has even been argued that the apparent absence of fire use in the early Middle Pleistocene, at sites such as Boxgrove, may be linked to a major advance in human social and intellectual capabilities, which did not take effect in northern Europe until about 400 kyr (cf. Dunbar, 1998; Rolland, 2004).

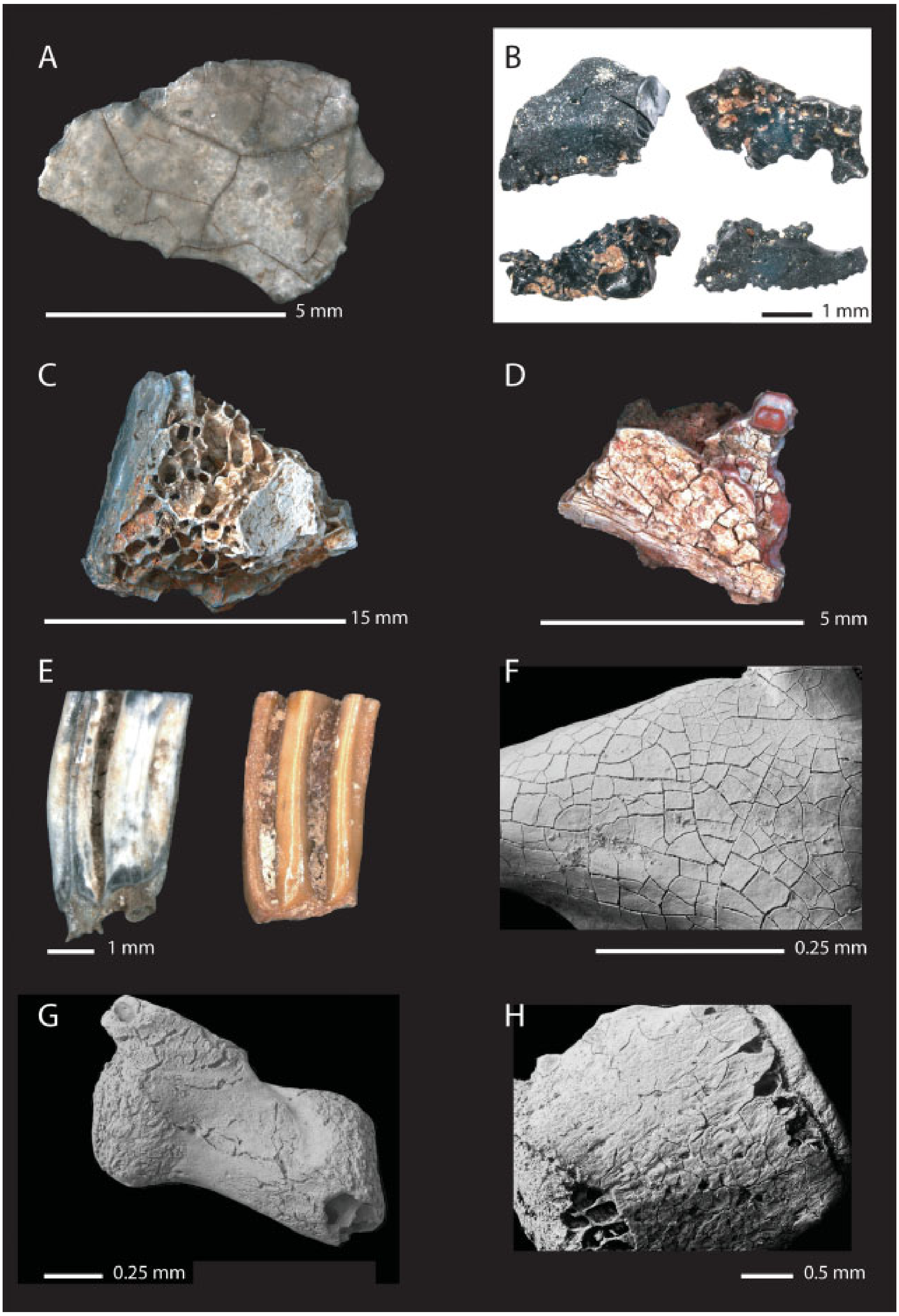

Figure 6 Photographs of burnt material: (A) burnt flint (Bed 3b); (B) 'clinker' (Bed 5); (C) burnt large mammal bone (Bed 3b); (D) burnt tooth fragment of large mammal (Bed 6); (E) comparison of calcined (left) and unburnt (right) molars of *Clethrionomys glareolus* (both Bed 3b); (F) burnt premolar of *Talpa minor* (Bed 6); (G) burnt vertebra of small mammal (Bed 5); (H) experimentally burnt vertebra of brown rat showing characteristic 'mosaic' cracking

Despite these arguments, there is compelling evidence for controlled use of fire at Beeches Pit (Hallos, 2004; Gowlett *et al.*, 2005; Gowlett, 2006). First, the stratigraphical coincidence of burning with the greatest concentrations of artefacts is highly suggestive. Moreover, the first evidence of burning (in Bed 3b) coincides with the earliest archaeology at the site. Second, careful excavation has shown that areas of intense burning are restricted to shallow depressions, two of which appear to intersect (Fig. 5). This implies a sequence of burning at discrete locations but with overlapping 'footprints'. Third, the spatial disposition of artefacts appears to respect the burnt areas (Fig. 5), interpreted as hearths. In particular, one refit series of almost 30 pieces, probably representing roughing out of a biface, is unburnt, except for two reddened flakes that moved forwards into the hearth area (Figs. 4b and 5). They both confirm that burning was highly localised and appear to imply fireside knapping. Fourth, burning events have been recognised in three Beds (3b, 5 and 6), indicating recurrent fire use over prolonged periods of the interglacial and into the ensuing cold period (Fig. 3). Fifth, various lines of evidence indicate burning of flint at temperatures of several hundred degrees. Crazed pieces indicate heating in excess of 350°C (Purdy and Brooks, 1971; Douglas-Price *et al.*, 1982) and the TL measurements show that some flakes from Bed 6 were heated to a temperature above 400°C (Gowlett *et al.*, 2005). Moreover, X-ray diffraction (XRD) analysis of three bones has confirmed that the charred and calcined bones from Bed 6 had been intensely heated at temperatures of between 600°C and 800°C (J. G. Francis, pers. comm.). This intensity of burning is never attained in grassland fires, which generally burn for only relatively short periods with temperatures exceeding 65°C for less than about 10 minutes (Shipman *et al.*, 1984). Grassland fires do not generate sufficient heat for a long enough time to alter bone colour beyond scorching (Seabloom *et al.*, 1991). Likewise forest or bush fires seldom reach temperatures above 300°C and burning tree stumps produce a prolonged soft glow but only at relatively low temperatures (Bellomo, 1993). Major forest fires can generate very high temperatures, but generally occur in interfluve situations where there is a long return time between fires (Johnson, 1992). Conversely, several authors have reported temperatures from camp-fires between 400 and 800°C; a maximum temperature of 900°C has even been measured from the oak coals of one camp-fire (Shipman *et al.*, 1984). At Beeches Pit, the occurrence of bones burned to grey or white (Fig. 6) implies more intense combustion than is usual for a natural fire, which often results in only partial and superficial burning (David, 1990). However, none of the large mammal bones from Beeches Pit bear cut-marks and it is not clear whether those that were burned were done so intentionally during cooking or disposal of food waste, or as a fuel for the fire.

Notwithstanding previous assertions, there are nevertheless several European sites where evidence for human use of fire in the Middle and Late Pleistocene is indicated (Fig. 1; cf. Gowlett, 2006). These include both hearths and charred artefacts from Schöningen (Thieme, 2005), the central German travertine sites of Bilzingsleben II (Mania, 1991) (all also attributed to MIS 11), Weimar-Ehringsdorf (Kahlke *et al.*, 2002), of probable MIS 7 age and Taubach (Bratlund, 1999), probably attributable to MIS 5e. In addition, the rock fissure of La Cotte de St Brelade, Jersey, is another MIS 7 locality with evidence for hearths (Callow *et al.*, 1986), whereas Grotte du Lazaret (archaeological unit UA25), near Nice, has been attributed to MIS 6 (de Lumley *et al.*, 2005). Much earlier evidence has recently come from the Acheulian site of Gesher Benot Ya'aqov, Israel, where localised burning in sediments nearly 790 kyr old has been attributed to the controlled use of fire by humans, including possible hearths (Goren-Inbar *et al.*, 2004). Deep caves, such as Tabun, also preserve hearths back into the Middle Pleistocene (Ronen and Tsatskin, 1995).

The extreme rarity of Lower Palaeolithic hearths may be due to taphonomic factors, in that burnt bones are susceptible to leaching in acidic environments (Lyman, 1994) and ash and charcoal are readily dispersed by water and wind. Sergant *et al.* (2006) have argued that non-structured hearths may be 'invisible' in the archaeological record. In the absence of discrete hearth structures, diagnosis of fire use is frequently based on the patterning of burnt material, such as micro-debitage at Gesher Benot Ya'aqov, Israel (Goren-Inbar *et al.*, 2004). However, this evidence is often ambiguous as it may be difficult to eliminate the possibility that the burning resulted from natural fires ignited by lightning strikes or spontaneous combustion. Therefore unless special factors have favoured the preservation and recognition of hearths, such as incorporation in an actively forming travertine (as at the German sites listed above), it is unlikely that anything other than a few burnt stones will survive in place. Beeches Pit, which also has calcareous precipitation and exceptional preservation of archaeological remains, is thus one of the rare sites in northern Europe that has the potential to preserve Middle Pleistocene hearths. The fact that hearths have not been found in fluvial contexts at Hoxnian sites such as Swanscombe and Clacton is entirely to be expected; humans might have procured food and other resources in fluvial environments, perhaps even engaging in tool-making on the gravel bars from which they obtained raw materials, but such locations are unlikely to have been favoured as home-bases. They are too exposed, would attract the attention of predators and would be liable to flooding. At Beeches Pit, the recurrent nature of the fire record, the flint knapping and range of tool types suggest that the woodland habitat (with its source of fresh water from the spring), served as a 'home-base'. Possibly fire was sustainable only in such favoured local environments (Gowlett, 2006).

Environmental context

Beeches Pit is a rare example of a European Lower Palaeolithic site where human occupation can be related to the local environment and to changes in that environment during different parts of an interglacial/glacial cycle. Since the sediments are strongly oxidised and so lack pollen, most of the environmental evidence at the site comes from faunal data, especially from molluscs, vertebrates and ostracods. The earliest evidence for occupation, from Bed 3b, coincides with an open environment at the edge of a small pool, surrounded by marsh. Drier areas of calcareous grassland existed, as did patches of open woodland. Subsequent archaeological activity (Beds 4 and 5) was located close to tufa-forming springs that would have represented a reliable source of clean fresh water. Areas of deeper, more permanent water existed, supporting aquatic molluscs such as *Valvata cristata*. The molluscan fauna ('the *Lyrodiscus* biome' *sensu* Rousseau *et al.* (1992)) associated with the artefacts in the base of the tufa shows that the humans were active at the height of the interglacial in a local environment dominated by closed deciduous woodland. The land snail fauna is dominated by woodland taxa (ca. 60%), including species (e.g. *Platyla polita, Helicodonta obvoluta* and *Zonitoides excavatus*) with the most shade-demanding preferences. Components of the vertebrate fauna, such as squirrel (*Sciurus* sp.), garden dormouse (*Eliomys quercinus*) and wood mouse (*Apodemus sylvaticus*) also attest to the presence of forest. Molluscan evidence suggests a slight opening of the woodland canopy in the upper levels of the tufa but otherwise similar conditions appear to have persisted into Bed 5, which yielded a small mammal assemblage dominated by woodland taxa (especially *Apodemus* spp.). A major environmental change is registered in Bed 6 by a shift in the composition of the small mammal assemblage towards species characteristic of open country (especially *Microtus* spp.). The presence of the bivalve *Pisidium obtusale lapponicum* in Bed 6 indicates that the sediments accumulated in a shallow, near stagnant water-body, during a cold climate episode. Further evidence for cold conditions comes from Bed 7, in which *P. obtusale lapponicum* persists, but is joined by several ostracod species (e.g *Amplocypris tonnensis*) and lemming (*Lemmus/Myopus*) indicative of cold climate. The overlying Bed 8, which is devoid of fossils, has been affected by periglacial disturbance. There is therefore unambiguous evidence of human occupation of a relatively open landscape during an episode of temperate climate (Bed 3b) and in full interglacial closed forest (Beds 4 and 5). Refitting flint clusters and evidence of fire use attest to *in situ* occupation during these periods. Flint artefacts and burnt bone have also been recovered from the overlying cold-climate deposits (Beds 6 and 7), implying human persistence at the site under these dramatically different conditions.

Some authors, in particular Gamble (1986, 1987), have argued that early humans in Europe were primarily adapted to open situations, being less able to survive in extreme environments, such as glacial maxima and dense interglacial forest, before the development of extensive 'alliance networks'. Gamble (1986) suggested that the main obstacle to long-term occupation of such 'high-risk environments' is not so much a lack of technology as the absence of appropriate social structures. Others, however, have argued (Roebroeks *et al.*, 1992) that European Middle Pleistocene humans were present in northwestern Europe during interglacial optima, albeit only in 'relatively open areas within interglacial forested environments' (Roebroeks and Tuffreau, 1999: 127). They have also argued that the shorter length of interglacials reduces the chances of sampling sites in a given phase.

Evidence for occupation of dense woodland is nevertheless exceptional. An explanation may perhaps be found in relation to the supply of raw material for tool making. Wenban-Smith (1998) has suggested that availability of raw material diminished during interglacials as slopes became vegetated and stable, leading to concealment and scarcity of flint sources. Thus a readily accessible source of flint from what is now Area AH might have led to frequent and repeated visits to the locality even at a time when it was within dense deciduous woodland.

Position within the interglacial cycle

The Hoxnian is one of the few intervals in the European Middle Pleistocene for which it is possible to assign archaeological contexts (e.g. at Swanscombe, Clacton-on-Sea and Barnham) to relatively short time-slices. At some of these sites, palynology can be used to place the contexts within the substages of the interglacial cycle (cf. Turner, 1970). Where pollen data are equivocal or unavailable, molluscan biostratigraphy has been used to correlate critical archaeological sites and to link them to the Hoxnian pollen stratigraphy (e.g. Kerney, 1971: Fig. 4). It is now possible to adopt a similar approach to the Hoxnian sequence at Beeches Pit and to suggest correlations with other sites (Fig. 7), and so to make first steps towards building a regional human ecology.

The pattern of occurrence of the land snails *Discus ruderatus* and *D. rotundatus* are important in this discussion. During the early Holocene (ca. 9500–8500 yr BP) in southern Britain only *D. ruderatus* (now extinct in Britain) occurs but this species is subsequently replaced by its southern congener *D. rotundatus* after ca. 8500 yr BP with only a brief period of overlap (cf. Preece and Bridgland, 1999). However, during several earlier interglacial periods, *D. ruderatus* was not restricted just to the early substage but appears to have persisted far later, resulting in a greater temporal overlap with *D. rotundatus*. During the early Hoxnian, it appears that, as in the early Holocene, *D. rotundatus* was absent or relatively scarce, whereas *D. ruderatus* was the only (or more dominant) species of *Discus* present (Kerney, 1971, 1977; Preece and Penkman, 2005).

The suggested correlations provide a chronological framework relevant to a discussion about the relation of the Clactonian (flake-and-core) industry to the Acheulian (handaxe) industry. The Clactonian has long been regarded as preceding the Acheulian within the Hoxnian, based originally on their superposition at Swanscombe (Kerney, 1971; Wymer, 1974). The Clactonian is found in southeast England from the late Anglian through to the middle of the early temperate substage of the Hoxnian (Ho II), when handaxes became prevalent (Wymer, 1974; Wenban-Smith, 1998; White, 2000; Wenban-Smith *et al.*, this issue, pp. 471–483). In addition to the Swanscombe area, evidence for this is based on the Clactonian type locality; both sites can be related to the terrace sequence

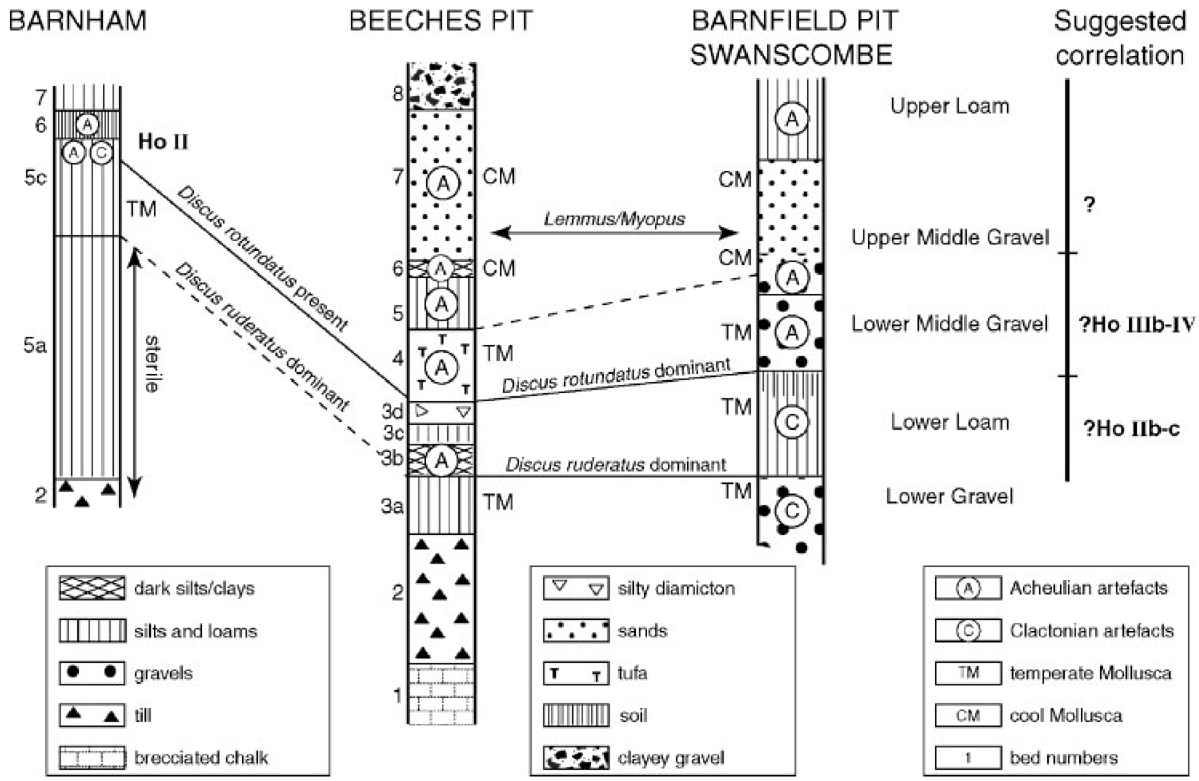

Figure 7 Suggested correlations between critical horizons at Beeches Pit, Barnham and Swanscombe with the substages of the Hoxnian

of the River Thames (Bridgland, 1994; Bridgland *et al.*, 1999). The Clactonian has also been recognised in sediments forming a lower terrace of the Thames at sites like Little Thurrock and Purfleet, which have been correlated with late MIS 10/early MIS 9 (Bridgland, 1994; Schreve *et al.*, 2002; White, 2000), suggesting at least two sequential Clactonian immigrations in consecutive climatic cycles (White and Schreve, 2000).

If the suggested correlations in Fig. 7 are correct and Bed 3b is broadly coeval with the Lower Loam at Swanscombe, the implication is that the Acheulian facies appeared earlier at Beeches Pit than at Swanscombe. At Barnham, 11 km to the northeast of Beeches Pit, the earliest evidence of handaxe manufacture is found within sediments (Unit 5c) yielding *Discus ruderatus* and those immediately above (Preece and Penkman, 2005), with early temperate pollen (Ho II). The molluscan evidence suggests that these sediments can be correlated with Bed 3b (from the later part of Ho II) at Beeches Pit (Fig. 7), which would therefore imply that handaxes occur earlier in the Hoxnian at both these East Anglian sites than in the Thames valley. It is also apparent that the Clactonian and Acheulian occur within the same substage (Ho II) of the Hoxnian (cf. Ashton *et al.*, 1994, 1998). However, the temporal resolution is insufficient to establish whether they overlapped chronologically or whether there was extremely rapid replacement of the Clactonian by the Acheulian (cf. White and Schreve, 2000).

Conclusions

The Beeches Pit site provides a rare record of human occupation of a land surface during a Middle Pleistocene interglacial, identified as the Hoxnian (= early part of MIS 11, onset about 424 kyr). The occurrence of conjoinable artefacts, which indicate primary context archaeology, within sediments containing evidence for a temperate deciduous woodland, establishes that humans were able to live in fully interglacial closed forests, despite earlier suggestions to the contrary. Discrete areas of burnt sediment are interpreted as hearths, which are thus amongst the oldest in northwest Europe. It is perhaps no coincidence that these features are preserved at a location where calcareous precipitation from a spring has led to exceptional preservation of terrestrial surfaces, something that Beeches Pit has in common with the travertine sites of central Germany, where hearths are also reported. Molluscan assemblages can be used to attribute the archaeological evidence to particular time-slices within the Hoxnian Stage, raising questions about the long-established notion that Clactonian knappers reached Britain earlier within that interglacial than those with an Acheulian (handaxe-making) tradition. The British variability needs to be assessed in relation to the patterns of tool manufacture seen elsewhere in continental Europe

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References

Aiello LC, Wheeler P, 1995. The expensive-tissue hypothesis: the brain and the digestive system in human and primate evolution. *Current Anthropology* **36**: 199–221.

Ashton NM, Cook J, Lewis SG, Rose J (eds). 1992. *High Lodge: Excavations by G. de G. Sieveking 1962–68 and J. Cook 1988*. British Museum Press: London.

Ashton N, McNabb J, Irving B, Lewis S, Parfitt S. 1994. Contemporaneity of Clactonian and Acheulian flint industries at Barnham, Suffolk. *Antiquity* **68**: 585–589.

Ashton NM, Lewis SG, Parfitt SA. (eds). 1998. *Excavations at the Lower Palaeolithic site at East Farm, Barnham, Suffolk 1989–94*. British Museum Occasional Paper 125: London.

Ashton N, Lewis S, Parfitt S, Candy I, Keen D, Kemp R, Penkman K, Thomas G, Whittaker J, White M. 2005. Excavations at the Lower Palaeolithic site at Elveden, Suffolk, UK. *Proceedings of the Prehistoric Society* **71**: 1–61.

Bellomo RV. 1993. A methodological approach for identifying archaeological evidence of fire resulting from human activities. *Journal of Archaeological Science* **20**: 525–553.

Bellomo RV, Kean WF. 1997. Evidence of hominid-controlled fire at the FxJj20 site complex, Karari Escarpment. Appendix 4A. In *Koobi Fora Research Project,* (Vol. 5): *Plio-Pleistocene Archaeology*, Isaac GL, Isaac B. (eds). Clarendon Press: Oxford; 224–233.

Boreham S, Gibbard PL, 1995. Middle Pleistocene Hoxnian Stage interglacial deposits at Hitchin, Hertfordshire, England. *Proceedings of the Geologists' Association* **106**: 259–270.

Bradley RC. Head G, Jenike M, Owen B, Rechtman R, Zechenter E. 1989. Hunting and gathering in tropical rain forest: Is it possible? *American Anthropologist* **91**: 59–82.

Brain CK, Sillen A. 1988. Evidence from the Swartkrans cave for the earliest use of fire. *Nature* **336**: 464–466.

Bratlund B. 1999. Taubach revisited. *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz* **46**: 61–174.

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

Bridgland DR, Lewis SG, 1991. Introduction to the Pleistocene geology and drainage history of the Lark valley. In *Central East Anglia and the Fen Basin*, Lewis SG, Whiteman CA, Bridgland DR (eds). Field Guide, Quaternary Research Association: London; 37–44.

Bridgland DR, Lewis SG, Wymer JJ, 1995. Middle Pleistocene stratigraphy and archaeology around Mildenhall and Icklingham, Suffolk: report on the Geologists' Association Field Meeting 27 June, 1992. *Proceedings of the Geologists' Association* **106**: 57–69.

Bridgland DR, Field MH, Holmes JA, McNabb J, Preece RC, Selby I, Wymer JJ, 1999. Middle Pleistocene interglacial Thames–Medway deposits at Clacton-on-Sea, England: reconsideration of the biostratigraphical and environmental context of the type Clactonian Palaeolithic industry. *Quaternary Science Reviews* **18**: 109–146.

Bristow CR, 1990. *Geology of the country around Bury St. Edmunds*. Memoir of the British Geological Survey.

Callow P, Walton D, Shell CA. 1986. The use of fire at La Cotte de St. Brelade. In *La Cotte de St. Brelade 1961–1978. Excavations by C.B.M. McBurney*, Callow P, Cornford JM (eds). Geo Books: Norwich; 193–195.

Clark JD, Harris JWK. 1985. Fire and its roles in early hominid lifeways. *African Archaeological Review* **3**: 3–27.

Connor MA, Cannon KP, Carlevato DC. 1989. The mountains burnt: forest fires and site formation processes. *North American Archeologist* **10**: 293–310.

Conway BW, McNabb J, Ashton NM. 1996. *Excavations at Barnfield Pit, Swanscombe, 1968–72*. British Museum Press: London.

David B. 1990. How was this bone burnt? In *Problem Solving in Taphonomy: Archaeological and Paleontological studies from Europe, Africa and Oceania*, Davidson I, Watson D (eds). Tempus, Anthropology Museum, University of Queensland: St Lucia, Queensland; 65–79.

de Lumley H, Echassoux A, Bailon S, Cauche D, Marchi M-P de, Desclaux E, el Guennouni K, Khatib S, Lacombat F, Roger T, Valensi P, 2005. *Le sol d'occupation acheuléen de l'unité archéostratigraphique UA25 de la Grotte du Lazaret, Nice, Alpes-Maritimes*. Edisud: Aix-en-Provence.

Douglas-Price TD, Chappell S, Ives DJ. 1982. Thermal alteration in Mesolithic assemblages. *Proceedings of the Prehistoric Society* **48**: 467–485.

Dunbar RIM. 1998. The social brain hypothesis. *Evolutionary Anthropology* **6**: 178–190.

Gamble C, 1986. *The Palaeolithic Occupation of Europe*. Cambridge University Press: Cambridge.

Gamble C, 1987. Man the shoveler: alternative models for Middle Paleolithic colonization and occupation in northern Europe. In *The Pleistocene Old World. Regional Perspectives*, Soffer O (ed.), Plenum Press: New York; 81–98.

Goren-Inbar N, Alperson N, Kislev ME, Simchoni O, Melamed Y, Ben-Nun A, Werker E. 2004. Evidence of hominin control of fire at Gesher Benot Ya'aqov, Israel. *Science* **304**: 725–727.

Gowlett JAJ. 2006. The early settlement of northern Europe: fire history in the context of climate change and the social brain. *Comptes Rendus Palevol* **5**: 299–310.

Gowlett JAJ, Harris JWK, Walton D, Wood BA. 1981. Early archaeological sites, hominid remains and traces of fire from Chesowanja, Kenya. *Nature* **294**: 125–129.

Gowlett JAJ, Chambers JC, Hallos J, Pumphrey TRJ. 1998. Beeches Pit: first views of the archaeology of a Middle Pleistocene site in Suffolk, UK, in European context. *Anthropologie* **36**: 91–97.

Gowlett JAJ, Hallos J, 2000. Beeches Pit: overview of the archaeology. In *The Quaternary of Norfolk and Suffolk*, Lewis SG, Whiteman CA, Preece RC (eds). Field Guide, Quaternary Research Association: London; 197–206.

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. *Journal of Eurasian Prehistory* **3**: 3–40.

Hallos J, 2004. Artefact dynamics in the Middle Pleistocene: implications for hominid behaviour. In *Lithics in Action*, Walker EA, Wenban-Smith F, Healy F (eds). Lithic Studies Society Occasional Paper no. 8, Oxbow Books: Oxford; 26–37.

Hallos J. 2005. '15 Minutes of Fame': exploring the temporal dimension of middle Pleistocene lithic technology. *Journal of Human Evolution* **49**: 155–179.

James SR. 1989. Hominid use of fire in the Lower and Middle Pleistocene. *Current Anthropology* **30**: 1–26.

Johnson EA, 1992. *Fire and Vegetation Dynamics: Studies from the North American Boreal Forest*. Cambridge University Press: Cambridge.

Kahlke R-D, Maul LC, Meyrick RA, Stebich M, Grasselt T. 2002. The Quaternary sequence from the late Middle to Upper Pleistocene site of Weimar-Ehringsdorf. In *The Quaternary of Central Germany (Thuringia and Surroundings)*, Meyrick RA, Schreve DC (eds). Field Guide, Quaternary Research Association: London; 163–177.

Kerney MP. 1971. Interglacial deposits in Barnfield Pit, Swanscombe, and their molluscan fauna. *Journal of the Geological Society of London* **127**: 69–93.

Kerney MP. 1976. Mollusca from an interglacial tufa in East Anglia, with the description of a new species of *Lyrodiscus* Pilsbry (Gastropoda: Zonitidae). *Journal of Conchology* **29**: 47–50.

Kerney MP, 1977. British Quaternary Mollusca: a brief review. In *British Quaternary Studies: Recent Advances*, Shotton FW (ed.). Clarendon Press: Oxford; 31–42.

Lewis SG. 1998. Quaternary stratigraphy and Lower Palaeolithic archaeology of the Lark valley, Suffolk. In *Stone Age Archaeology: Essays in Honour of John Wymer*, Ashton N, Healy F, Pettitt P (eds). Lithics Studies Society Occasional Publication no. 6, Oxbow Monograph no. 102: Oxford; 43–51.

Lewis SG. 1999. Eastern England. In *A revised correlation of Quaternary deposits in the British Isles,* Bowen DQ (ed.). Special Report no. 23, Geological Society of London; 10–27.

Lyman RL. 1994. *Vertebrate Taphonomy*. Cambridge University Press: Cambridge.

Mania D. 1991. The zonal division of the Lower Palaeolithic open-air site Bilzingsleben. *Anthropologie* **29**: 17–24.

O'Connell JF, Hawkes K, Blurton Jones NG, 1999. Grandmothering and the evolution of *Homo erectus*. *Journal of Human Evolution* **36**: 461–485.

Ovey CD (ed.). 1964. *The Swanscombe Skull. A survey of research on a Pleistocene site*. Occasional Paper no. 20, Royal Anthropological Institute of Great Britain and Ireland; 77–83.

Parfitt S. 1998. The interglacial mammalian fauna from Barnham. In *Excavations at the Lower Palaeolithic Site at East Farm, Barnham, Suffolk 1989–94*, Ashton NA, Lewis SG, Parfitt S (eds). British Museum Press: London; 111–147.

Penkman KEH. 2005. *Amino acid geochronology: a closed system approach to test and refine the UK model*. PhD thesis, University of Newcastle.

Perlès C, 1975. L'homme préhistorique et le feu. *La Recherche* **6**: 829–839.

Preece RC, Bridgland DR. 1999. Holywell Coombe, Folkestone: a 13,000 year history of an English chalkland valley. *Quaternary Science Reviews* **18**: 1075–1125.

Preece RC, Penkman KEH. 2005. New faunal analyses and amino acid dating of the Lower Palaeolithic site at East Farm, Barnham, Suffolk. *Proceedings of the Geologists' Association* **116**: 363–377.

Preece RC, Lewis SG, Wymer JJ, Bridgland DR, Parfitt S. 1991. Beeches Pit, West Stow, Suffolk (TL 798719). In *Central East Anglia and the Fen Basin*, Lewis SG, Whiteman CA, Bridgland DR (eds). Field Guide, Quaternary Research Association: London; 94–104.

Preece RC, Bridgland DR, Lewis SG, Parfitt S, Griffiths HI. 2000. Beeches Pit, West Stow, Suffolk (TL 798719). In *The Quaternary of Norfolk and Suffolk*, Lewis SG, Whiteman CA, Preece RC (eds). Field Guide, Quaternary Research Association: London; 185–195.

Purdy BA, Brooks HK. 1971. Thermal alteration of silica minerals: an archaeological approach. *Science* **173**: 322–325.

Roberts MB, Parfitt SA. 1999. *Boxgrove, A Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex*. English Heritage: London.

Roebroeks W. 2001. Hominid behaviour and the earliest occupation of Europe: an exploration. *Journal of Human Evolution* **41**: 437–461.

Roebroeks W, Tuffreau A, 1999. Palaeoenvironmental and settlement patterns of the northwest European Middle Palaeolithic. In *The Middle Palaeolithic Occupation of Europe*, Roebroeks W, Gamble C (eds). University of Leiden: Leiden; 121–138.

Roebroeks W, Conard N, Kolfschoten T van. 1992. Dense forests, cold steppes and the Palaeolithic settlement of northern Europe. *Current Anthropology* **33**: 551–586.

Rolland N. 2004. Was the emergence of home bases and domestic fire a punctuated event? A review of the Middle Pleistocene record in Eurasia. *Asian Perspectives* **43**: 248–280.

Ronen A, Tsatskin A, 1995. New interpretation of the oldest part of the Tabun cave sequence, Mount Carmel, Israel. In *Man and Environment in the Palaeolithic*, Ullrich H (ed.). ERAUL 62: Liège; 265–281.

Rose J. 1989. Tracing the Baginton–Lillington sands and gravels from the West Midlands to East Anglia. In *The Pleistocene of the West Midlands*, Keen DH (ed.). Field Guide. Quaternary Research Association: Cambridge; 102–110.

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

Rose J, Moorlock BSP, Hamblin RJO. 2001. Pre-Anglian fluvial and coastal deposits in Eastern England: lithostratigraphy and palaeoenvironments. *Quaternary International* **79**: 5–22.

Rousseau D-D, Puisségur J-J, Lécolle F. 1992. West-European terrestrial molluscs assemblages of isotopic stage 11 (Middle Pleistocene): climatic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology* **92**: 15–29.

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

Schreve DC, Bridgland DR, Allen P, Blackford JJ, Gleed-Owen CP, Griffith HI, Keen DH, White MJ. 2002. Sedimentology, palaeontology and archaeology of late Middle Pleistocene River Thames terrace deposits at Purfleet, Essex, UK. *Quaternary Science Reviews* **21**: 1423–1464.

Seabloom RW, Sayler RD, Ahler SA. 1991. Effects of prairie fires on archeological artifacts. *Park Science* **11**: 1–3.

Sergant J, Crombé P, Perdaen Y. 2006. The 'invisible' hearths: a contribution to the discernment of Mesolithic non-structured surface hearths. *Journal of Archaeological Science* **33**: 999–1007.

Shipman P, Foster G, Schoeninger M. 1984. Burnt bones and teeth: an experimental study of color, morphology, crystal structure and shrinkage. *Journal of Archaeological Science* **11**: 307–325.

Thieme H, 2005. The Lower Palaeolithic art of hunting: the case of Schöningen 13 II-4, Lower Saxony, Germany. In *The Hominid Individual in Context: Archaeological Investigations of Lower and Middle Palaeolithic Landscapes, Locales and Artefacts*, Gamble CS, Porr M (eds). Routledge: London; 115–132.

Turner C. 1970. The Middle Pleistocene deposits at Marks Tey, Essex. *Philosophical Transactions of the Royal Society of London* **B257**: 373–440.

Warren SH. 1955. The Clacton (Essex) Channel deposits. *Quarterly Journal of the Geological Society of London* **61**: 283–387.

Wenban-Smith FF. 1998. Clactonian and Acheulian Industries in Britain: their chronology and significance reconsidered. In *Stone Age Archaeology: Essays in Honour of John Wymer*, Ashton N, Healy F, Pettit P (eds). Lithics Studies Society Occasional Paper 6, Oxbow: Oxford; 90–97.

West RG. 1956. The Quaternary deposits at Hoxne, Suffolk. *Philosophical Transactions of the Royal Society of London* **B239**: 265–356.

Whitaker W, Woodward HB, Bennett FJ, Skertchly SBJ, Jukes-Browne AJ. 1891. *The Geology of Parts of Cambridgeshire and of Suffolk (Ely, Mildenhall, Thetford)*. Memoir of the Geological Survey of Great Britain, HMSO: London.

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

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

Wrangham RW, Conklin-Brittain N, 2003. Cooking as a biological trait. *Comparative Biochemistry and Physiology, Part A* **136**: 35–46.

Wrangham RW, Jones JH, Laden G, Pilbeam D, Conklin-Brittain N, 1999. The raw and the stolen: cooking and the ecology of human origins, *Current Anthropology* **40**: 567–594.

Wymer JJ. 1974. Clactonian and Acheulean industries in Britain: their chronology and significance. *Proceedings of the Geologists' Association* **85**: 391–421.

Wymer JJ, 1985. *Palaeolithic Sites of East Anglia*. Geobooks: Norwich.

Wymer JJ. 1999. *The Lower Palaeolithic Occupation of Britain*. Wessex Archaeology: Salisbury.

