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C. R. Palevol 5 (2006) 299–310

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Human Palaeontology and Prehistory

The early settlement of northern Europe: Fire history in the context of climate change and the social brain

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Received 2 February 2005; accepted after revision 5 October 2005
Available online 28 November 2005
Written on invitation of the Editorial Board

Abstract

Evaluation of the first early human settlement of northern Europe is closely bound up with issues of climate change, human social and technical capability, and sampling visibility. The finds from Dmanisi (1.7 Ma) suggest that small-brained early *Homo* with simple technologies was able to colonise temperate regions, and it is unlikely that Europe presented insuperable problems compared with Georgia; or that hominids who colonised the South of Europe in favourable conditions could not advance to the north within a few thousand years. Consideration of the geological record, however, shows how much has been lost: apart from large areas currently under sea, evidence of past rivers such as the proto-Thames and Bytham helps measure the extent of erosion, much of it caused by glacial planing. Fire history, in terms of controlled fire use, appears in northern Europe by isotope stage 11, when it is widespread across the continent. Beeches Pit is a prime example indicating fire control, and social activity around fires and in fire management. Fire is however puzzlingly absent from many sites, including those of OIS13. The paper considers the alternative possibilities: that fire use was introduced through an increase in human social/intellectual capability around OIS 11, and that sampling limitations greatly reduce our chances of seeing it on earlier sites. ***To cite this article: J.A.J. Gowlett, C. R. Palevol 5 (2006)***.

Résumé

Première colonisation du Nord de l'Europe : histoire du feu dans le contexte du changement de climat et cerveau social. La première date de la colonisation par l'homme du Nord de l'Europe doit rester très incertaine, bien que d'excellentes découvertes, ces dernières années, révèlent sa présence il y a environ 600 000 ans. Les découvertes réalisées à Dmanisi (1,7 Ma) suggèrent qu'un *Homo* à petit cerveau, avec des techniques simples, a été capable de coloniser les régions tempérées et qu'il est improbable que l'Europe présente des problèmes insurmontables, en comparaison de la Géorgie, ou que les hommes qui ont colonisé le Sud de l'Europe dans des conditions favorables n'aient pu progresser vers le nord pendant plusieurs milliers d'années. L'enregistrement géologique montre, cependant, combien beaucoup a été perdu : mises à part de vastes zones en général sous la mer, des rivières du passé, telle la proto-Tamise ou la Bytham, aident à mesurer l'extension de l'érosion dont la moyenne partie résultait de l'aplanissement glaciaire. L'histoire du feu, en terme d'utilisation contrôlée du feu apparaît dans le Nord de l'Europe au stage isotopique 11, quand celui-ci est très étendu sur le continent. Beeches Pit est un exemple de première importance, indiquant le contrôle du feu et l'activité sociale autour des feux et dans la gestion du feu. Cependant, l'absence de feu de nombreux sites, incluant ceux de OIS13, intrigue. L'article considère les possibilités alternatives : celle que l'usage du feu ait été introduit par suite

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doi:10.1016/j.crpv.2005.10.008

d'une augmentation des aptitudes sociales et intellectuelles de l'homme aux alentours d'OIS 11, et que les limites de l'échantillonnage aient grandement réduit nos chances de la caractériser dans des sites plus précoces. ***Pour citer cet article : J.A.J. Gowlett, C. R. Palevol 5 (2006)***.

Keywords: Fire; Middle Pleistocene; Northern Europe; Beeches Pit

Mots-clés : Feu ; Pléistocène moyen ; Nord de l'Europe ; Beeches Pit

1. Introduction

Views of the record of the early settlement of northern Europe have changed very rapidly from those obtaining as recently as the 1990s, when the issue of early or late occupation pivoted around the date of ~500 000 [25,28,74–76].

This change in perspective, exemplified by sites such as Dmanisi, is a signal that further rapid developments are likely to follow, and it follows that realistic assessment should depend not so much on actual evidence within the area, as potential that can be seen already in the major outlines of human evolution.

Within Europe, actual finds indicate a prehistory lasting some 800,000 to a million years in the south, and seemingly somewhat less in the north [18,28,74,84]. Among all the finds, Dmanisi, far away in Georgia, provides the most important evidence, demonstrating that early human capabilities extended to a northern presence towards 2 Myr ago [23,24].

Dmanisi shows that such colonisation could be conducted by small-brained hominids, with simple toolkits, adapted to Eurasian species (a major change of habitat from African homelands), and perhaps without fire.

The time gap between Dmanisi and most evidence of further European colonisation can be seen as a problem, but we may also ask 'what kind of problem?' From Europe, Dmanisi may look an isolated case, but in world view it now fits with widespread evidence of early occupation of Eurasia; lying north of almost 500 km of rugged mountain chains, it must testify to an accomplished adaptation to demanding environments [10,24]. Dmanisi thus poses questions and problems for previously accepted interpretations – how could early hominids survive so far north without large brains and advanced toolkits?

Northern and western Europe simply add further aspects to the issues of local barriers and regional adaptation, and highlight the problem of life with or without fire. But Europe, even in the north, does not offer problems utterly different from Georgia – except when the major issue of climate is introduced, the rolling cycle of ice age changes [10,24,28,43].

1.1. Competing hypotheses

Briefly then this is the interplay of the main issues.

How could early *Homo* adapt to the climates of the north (at all)? Then, given the cycles of climatic change for which there is abundant evidence [43,44,60,81], how could they adapt to colder periods: Was fire-use a major part of, and indicator of, such changes? [33,35,77,84,96,97]

And then, there is an opposition to consider:

- Was climate change the dominant influence in allowing human occupation?
- Or: did major behavioural changes of a social nature alter human capability to exploit these regions?

Such major change of the latter kind might account for the appearance of much more abundant occupation within the last half million years. The 'Social Brain' hypothesis makes predictions relating brain size and organisation (as measured through neocortex ratio) and social network size [20–22,100]. It implies that larger brains are necessary for managing larger social networks. Phases of major increase in human brain size come at roughly 2.0–1.7 Ma, and again at 0.5–0.3 Ma [1,2]. Changes in network size may be accompanied by greater ability to exploit particular environments, increased language capacity, and perhaps in associated socio-technical skills such as fire management [77,78].

Appearance of fire use at about 0.4 Ma may be a consequence of such change. An alternative hypothesis is that preservation – itself largely dictated by cycles of past climate change – might be the dominant factor affecting our interpretation of issues, and making us think that one region is greatly different from another in its early prehistory.

Fire is perhaps the greatest mystery in assessing such issues. There can be no doubt that fire would be of enormous assistance to hominids in exploiting current temperate regions, even in interglacial times, let alone in glacial periods. Much of the older record, however, lacks clear fire evidence. As the northern record is now a very long one, the hypothesis must at least be considered that early humans became hardy enough to exploit the north before they mastered fire.

As fire can affect diet, and diet the potential for larger brain size, these issues become bound up with the issue of the 'social brain', and particularly the idea that a large brain was the prerequisite for larger social networks necessary for successfully exploiting marginal environments. These issues will be discussed in the light of early fire history below.

2. Environments of preservation

The present-day Great Britain is almost the only substantial part of northern Europe with high potential for preservation of early sites, in addition to posing questions from the later record [57,58]. It has already been shown to preserve several sites older than the Anglian glaciation (= OIS 13 or greater), and may well preserve earlier material [6,26,48,69,70,73,98,99].

The preserved landscape can also be given as an example illustrating the power of environmental forces to restrict our record. Currently as much as 95% of the terrestrial record that might be available in the north is severely restricted in access, because it is undersea, or has been covered by the Devensian or Anglian ice sheets [12,46,66]. The postglacial encroachment, an absolute rise of some 130 m, has covered large areas of the continental shelf [11]. The glaciers have advanced from the north at least twice, covering at least two-thirds of the British landmass. Southeastern England thus makes up a relatively narrow window between these two major influences, preserving a quite dense distribution of Lower Palaeolithic sites through parts of the last half million years, but only within about 75 000 km^2 of the maximum $1.0–1.5 \times 10^6$ km^2 potentially available (Fig. 1).

The preserved sites fall chiefly into three categories (Fig. 2):

- river terrace sites (especially of the Thames [13–15, 79,80,95]);
- interglacial sites preserved on clay landscapes (e.g., Hoxne, Elveden, Barnham [7–9,49,99], Beeches Pit);
- coastal sites (notably Boxgrove [69,70]).

Such good preservation can be used to illustrate just how great the loss is in other regions. Glaciers advancing from the north across Britain have greatly modified the landscape, removing huge amounts of material in a way that can sometimes be clearly documented [12, 16].

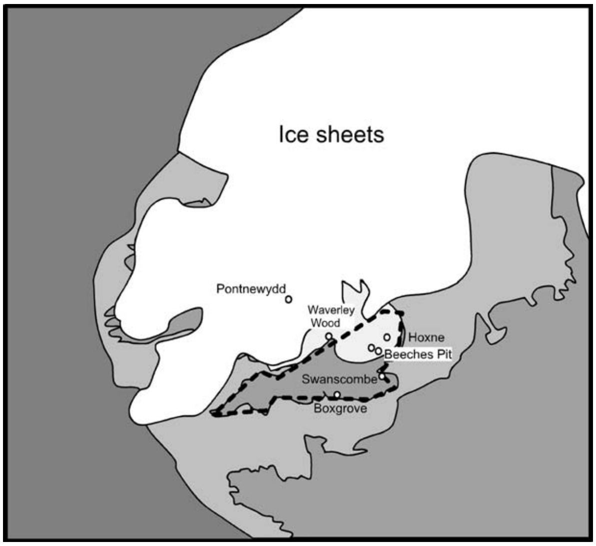

Fig. 1. Northern Europe – map showing how as much as 95% of the total potential 'northern Europe' is lost through glacial cover and current high sea levels. In places, Pleistocene glacial erosion may have removed 200 m of rock and sediment. The dotted line encloses the surviving window rich in Palaeolithic sites. Pontnweydd and Waverley Wood are rare examples of sites that have survived former thick ice cover (incorporating information from [11,46,80]).

Fig. 1. Nord de l'Europe, carte montrant que 95% du potentiel total de « l'Europe du Nord » sont perdus à cause de la couverture de glace et des fréquents hauts niveaux de la mer. Par endroits, l'érosion glaciaire pléistocène peut avoir arraché 200 m de roches et de sédiments. La ligne en pointillé entoure la fenêtre préservée, riche en sites paléolithiques. Pontnweydd et Waverley Wood sont de rares exemples de sites qui ont « survécu » à une épaisse couche de glace antérieure (incorporant les données de [11,46,80]).

2.1. Ancient river systems

Analysis of clasts found in gravels shows that material from northwestern Wales, more than 150 km beyond the current catchment of the Thames, was transported into southeastern England by an ancestral river [48,79,80]. The bed of this river must have passed above the ridge of the Cotswold Hills, which now form the upper limit of the Thames watershed. This evidence, plotted on a long section, gives the information that in the present Severn catchment, between 100- and 200-m depth of sediment must have been removed during the Pleistocene, partly by water erosion, but without doubt also by major glacial excavation [12,16,79]. Although there are good prospects of recovering early sites from the lower course of the ancestral Thames, especially in East Anglia, these circumstances make plain that to find

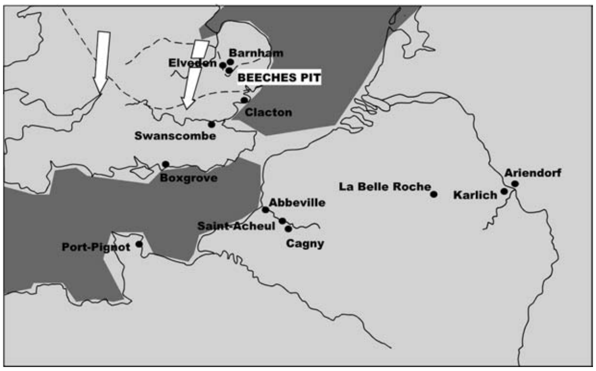

Fig. 2. Britain and northwestern Europe: major sites in the context of palaeogeographic change. Arrows show the main axes of erosion which had destroyed former river systems by the end of OIS12. Coastlines are approximately as they may have been during OIS11 (incorporating data from [13,56,46,80]).

Fig. 2. Bretagne et Nord de l'Europe : sites principaux dans le contexte du changement paléogéographique. Les flèches montrent les principaux axes de l'érosion qui a détruit des systèmes fluviatiles antérieurs à la fin d'OIS 12. Les lignes de côte sont approximativement telles qu'elles devraient l'avoir été pendant le stade OIS 11 (incorporant les données de [13,46,56,80]).

earlier sites upstream is an impossibility – only on some hillside might there be preserved some small patch of gravel at 300 or 400 m.

Geological research over the last fifteen years has shown that a second major river system flowed from west to east, about 100 km north of the Thames and roughly parallel to it (now usually known as the Bytham [79,80,48]). Its course was finally sundered during the Anglian glaciation, when the large embayment of the Wash was created [16,46]. Some of Britain's oldest sites such as High Lodge and Warren Hill are situated alongside this river [5,71,72,99], and current investigations have the prospect of finding the oldest sites in the whole system [86,99].

The Anglian glaciation of about 450 ka, however, greatly levelled the pre-existing landscape, reducing the height of the chalk ridge from approximately 250 m, which it now reaches in the Luton area, southwest of the major ice extent, down to a level of about 100 m, often capped by 20 m of glacially derived clay – in effect the action of a giant bulldozer, which in places moved chalk blocks larger than houses [12 (p. 239)]. In East Anglia, the pocked and dimpled surface left after the final Anglian retreat created a landscape of ponds and lakes in the succeeding interglacial, giving preservation potential for many of the best known Palaeolithic sites belonging to Stage 11, including Hoxne, Barnham, Elveden [5,7–9,49,56,83,99] and Beeches Pit, mentioned below [35–37,67,68] (Fig. 2).

The current record therefore gives pointers to further preservation potential, in other regions. The site of Pontnewydd in North Wales shows that in exceptional circumstances a site can be preserved – in this case a cave which must have been later covered by several hundred metres of Devensian ice [4,38]. In the British midlands, Waverley Wood is an example similarly of deep burial, in this case under later glacial sediments [46,82].

Recent studies across the English midlands show also that Middle Pleistocene river-system deposits may be more common than once thought; there is however only the thinnest scatter of archaeological finds. As flint is rare in the area, it appears that there was greater use of quartzite, which is far less distinctive to the untrained eye.

These various examples show the enormous potential for reduction of archaeological evidence in a highly erosional area. They have been emphasised to demonstrate the major effect that they can have on hypotheses, as in the case of fire use. In this respect, there is a sudden concentration of sites with early fire evidence around the period of the Middle Pleistocene 400 000 years ago. These are scattered far and wide in Europe, including Terra Amata, Grotte du Lazaret, Bilzingsleben, Schöningen, Menez Dregan, Vèrtesszöllös [39,47, 50–53,59,87–90] and Beeches Pit.

These are generally taken to represent 'first appearance' of fire in the region, but a consequence of the reduction effect is that specific kinds of evidence, such as burning, which occur at a low frequency in the first place, can be so reduced in the sampling that their preservation becomes almost random.

3. Beeches Pit: Fire History

Beeches Pit provides one example of early fire-use in northern Europe [35–37,67,68]. A Middle Pleistocene archaeological site in East Anglia, it lies close to the former course of the Bytham/Ingham river. The site lies on clays deposited within this valley by the Anglian glaciation, and is dated by TL, U-series, and palaeoenvironmental indicators to OIS11, with an age of about 400,000 years [15,35,37,68]. Preece et al. [68] attribute first occupation of the site to an early phase of this long interglacial on grounds of stratigraphy and palaeoenvironmental evidence, especially of microfauna and molluscs.

A sequence of environmental change within the interglacial is preserved. The site represents a place, or set of localities, where early humans occupied the north bank of a pond, probably attracted by those features which so commonly recur in the record: freshwater springs, protection on one side by a water body, access to flint raw material, and perhaps to other resources. The presence of springs is attested by the local presence of tufa, mostly in the form of calcareous tufaceous clays. In this respect the site has some similarities of setting to Bilzingsleben and other interglacial sites in Germany.

In the local environment of Beeches Pit hominids were active in flint knapping, probably on numerous occasions. In Area AH, the lower stratigraphic occurrence, flint finds are ranged through more than 50 cm. A number of refitting sets have been found [35,37] studied in detail by Hallos [40,41], and providing data to show the slope of the sediments, and the limited disturbance. Large flint cobbles (~20–30 cm) were available locally. A number of these were used as cores, and sequences of flakes were struck from them, but often the cores were tested and rejected after one or two flakes.

Although flint was abundant, and a good deal of knapping took place, it was not intensive. Detailed studies have indicated that few bifaces were reduced in the area, and few retouched tools occur. Artefacts from primary flaking are densely distributed across the surfaces, but characteristic Acheulean hand-axes are rare, with about eight known from the site all together. Two of these come from an upper occurrence, Area AF.

Evidence of fire is commonplace on the site, in the first place, in burnt flints, often reddened and shattered. These served as the basis for TL dating of the site, and gave an indication of burning temperatures of over 400 °C in studies by Debenham (in [37]).

It was also found that there were sharply delimited features, around one metre across, which we interpret as hearths. Generally they have dark fills and are characterised by reddening of sediments underneath and/or at the margins.

4. Main features on AH

In this area, the slope towards the pond was gentle, and the excavations uncover it across an area of approximately 10 × 8 m. The north part of this area, further from the water, is a sloping surface of clays, probably deposited colluvially by surface flow, perhaps partly by water from springs. The front area closer to the water consists of much darker silty clays, which overlie areas of the lighter brown clay.

Within the front area, there was found to be a series of hearths, which can be traced in stratigraphic succession from a lowest point close to the pond margin to a highest point some four metres to the northwest, and about 30 cm higher (Figs. 3,4). The clay surfaces underlying the hearth fills have sometimes been rubefied by the burning.

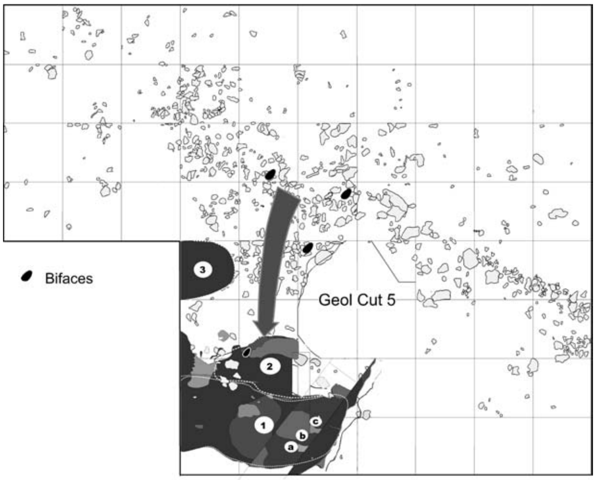

Fig. 3. Hearths in area AH at Beeches Pit. The arrow indicates the trend of the main series of refits, consisting of thirty pieces, and including two burnt flakes which had travelled forward into a hearth.
Fig. 3. Foyers dans la zone AH à Beeches Pit. La flèche indique l'orientation de la principale série de réparations, consistant en 30 pièces et incluant deux écailles brûlées, qui avaient été déplacées dans un foyer.

4.1. The refit series

Artefacts form key evidence in the interpretation of the hearth zone. Several bifaces of varied forms were found in this region, together with a number of cores and much flaking debris [35,36,40]. It has been possible to conjoin some of the pieces, in some 20 sets. The largest set consists of about 30 pieces, scattered down-

Fig. 4. Photograph – hearths in Area AH at Beeches Pit. View looking east, showing 77–79E/89–92N, an area of 3 m by 2 m.
Fig. 4. Photo de foyers dans la zone AH de Beeches Pit, vue vers l'est, dans la direction 77–79 E/89–92 N : une surface de 3 m sur 2.

slope along an axis from north to south, for 3–4 m, and across a width of about 2–3 m (Fig. 3).

The nucleus of the set was probably intended to become a biface. The knapping ended, however, when a major flaw became apparent in this piece, which was abandoned when it had a weight of ca. 1280 g, about three times the weight of the average biface on the site. Two flakes from this series of refits fell forward and became burnt in a hearth, thus providing an exceptional association between an individual's knapping and a fire [37,41]. It may never be known whether this individual interacted with others around the fire, but the presence of several bifaces of varied forms [41] suggests the possibility.

5. The evidence of area AF

Complementary evidence is preserved from area AF, around 20 m to the west. Here the archaeological remains overlie a bank of calcareous clay or tufa, which runs from the upper part of AH, indicating that the entire AF sequence dates from somewhat later in the interglacial. Further fire evidence is preserved, at two levels. In the lower, a 'pastille' of reddened sediments is preserved, associated with burnt flint. It is slightly more than 1 m across, and appears to have tilted through soil-creep. It is taken to represent a hearth similar to those in AH, but set on a steeper bank. At a somewhat higher level is evidence of a wider spread of organic and burnt material (unit 6), which mantles the slope. Its source area has been eroded away. Within it are two small hand-axes in fine condition, separated by just 30 cm, and confirming continued human presence [34,36,37].

6. Interpretation of the Beeches Pit evidence

Beeches Pit preserves a series of hearths, some separated at two stratigraphic levels, all in similar context near the edge of a pond or water body. In the Beeches Pit type of setting, the attraction seems to have been the availability of fuel on one side, and water on the other, separated perhaps by a band of open strandline. Similar settings by ponds survive in hollows created as kettle holes or by outwash during the last Wurm or Devensian glacial (thousands are present in northwestern England), and they suggest that deadwood was often available in such local positions, partly because of seasonal rises and falls in water levels.

The large tails of burnt material at Beeches Pit, if correctly interpreted, suggest that fires were burnt through prolonged periods, perhaps continuously. If hominids had not yet mastered fire kindling methods, then this would be the only means of sustaining fire, most easily done close to 'tethered' resources as considered by Potts [65].

Modern evidence indicates that in any one area, forest fires are rare, with return times in the range 10–300 years or more [42,45,61,92]. Fires along water courses are rarer again, giving further support to the idea that there was human control when it features in such contexts. Some modern studies of human population distribution in temperate environments, however, indicate a strong preference for settlement along water courses in low lying valleys [92]. At Beeches Pit, the combination of freshwater springs and local raw material source would add to the attraction of the position – factors somewhat similar to those known at Schoningen, Bilzingsleben and elsewhere.

In summary, the local evidence from Beeches Pit, as described by Gowlett et al. [35,37] presents these features, which also seem consistent with other Middle Pleistocene fire occurrences:

- large fires, ca. one metre across;
- repeated fires of long duration;
- high temperatures of burning [64];
- association with bone fragments;
- selected location;
- structured relationship with artefact finds (stone knapping).

These features indicate a carefully organised social setting, not necessarily analogous to any modern pattern of fire use.

7. Discussion: fire and social capability

Climate change, and human interactions with it are the theme of the Colloquium. In the North of Europe, there have been huge climatic changes through the Pleistocene, many times over [43,44,81], and it seems indubitable that these created selection pressures which have played a major part in human evolution, for example in relation to the role of fire.

Major uncertainties nevertheless remain over the nature and significance of the fire record. This paper concentrates on considering and if possible deciding between two hypotheses. Material to these is the fire evidence from Beeches Pit, which is very like that in some Middle Palaeolithic caves, such as Abric Romani [62,93], and much other evidence from other open sites (Fig. 5). It provides a clue that there was an entrenched long-term pattern of fire-use in the Middle Pleistocene, of which we understand only some aspects at present. Why do we not find sites such as Beeches Pit at earlier dates in northern Europe?

Hypothesis 1 is that there were such sites, perhaps from the time of the earliest colonisation (~1 Ma or more?) – and that fire use of this nature is a necessity of human occupation in the north – but that our chance of sampling them is very remote.

Hypothesis 2 is that such fire-use sites indicate a major advance in human social and intellectual capabilities which came only about 400 000 years ago, and which greatly extended human capacity to occupy the North.

To evaluate this restricted issue it seems that in fact we need to examine the earlier long period of potential occupation and fire use, much as Stiner has done for carnivory [84]. As an artificial convenience the phases can be laid out as:

- (a) early period of possible fire use, 1.7–0.5 Ma;
- (b) Middle Pleistocene fire use perhaps not on modern model, ca. 0.5–0.05 Ma;
- (c) Late Pleistocene fire use in varied patterns, ca. 40 000 BP onwards.

The answers are unlikely to come entirely from Europe, bearing in mind that only a handful of earlier fire sites are generally accepted anywhere [94], with Gesher Benot Ya`aqov in Israel offering some of the most suggestive evidence of hearths at a date of ca. 700 000 [30]. Earlier examples in Africa such as Chesowanja at 1.4 million cannot now be ruled out [32], given our knowledge that hominids were already widely dispersed across temperate zones at this stage [24,31].

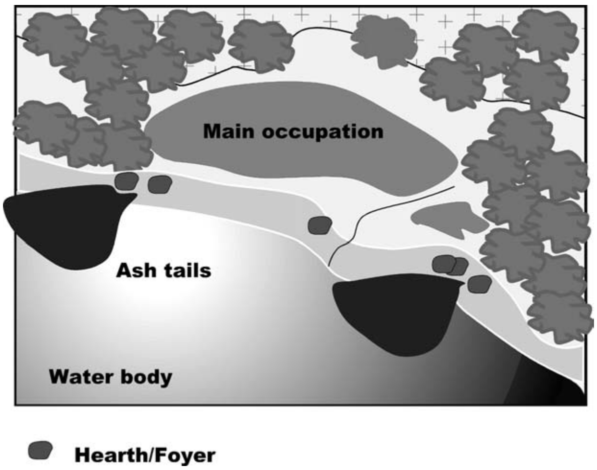

Fig. 5. A model for the pattern of fire use at Beeches Pit, and possibly other Middle Pleistocene open sites.

Fig. 5. Modèle de configuration pour l'utilisation du feu à Beeches Pit, et d'autres sites ouverts possibles du Pléistocène moyen.

On balance, even in a state of great uncertainty there seem to be several reasons for hypothesising some fire use in the north at early periods:

- general dietary models [96,97];
- extent of carnivory [84];
- extent of seasonality [18].

Granted that colonisation is a complex process [10, 18,28], north of latitude 40° even occupation in most favourable conditions requires a developed adaptation geared to bridging a gap of energy budget and resources through the winter months.

The intensity of geological erosion underlined above is a further major issue in assessing chances of preservation, and whether the apparent 400 000-year fire threshold in Europe is a real one. Since there are no major site complexes older than 500 000 (in the sense of Olorgesailie, Isimila or Kilombe in Africa), and since Middle Pleistocene fire appears to have been used only in particular settings which are rarely preserved, the chances of earlier fire evidence being known in the North are extremely small. Although this is negative evidence, it could be said that there is positive evidence for expecting the current position.

Overall these factors appear to argue in favour of Hypothesis 1 – there is early fire evidence elsewhere in the world, which can be linked with hypotheses about fire and dietary change [96,97]; there was massive glacial activity in the North, such that preservation opportunities are very poor in deep time; and the nature of Middle Pleistocene fire use seems to have been so restricted when it does occur, that sampling chances are further reduced.

This analysis appears to argue contra Rolland [77], who postulates a linked first appearance of domestic fire and home-bases at about 400 000. It remains possible, or likely, however, that developments in human ability to control fire had major importance in connection with changes of brain size at 500 000–300 000, which can be seen as one facet of a co-evolution with network size and language evolution [19]. Recent study of auditory canals of *Homo heidelbergensis* from Atapuerca provides suggestive independent evidence that language was present at this time [55].

The social brain hypothesis allows us some independent view of the development of social (and to an extent technical) adaptations. It asserts that the larger brains are linked with larger social network sizes, which impose larger 'managing' loads on the brain [20,22]. The costs of such larger brains may be met, to an extent, by the combination of higher grade diet and a reduced gut [3], which are facilitated through preparation of food by cooking. These factors stress the potential importance of fire in a co-evolution of higher abilities [19]. That importance is reinforced by fire's propensity to provide technical support at times of change and in marginal situations.

To gain a detailed view of changes in brain size from the fossil hominid evidence is difficult in view of the fragmentary finds, but from the evidence of Atapuerca and Ceprano there are grounds for thinking that *Homo* with cranial capacity of c. 1000 cc was already present in Europe ~ 1.0–0.8 Ma, possibly though not certainly the ancestor of *Homo heidelbergensis* [54,85,29]. Overall a doubling in brain size from about 700 cm^3 at 1.7 Ma to 1400 cm^3 at 0.2 Ma is attested, with particularly fast change renewing around 500 000 [1], and not accounted for by change in body size. These changes must have major social significance, but their relationship with fire-evidence is not plain for early periods. The limitation lies mainly in our current inability to devise a convincing developmental model for fire use – to postulate a simple 'proto-fire-use' is rather similar to postulating 'proto-language' and tends to reduce to a declaration of expectation such as 'opportunistic and limited to the most manageable of circumstances'.

The preserved fire evidence does however gives hints of relevant factors, and documentation of these is progressing rapidly. In particular, there is a very strong pattern to the first Middle Pleistocene evidence, as at Beeches Pit (Fig. 6), which may distinguish it from earlier fire use. On initial evidence, the Middle Pleistocene fire pattern in Europe may also be different from that associated with the last 40 000 years. It is characterised by:

- fire only in select contexts – caves and channel banks;
- quite large fires at high temperatures maintained over long periods;
- probability that fuel and animal resources are transported into sites.

Judging by the similarities of various sites, this pattern may have been maintained from the times of *Homo heidelbergensis* through to the Neanderthals.

A tentative hypothesis or scenario to be put here combines several possibilities. First, it suggests that fire use became advantageous at an early date, for reasons of adaptation to climate, and extension of diet, but that perhaps early humans could control it only in particular

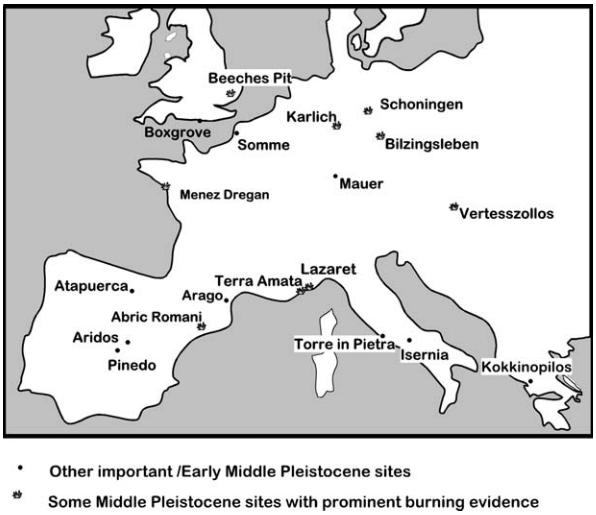

Fig. 6. Beeches Pit and some other Lower/Middle Pleistocene sites in Europe, with evidence of burning.
Fig. 6. Beeches Pit et d'autres sites du Pléistocène inférieur/moyen en Europe, présentant des traces de calcination.

circumstances. This would explain why so many early sites have no fire evidence, including for example Boxgrove. It would explain why so many sites dating *later* than attested fire traces also lack evidence. Support for such a possibility is given by landscape studies on the Somme, which suggest that particular landscape situations were favoured for highly specific activities, sometimes over very long periods of time [91].

In the case of fire, it appears that one favoured setting was the relatively quiet and protected zone of water edges, perhaps particularly where there was a slope down to the water. This is the setting seen at Beeches Pit, and perhaps Schoningen and Bilzingsleben [52,53, 89,90]. The other main setting would be in the differently protected environment of caves and rockshelters, as at the later Abric Romani [62,93], and in many other earlier and later shelters, including Menez Dregan and the Grotte du Lazaret [39,50,59].

Next, a key point in considering the questions of human capability and co-evolution of its facets is the *cost of technology*. It is evident that through the Pleistocene hominids invested heavily in stone technology, gaining in return high rewards at relatively low risk. If kindling had not been mastered, fire would similarly offer benefits in return for a major investment of effort in fuel procurement. In optimum climate conditions, risks would also be low. *In extreme cold conditions, however, fire is quite different from some other technologies: it gives the highest return in circumstances of highest risk: if it should fail, the results are disastrous.*

In Europe, we first see fire in temperate conditions, but this need not mean that a solution to the high risk problem had been found in such conditions. We do know that the problem had been effectively solved by 40 000 BP, as shown by the presence of sites north of the arctic circle in extreme cold conditions [33,63]. It is therefore possible that the type of fire pattern mentioned above was shaped by human response to the major glaciations that occur in Europe from about 700 000 onwards. The pattern probably required some division of labour, both to sustain fires, and to bring in fuel [81]. Greater selective pressures may have led to niche broadening, so that a similar robust pattern could be advantageous both in very cold conditions, and in temperate closed-vegetation conditions, as in OIS11.

In any case, the high investments required by the fire pattern as observed at Beeches Pit suggest the need for a strong local social network of the kind discussed by Gamble [27,28]. The pattern is interpreted here as suggesting that fire could not be kindled. If the interpretation is correct (which is not sure), then once lost, fire could only be replenished by network links, or by gaining fire from lightning strikes. A consequence is that hominids would probably need to bring in fire, both to water-edge sites and cave sites. Darwin appreciated that early humans would be aware of fire from lightning strikes [17]. The possibility sounds happenstance until we consult modern forest management records, which indicate a systematic density of around 3 strikes per square kilometre per year in temperate environments [61,92].

For systematic fire use in such circumstances, a strong social network would be necessary both for sustaining a fire alongside other subsistence activities and for managing the use of fire through replenishment. Arguably it would be in the most extreme conditions that the network would be at a premium, and it is here too that fire could play its most crucial role. Perhaps this would be expressed the most by capacity to survive in marginal environments at very low population densities, a situation which – if present-day hunters and gatherers can be used as a guide – requires fission and fusion of bands across large distances, and in turn brains which are organised to handle such variations in group size [100].

8. Conclusion

In addition to an example providing new evidence of humanly-controlled burning on the Middle Pleistocene site of Beeches Pit, some possible explanations have been given for the patterns of early fire use, and their accordance with current findings in northern Europe.

Standing back from the detail, it seems clear that the earliest hominids to exploit the north still had small brains (600–800 cm^3), and that by half a million years ago they had been succeeded by generally more modern, if still robustly built, humans with larger brains. Such *Homo heidelbergensis* grade hominids were formidable in body strength, but overlap in brain size with fully modern humans, even near the beginning of another phase of rapid brain growth (0.5–0.3 Ma). All these hominids could have benefited from fire in numerous ways, but at present there are no effective means of modelling the nature of earliest fire-use. The selection pressures of early northern environments may have been a greater stimulus towards fire-use than more southerly climes which provide fuller evidence. Fire's scarcity or absence in the early northern record may therefore be the product of erosional factors of which we have positive evidence, and of the apparent restriction of fire use to highly specific locales.

The social brain hypothesis provides a useful parallel framework for modelling, postulating that larger brains are linked with larger social network sizes, which provide ecological and other advantages, but impose heavy 'management' loads. As the costs of the larger brains need to be met, partly through the combination of high grade diet and reduced gut [3], fire clearly enters the equation through its role in cooking (as well as reducing energy loss). Fire-use itself has high costs and sometimes high risks, particularly if means of kindling and replenishment are limited, and thus provides evidence that it repaid such costs. In that context, by the Middle Pleistocene at least, fire can be seen as a particular aid to and component of networking, a kind of lubricant, necessitating a broader logistical framework of supporting knowledge and social links but also establishing social focus both on the small scale (the group around a hearth), and the large scale.

Acknowledgements

Thanks are due to the British Academy for major support of the field project and current support in the Centenary Research Project; AHRB gave support to final fieldwork and processing of finds; also the University of Liverpool, and Forest Entreprise; also to J. and M.-G. Browning; to J. Hallos, R. Preece, D. Bridgland, S. Lewis, S. Parfitt, and N. Debenham, Investigation in the British Palaeolithic has been greatly stimulated by collaborative research such as the English Rivers Project [26,99] and the current AHOB project [86].

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