**Cultural mosaics, social structure and identity: The Acheulean threshold in Europe**

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**Abstract**

The period between 600–400 ka is a critical phase for human evolution in Europe. The south and northwest saw a dramatic increase in sites, the spread of handaxe technology alongside bone and wooden tool manufacture, efficient hunting techniques and the use of fire. Lithic assemblages show considerable variation, including presence/absence of handaxes and tool morphology. To explain this variation we propose the Cultural Mosaic Model, which suggests that there is a range of expressions of the Acheulean, with local resources being instrumental in creating distinct material cultures with or without handaxes. We argue that if typologically and technologically distinct assemblage types are regionally distributed, chronologically separated and persistent over time, then they are unlikely to be caused purely by raw material constraints or functional variation, but rather reflect populations with different material cultures. We initially assess the model using the British data. Britain was a northwestern peninsula of Europe, and oscillations in climate led to episodic occupation. The terraces of the pre-MIS 12 Bytham River provide a framework for dating occupation to MIS 13 and 15, while during MIS 11, archaeological sites with rich environmental records can be dated to sub-stage level. We suggest there are six chronologically and typologically distinct assemblage types that reflect a series of population incursions into Britain. We review the broader European lithic record, which is consistent with the Cultural Mosaic Model. In developing the model, we suggest that during stable climate, localized cultures developed, while climatic change led to shifts in population, with increased knowledge exchange and gene flow. We suggest that group expression through material culture was an important stage in social development, by promoting group cohesion, larger group size, better cooperation, improved knowledge transfer and enabling populations to survive in larger foraging territories in northern Europe.

**Keywords:** Middle Pleistocene; Britain; Material culture; Demography; Handaxes

## 1. Introduction

The last twenty years has seen improved understanding of the earliest human occupation of Europe with the earliest sites in the south dating to over 1.4 Ma (Arzarello et al., 2007; Carbonell et al., 2008; Toro-Moyano et al., 2010; Mosquera et al., 2013), although a shorter chronology after 900 ka has been suggested by Muttoni et al. (2018). There appears to be sporadic occupation of northern Europe from potentially 0.95 Ma at Happisburgh Site 3 and 0.7 Ma at Pakefield (Parfitt et al., 2005, 2010) with these assemblages consisting of relatively simple core and flake working without handaxe technology. The first hints of bifacial tools begin to appear after 1 Ma at La Boella in northeast Spain (Vallverdú et al., 2014) and at Cueva Negra del Estrecho del Río Quípar in southeast Spain (Walker et al., 2020). Whether the few bifacial tools from these sites were one-off innovations or part of a more sustained attempt at introducing this technology is not clear. Better evidence of the establishment of handaxe technology comes during MIS 16 (c. 676–621 ka) from Notarchirico (southern Italy; Lefèvre et al., 2010; Pereira et al., 2015), la Noira (central France; Despriée et al., 2011; Moncel et al., 2013) and Moulin Quignon, Abbeville (northern France; Antoine et al., 2019). There is now good evidence in mainland Britain (henceforth shortened to Britain) for the introduction of bifacial technology from MIS 15, which fits the pattern of a northward expansion of groups with handaxes into northwest Europe between c. 670 and 560 ka.

Britain has a rich archaeological record between Marine Isotope Stage (MIS) 15 and 11 and is an important area for investigating the human occupation of northern Europe and the introduction of handaxe technology during the Middle Pleistocene. Due to cyclical changes in climate, the human presence is probably associated with warmer stages and therefore the history of occupation is of colonization, followed by retreat or local extinction, and recolonization (White and Schreve, 2000; Ashton and Lewis, 2002; Stringer, 2006; Ashton et al., 2011, 2016; Hosfield, 2011). It was likely to have been one of the 'sink' areas with populations arriving from 'source' areas further south (Dennell et al., 2011). This paper reviews the evidence of the typological and technological variation in the lithic assemblages from the principal sites that contribute to this punctuated record of occupation and whether such variation is mirrored by the wider context of mainland Europe.

To help explain the typological and technological variation in the assemblage types at a European level, we propose the 'Cultural Mosaic Model'. The model suggests that material culture develops in response to local environment which, through strong social learning, creates a plethora of small-scale cultural signatures. These signatures are suggested to be delimited in space and time, in part due to disruption caused by cyclical climate change. The model is first evaluated against the British data with two questions: 1. Can assemblage types be recognized that are typologically and technologically distinct? 2. Are the assemblage types discrete in space and time? If persistent, regional signatures can be recognized, then this suggests that functional or raw material considerations play little role in the formation of the assemblage types, and they are likely instead to represent small populations with distinctive material cultures. This leads to the third question of whether localized or regional variation over a few millennia can be identified in mainland Europe. These questions will provide an assessment of the Cultural Mosaic Model, and form the basis of testing in the future.

A characteristic of the British record is the absence of handaxes in some assemblages. Traditionally, the presence of handaxes has been seen as the defining feature of the Acheulean (de Mortillet, 1872; Commont, 1910; Bordes, 1961; Wymer, 1968; Roe, 1981). However, the problem of labelling assemblages without handaxes, which might be due to functional facies, difficult raw materials, inadequate sampling or a genuine cultural signature, has led to questions over the traditional definition. An early recognition of the problem arose in an African context, whereby Developed Oldowan B (DOB) assemblages contained small numbers of handaxes. The response was to define Acheulean assemblages as having a high percentage of handaxes (Kleindienst, 1961; Leakey, 1971). Since then, the chronological overlap between DOB assemblages and those with abundant handaxes has led many researchers to incorporate the DOB under an Acheulean umbrella (e.g., Isaac, 1969; de la Torre, 2016). In a European context similar debates have ensued for the Clactonian in Britain (Ashton and McNabb, 1994; Ashton et al., 1998, 2005; White, 2000), the Colombanien of western France (Monnier and Molines, 1993; Molines et al., 2005; Ravon, 2019; Ravon et al., submitted), or other assemblages in central and eastern Europe that lack handaxes, such as Bilzingsleben, Schöningen, Vértesszőlős and Marathousa 1 (Pasda, 2012; Serangeli and Conard, 2015; Rocca et al., 2016; Tourloukis et al., 2018). As a result, some researchers have suggested either abandoning the term Acheulean (Rocca et al., 2016), or using the term for a technocomplex, with or without handaxes, that shares other technological characteristics, and that in Europe usually dates between c. 700 and 300 ka (Mosquera et al., 2013; Ashton, 2015; Moncel et al., 2015; de la Torre, 2016; Moncel and Ashton, 2018; Davis and Ashton, 2019). It is argued that bifacial technology is sometimes, but not always, one of the more visible elements of a suite of technological and behavioral innovations that mark the appearance of the Acheulean in Europe. For the purposes of this paper, we use this definition to explore the variation in lithic assemblages through this period, to get beyond the bifold division of handaxe and non-handaxe industries.

The shared aspects of the technocomplex in Europe include orthogonal or alternate core working, together with a ubiquitous, but limited range of flake tools (McNabb, 1992; Moncel et al., 2013; Mosquera et al., 2013; Rawlinson et al., submitted). However, there are some components of Lower Paleolithic technology that only rarely survive but suggest much wider distribution (Roebroeks, 2001). Several Italian sites show the use of elephant bone for handaxe manufacture (Zutovski and Barkai, 2016), and the use of bone for other tools is being increasingly recognized elsewhere in Europe (Kretzoi and Dubosi, 1990; Brühl, 2003; Julien et al., 2015; van Kolfschoten et al., 2015; Moigne et al., 2016). Wooden tools survive even more rarely at Clacton and Schöningen, but must reflect much wider use (Warren, 1911; Thieme, 1997; Schoch et al., 2015). Good evidence of fire is often enigmatic, but there is a growing pattern of its rare, but geographically spread, use in western Europe from c. MIS 11 at Terra Amata in southern France, Menez-Dregan in western France, Beeches Pit in eastern England and Gruta da Aroeira in Portugal (Gowlett et al., 2005; Mania, 1995; Preece et al., 2006; Roebroeks and Villa, 2011; de Lumley et al., 2015; Ravon et al., 2016a, b; Sanz et al., 2020). It may well be more widespread, but issues of preservation and the difficulties of distinguishing between natural and anthropogenic use, make recognition difficult. In addition to these technologies, there is indirect evidence of efficient hunting, hide-processing and use for clothing and shelters (Roberts and Parfitt, 1999; Voormolen, 2008; Milks et al., 2016, 2019; Milks, 2018). There is little patterning in this scattered evidence, other than reflecting the underlying technological capabilities of European hominins during the period 600 to 400 ka.

The innovations seem to correspond with the evident increase in the number of sites and probably a more sustained occupation of Europe by at least 500 ka (Roebroeks and van Kolfschoten, 1995; Roebroeks, 2001; Ashton and Lewis, 2012; Mosquera et al., 2013; Hosfield, 2020). The expansion might in part relate to the Mid-Pleistocene Transition (MPT). This saw the change from 41 to 100 ka climatic cycles that provided longer warm periods by 700 ka in which to establish more sustained occupation of northern Europe (Ruddiman et al., 1989; Dennell et al., 2011; Kahlke et al., 2011). But the larger number of sites also corresponds to general increases in hominin brain size that had reached levels of over 1200cc by 500 ka (Rightmire, 2004; Shultz et al., 2012; Hosfield and Cole, 2018; Galway-Witham et al., 2019). It is suggested that increased memory supported larger group sizes, approaching the 'Dunbar number' of c. 150, with an important effect on social structure and relationships (Dunbar, 1992, 1998, 2003; Roebroeks, 2001, 2006; Gamble et al., 2014; Davis and Ashton, 2019).

This brings into focus the role of material culture in the development of early human societies in enabling larger groupings and enhancing cooperation. Research suggests that many nonhuman primate practices depend on learned behaviors, which are culturally transmitted, although they can be easily reinvented and lack persistence over significant lengths of time (Whiten et al., 1999; Hohman and Fruth, 2003; van Schaik et al., 2003; Hopper et al., 2007; Whiten, 2017). In contrast, modern human culture consists of a complex set of practices and beliefs accumulated, adapted and improved over generations, often termed 'cumulative culture' with high-fidelity social learning (Tomasello, 1999; Boyd et al., 2011; Pradhan et al., 2012; Dean et al., 2014; Henrich and Tennie, 2017; Pargeter et al., 2019; Stout et al., 2019). At some phase of our past, technologies progressively became more complex, taking generations to develop, knowledge transfer became increasingly essential for survival, with enlarged social networks providing the best environments for learning (Henrich, 2015; see also Mithen, 1994). Stout et al. (2019) argue that high-fidelity social learning was already a feature of Oldowan stone tool manufacture at 2.5 Ma, which paved the way for the development and maintenance of more complex technology. For Europe from around 500 ka, it can be demonstrated that humans had become top predators, which must have been dependent on intimate knowledge of animal behavior and the landscapes they inhabited, together with cooperative hunting and efficient equipment (Roberts and Parfitt, 1999; Roebroeks, 2001; Milks et al., 2016, 2019; Zutovski and Barkai, 2016). This pool of knowledge, alongside tools and techniques for hide removal, efficient butchery, construction of shelters and the ability to make fire were all cultural practices. For long-term success, they had to be successfully maintained through effective learning processes within a social group, with their complexity reflecting a level of cumulative culture (Henrich, 2015).

Although the various technologies can be demonstrated archaeologically and inferences made about cooperation, learning and social cohesion, it is more difficult to find evidence of how the social structures operated to ensure long-term success. In Britain, an unusual set of circumstances allows us to investigate material culture at a millennial to sub-millennial scale and move discussion beyond the inference stage of understanding group social structures. We present this evidence and then elaborate on how this might be understood within the framework of the Cultural Mosaic Model.

## 2. Materials and methods

### *2.1. Sites*

The main artifact assemblages used in the paper have been analyzed and published over the last 30 years using comparable methodologies. They consist of Brandon Fields, Maidscross Hill (Moncel et al., 2015; Davis et al., 2021), Rampart Field and Warren Hill (Davis et al., 2021), High Lodge (Ashton, 1992; Brumm and McLaren, 2011; Shipton and White, 2020; Davis et al., 2021), Boxgrove (Roberts and Parfitt, 1999; Garcia-Medrano et al., 2019), Hoxne (Singer et al., 1993; Ashton et al., 2008), Barnham (Ashton, 1998; Ashton et al., 2016), Elveden (Ashton et al., 2005), Swanscombe (Conway et al., 1996; White et al., 2019; Garcia Medrano et al., 2020; Shipton and White, 2020;), Clacton (McNabb, 1992, 2007), Greenhithe and Dartford Heath (White et al., 2019).

The assessment of the Cultural Mosaic Model requires the identification of lithic 'Assemblage Types' that can be delimited in space and time. To argue against functional and raw material explanations, the Assemblage Types should be represented by several site assemblages to show regional expression and to persist at a millennial or sub-millennial time-scale.

### *2.2. Artifact analyses*

As some of the assemblages derive from old collections with an overrepresentation of finished tools, the analyses are limited to handaxes and retouched flake tools. The typological analyses for the handaxes in the published papers used the methods of Wymer (1968) and Roe (1968) to divide into basic morphological forms (pointed, sub-cordiform, cordiform and ovate), with the additional recording of hammer mode, cortex retention, tip morphology (e.g., tranchet finish) and butt morphology. In some cases, this basic typological division has been supported by 3D morphometric analyses (Garcia Medrano et al., 2019, 2020; Shipton and White, 2020). Use of the term 'crude' refers to handaxes made by hard hammer with sinuous edges, thick in form and often retaining cortex, particularly at the base. The analyses of flake tools derive from the methods in Ashton (1992), Brumm and McLaren (2011) and Davis et al. (2021).

Several of the collections consist of mixed assemblages, where condition in combination with typology has been critical for disentangling the different elements. The published papers use the methods of Ashton (1998) for recording condition using a four-scale recording of abrasion, patination and staining, with additional recording of 'frost-cracking'. The correlation between typology and condition is particularly important for the three assemblage types identified from the Bytham collections. However, High Lodge provides a cross-check by providing a stratigraphic relationship between two assemblage types and the complete absence of the third.

### *2.3. Chronology*

The dating of the sites and their stratigraphic relationship is critical for identifying the different assemblage types. The primary chronological separation is into those sites that pre-date the Anglian glaciation, attributed to MIS 12 (Bowen, 1999; Lewis, 1999; Preece and Parfitt, 2012), and those that post-date this major event. The tills from this glaciation extend down to the Thames Valley and can be found over much of central and eastern England. In the English Midlands and central East Anglia, terrace remnants of the extinct Bytham River survive, particularly in the Breckland of Suffolk (Rose, 1987, 1994, 2009; Lewis, 1993; Lewis et al., submitted). In the Breckland, the deposits often underlie Anglian till and are identified by their eastward paleoflow directions—in contrast to the post-Anglian westward drainage—and high quartz and quartzite content derived from the Midlands that is distinctive from the local flint. At least four separate aggradations have been recognized and interpreted as terrace remnants. They have been named from the top (oldest) the Seven Hills, Ingham, Knettishall and Timworth terraces. The youngest Bytham sediments are the Warren Hill deposits (at Maidscross Hill lower sequence and Warren Hill), but cannot be classed as a terrace. They are interpreted as a set of deltaic sediments deposited within a pro-glacial lake that formed as a result of the river being blocked downstream by ice during the early Anglian (Lewis et al., submitted). The Warren Hill deposits are the final iteration of the river, prior to its destruction during the Anglian glaciation. As the Timworth aggradation represents the lowest pre-Anglian terrace, it would suggest attribution to MIS 14–13. Although a much younger age (MIS 7–6) has been suggested for the Bytham sites (Gibbard et al. 2009, 2012, 2018), the geological interpretation of a pre-MIS 12 age is now supported by a large ESR dating program on the Bytham terrace deposits (Lewis et al., submitted).

High Lodge is also a Bytham River site, where interglacial floodplain clayey-silts (Beds B and C) have been attributed to MIS 13, based on lithostratigraphy and biostratigraphy (Ashton et al., 1992; Lewis, 1993; Lewis et al., 2019b; although see West et al., 2014, for alternative view). Structures indicate that the clayey-silts have been glacio-tectonized by Anglian ice and shunted as frozen rafts. The overlying silts and sands of Beds D and E show similar deformation and may also date to MIS 13 (Davis et al., 2021; Lewis et al., submitted). The transported sediments are unlikely to have moved far from their original stratigraphic position, the most likely place being above gravels of the Timworth Terrace and therefore post-date this terrace aggradation, which is attributed to MIS 14.

Chronological understanding of the post-Anglian (MIS 11) Paleolithic record is primarily based on a series of sites in East Anglia with lacustrine sediments that formed in kettle-holes above Anglian till. The lake deposits preserve long pollen sequences from the Hoxnian interglacial, sometimes in association with a range of faunal remains and artifacts. The lacustrine sequences at Hoxne and Marks Tey provide the main palynological records for understanding the Hoxnian vegetational succession with the recognition of four main pollen zones, HoI to HoIV and several subzones (West, 1956; Turner, 1970). The Hoxnian has since been attributed to MIS 11c, lasting c. 30,000 years (Ashton et al., 2008; Candy et al. 2014). The association of archaeology with vegetational sequences enables fine-tuned correlation to palynological sub-zones and therefore dating to within a few thousand years or less. The combination of palynology and molluscan biostratigraphy enables further correlation between sites, including those in the Thames Valley. Here, several sites relate to the Boyn Hill-Orsett Heath Terrace that in places lies on Anglian till and is also attributed to MIS 11 (Bridgland, 1994; Schreve, 2001; Penkman et al., 2011; White et al., 2013).

### *2.4. Geography*

The final element in identifying assemblage types is the spatial distribution. Britain naturally forms a 'cul-de-sac' of northwest Europe with clear geographical boundaries and forms a natural region. All the main sites under study occur in East Anglia or south-east England, which further delimits the area. This area shares Cretaceous Chalk as the main bedrock, which results in the widespread availability of flint for artefact manufacture.  For most of the period under study there seems to have been a continuous land-link to mainland Europe (Smith, 1985; Gibbard, 1995; Ashton and Lewis, 2002; Toucanne et al., 2009; Ashton et al., 2011; Hijma et al., 2012). Prior to the Anglian glaciation dry land survived between embayments in the English Channel region and the southern North Sea. After the formation of the Strait of Dover in MIS 12, the land-link was limited to the southern North Sea Basin. Natural routeways into Britain would have been along the Thames Valley or the East Anglian Rivers, naturally forming two regional areas for occupation.

## 3. Results

### *3.1. Pre-Anglian: Bytham River sites*

Sites on the Bytham River survive from Waverley Wood in the west (Shotton et al., 1993; Keen et al., 2006) to Pakefield in the east (Parfitt et al., 2005), but a critical area for understanding the archaeological evidence is in the Breckland on the Suffolk-Norfolk border where several sites lie on a 15 km stretch of the former river (Fig. 1; Lewis, 1998; Davis et al., 2017; Hardaker and Rose, 2020; Davis et al., 2021; Lewis et al., submitted). Small numbers of hard hammer flakes have been found in the Knettishall and Ingham terraces, but the first large collections with handaxes are from the Timworth Terrace (Davis et al., 2021).

Timworth Terrace (MIS 14–13) There are three sites which have been assigned to the Timworth Terrace: Brandon Fields, Maidscross Hill (upper sequence) and Rampart Field. Virtually all the material was recovered in the late 19th century. The earliest collection was by Flower (1869; Evans 1872, 1897) at Brandon Fields and Maidscross Hill who provided a clear description of their recovery from 3 m of quartz-quartzite gravels at the summits of adjacent hills (Davis et al., 2021). Despite large collections being reported from Rampart Field (Evans, 1872, 1897), only a few existing artifacts are clearly marked and attributed with certainty to the site, but there are several artifacts from recent fieldwork, including a scraper and a cordiform handaxe.

The artifacts from Brandon Fields and Maidscross Hill have been analyzed in detail by Davis et al. (2021). The condition, technology and typology suggest that three groups of material can be identified, which have become intermixed at the sites. Numerically the largest, Assemblage Type 1 consists of rolled, crude, narrow handaxes, with low levels of refinement, thick butts and less intensive shaping, often by hard hammer (Figs. 2A–D). Assemblage Type 2 consists of just a few scrapers, which are remarkably similar to those from High Lodge (Fig. 3A; see below). They are made on large hard-hammer flakes with invasive retouch, are slightly to moderately rolled with variable patination. Assemblage Type 3 forms a significant component of the assemblages, consisting of ovate and cordiform handaxes (Figs. 4A, B). They are generally in a similar condition to Assemblage Type 2 material, being less rolled and more patinated than Group 1, and made with a soft hammer. Of significance, those from Brandon Fields are often patinated and frost-cracked. The small assemblage from Rampart Field also seems to have elements of Assemblage Types 1, 2 and 3, including an invasively retouched scraper and a cordiform handaxe recovered from the upper part of the gravels during recent fieldwork (Bridgland et al., 1995; Davis et al., 2021).

High Lodge (MIS 13) There has been extensive collection and fieldwork at High Lodge with the main excavated assemblages recovered in the 1960s (Ashton et al., 1992). There are two main assemblages both in fresh condition. The first from Beds B and C consists of hard-hammer flakes and cores with a distinctive set of flake tools (Ashton, 1992). Of particular note are the finely-made scrapers made on hard-hammer flakes with invasive retouch sometimes along two or more edges (Figs. 3D–E; Brumm and Maclaren, 2011). They are similar to the few scrapers from the Timworth Terrace and Warren Hill (see below), and form the major component of Assemblage Type 2.

The second assemblage from High Lodge is from the overlying Bed E and is markedly different to the assemblage from Beds B and C (Figs. 4E, F). Although there is hard-hammer core and flake working, there are no invasively retouched scrapers. In contrast, there is a series of ovate to cordiform handaxes. They were finished with a soft hammer, occasionally with tranchet sharpening to the tip and sometimes made on flakes. They form an important component of Assemblage Type 3.

Warren Hill (MIS 12) Although there has been both extensive collection and fieldwork at Warren Hill, there have been no large-scale excavations, so the assemblage is predominantly from 19th and early 20th century collection with over 2000 handaxes and smaller series of cores, flakes and flake tools. Detailed study of a sample of the assemblage has been recently undertaken by Davis et al. (2021) and can again be divided into three groups. The largest component is of ovate to cordiform handaxes made with soft-hammer, in slightly to moderately rolled condition and many with characteristic mottled, 'toad belly' patination (Figs. 4C, D). They form a part of Assemblage Type 3. The second component is of more rolled, generally crude handaxes, with thick butts, probably made with a hard-hammer and form a part of Assemblage Type 1 (Figs. 2E, F). In addition, there is a small group of 29 finely-made scrapers with invasive retouch in moderately fresh condition with marked similarity to those from High Lodge and therefore forming a part of Assemblage Type 2 (Figs. 3B, C; Davis et al., 2021).

Interpretation of Bytham Breckland sites Most of the Bytham River collections are clearly mixed, but can be divided into the three typological groups (Table 1). The key to understanding them is the MIS 13 site of High Lodge. Here Assemblage Type 1 is absent, supporting its distinction from Assemblage Types 2 and 3. These latter assemblages occur in stratigraphic order in primary context with Type 2 in Beds B and C, overlain by Type 3 in Bed E. All three assemblage types occur in the MIS 14–13 Timworth terrace sediments and in the MIS 12 Warren Hill deposits, but important differences occur (Davis et al., 2021). First, the Timworth terrace deposits have a significantly higher proportion of Type 1 handaxes and much lower proportions of Type 2 scrapers and Type 3 handaxes compared to Warren Hill. Second, the Type 1 handaxes are more rolled and stained at all these sites compared to Type 2 and 3 assemblages, suggesting a longer taphonomic history and a likely older age. Third, the Type 2 and 3 assemblages in the Timworth terrace have a higher degree of patination and in many cases have frost cracking. Both these attributes are suggestive of sub-aerial exposure, perhaps on the terrace surface.

Therefore, the combination of relative artifact proportions, condition and the important stratigraphic information from High Lodge suggests three chronologically distinct assemblages with the following interpretation. The rolled and stained handaxes of Assemblage Type 1 occur in MIS 14 gravels, and have probably been reworked from MIS 15 or earlier land-surfaces. The less abraded and patinated scrapers and handaxes that are typical of Assemblage Types 2 and 3 appear to have been exposed on a land-surface for at least part of their history, which was probably above the Timworth terrace and likely to date to MIS 13 (Davis et al., 2021). This concurs with the date for the primary context assemblages at High Lodge, where Type 2 lies stratigraphically beneath Type 3.

Finally, Warren Hill is the youngest of the sites and downstream from the Timworth terrace sites of Brandon Fields and Maidscross Hill, and from High Lodge. The co-occurrence of all three assemblage types can be explained through further reworking of Timworth terrace deposits, together with those from High Lodge, at the end of MIS 13 or early in MIS 12, which resulted in all three groups being reworked into the sediments at Warren Hill. The large assemblage from this site may be explained by the sudden fall in water velocity as the Bytham flowed into the pro-glacial lake and dropped its heavier load (Lewis et al., submitted). Of note are 'armored clay balls' in the Warren Hill deposits, which are interpreted as being derived from the High Lodge clayey-silts, 1 km to the north (Lewis et al., submitted). This supports the argument for the derivation of artifacts from High Lodge and other sites to Warren Hill, and for their relative age.

Other Bytham River sites Immediately to the north of the Breckland study area, is Frimstone Pit at Feltwell (Fig. 1). The quarry was still active until recently and a large collection of handaxes was recovered from gravel reject heaps (MacRae, 1999; Hardaker and MacRae, 2000; Hardaker and Rose, 2020). The deposits include both Anglian and pre-Anglian sediments, the latter probably relating to the same gravels as Warren Hill (Lewis et al., submitted). The assemblage requires further study, but includes well-made ovate handaxes, which might relate to Assemblage Type 3.

More is known about the Bytham site of Waverley Wood near Coventry (Fig. 1; Shotton et al., 1993; Keen et al., 2006). Here, a series of channel deposits contain organic remains and have been attributed to MIS 13. The small assemblage of handaxes collected from Waverley Wood includes finely-made ovate handaxes on local erratics of good quality andesite, but also more irregular handaxes made on poor raw materials of flint and quartzite. It would appear that if good quality raw material was available, then ovate handaxes were the preferred form, again perhaps attributable to Assemblage Type 3.

Finally, Happisburgh Site 1, Norfolk, is formed of channel sediments that are part of a north-eastwards flowing drainage, although it is not known whether they relate to the Bytham system (Fig. 1; Lewis et al., 2019a). The sediments have been attributed to MIS 13 and among the in situ assemblage is an ovate handaxe. A number of other handaxes, including ovate forms, have been found in the Happisburgh area as surface finds, but so far, no others can confidently be attributed to in situ sediments (Bynoe et al., 2021). The handaxes would fit with Assemblage Type 3.

Sites contemporary with Bytham sites The only other well-dated pre-Anglian site is Boxgrove in Sussex, which is well-known for its ovate handaxes, finely-made by soft hammer with a tranchet finish across the tip (Fig. 1; Roberts and Parfitt, 1999; Garcia-Medrano et al., 2019). They share similarities in technology and form to the Assemblage Type 3 handaxes from the Breckland sites and also date to late MIS 13 (Shipton and White, 2020).

Elsewhere in southern England there are indications of two higher terrace assemblage types, which are sometimes mixed and perhaps mirror the handaxes of Assemblage Types 1 and 3 of the Breckland (Fig. 1; Roe, 2001; White et al., 2018; Davis et al., submitted). Although the ages of the sites are currently uncertain, they are likely to be Anglian or pre-Anglian in date. Assemblages characterized by crudely-made handaxes, made by hard-hammer include Farnham Terrace A in Surrey and Fordwich in Kent (Roe, 1968; Bridgland et al., 1998; Bridgland and White, 2014; White, 2015). Mixed assemblages can sometimes be separated by condition and form into a generally rolled crudely-made set of handaxes, and a second set with handaxes in fresher condition and usually ovate or cordiform in shape. These assemblages include Corfe Mullen (Roe, 2001; McNabb et al., 2012; Davis, 2013) and Ridge Gravel Pit (Davis, 2013; Davis et al., submitted) in the Solent Basin, where the terrace gravels have been tentatively attributed to MIS 13. The gravels probably include rolled handaxes from higher terraces. Assemblages from the Black Park Terrace in the Middle Thames have a similar mix of handaxes (White et al., 2018). The gravels have been dated to late MIS 12, but the handaxes are almost certainly derived from older sediments.

Summary of pre-Anglian archaeological record The Bytham sites are critical for understanding the British pre-Anglian record from MIS 15 to 13 (Table 2). Three assemblage types have been identified and High Lodge is the key to understanding them through the absence of Type 1 and the stratigraphic relationship of Type 2 underlying Type 3. Furthermore, the relative proportions of assemblage types combined with artifact conditions at Timworth terrace sites and at Warren Hill support a chronological separation between them. Type 1 consists of crude, often elongated, thick handaxes made by hard hammer that probably date to MIS 15. These forms of handaxe occur at a number of sites across southern England and may indicate a wide distribution of Type 1 assemblages. Type 2 is characterized by finely-made, invasive scrapers on hard hammer flakes, as typified by High Lodge, where it dates to MIS 13. There appears to be a limited distribution, with little evidence outside the Breckland. Type 3 consists of ovate and cordiform handaxes made by soft-hammer, dating to MIS 13. There is a wide distribution across southern England. Boxgrove is one of several sites that belong to this assemblage type, dating to late MIS 13, which may also apply to other Type 3 sites. The evidence suggests the introduction of Type 1 assemblages in MIS 15, a probable hiatus in MIS 14, and then the introduction of Type 2, followed quickly by Type 3 in mid to late MIS 13. The time separation and typological distinctions between the three assemblage types strongly suggest different material cultures representative of different cultural groups (see discussion).

### *3.2. MIS 11 sites*

There are six well-dated sites attributed to MIS 11, which can be correlated through palynological and molluscan biostratigraphy. Three main assemblage types can be identified and separated chronologically, and are numbered following the pre-Anglian assemblage types. Assemblage Type 4 occurs in the early part of the Hoxnian Interglacial (MIS 11c) and consists of cores, flake and flake tools, but no handaxes, and has traditionally been termed 'Clactonian'. Type 5 occurs in the middle part of the Hoxnian Interglacial and contains these elements as well as handaxes and may be divisible into Type 5a with ovate handaxes in East Anglia and Type 5b with pointed handaxes in the Thames valley. Type 6 is post-Hoxnian (MIS 11a) in age and is characterized by 'twisted-ovate' handaxes. The sites and assemblages are reviewed below.

<u>Barnham and Elveden</u> Barnham can be correlated with the Hoxnian pollen sequence and is a key archaeological site (Fig. 1; Paterson, 1937; Wymer, 1985; Ashton et al., 1998, 2016). It is situated within a small dry valley, once a minor tributary of the Little Ouse river. Here, a small basin in Anglian glacial deposits is overlain by lacustrine sediments sealed by a paleosol and overlying colluvium. The lacustrine silts and clays show the vegetational sequence of pollen zones HoI and HoII with the formation of the paleosol probably at the HoII/HoIII boundary (Fig. 5). The upper part of the silts and clays are associated with core and flake working, but no evidence of handaxes (Fig. 6, Assemblage Type 4), whereas the paleosol is associated with handaxe manufacture (Fig. 7C, Assemblage Type 5; Ashton et al., 2016). The few handaxes recorded from the site are ovate in form, two of which have twisted profiles (Davis and Ashton, 2019). There is clear burning associated with the paleosol, although it is not yet clear whether this was from human fire-use or natural burning. At Elveden, 7 km to the west, there is a very similar stratigraphic sequence and vegetational record (Figs. 1 and 5; Paterson and Fagg, 1940; Ashton et al., 2005). The assemblage here is associated with, or immediately beneath a paleosol, consisting of a larger series of ovate to cordiform handaxes, about 30% of which have twisted profiles, similar to those from Barnham and attributed to Assemblage Type 5 (Figs. 7A, B; White, 1998a; White et al., 2019). There is no record of an underlying core and flake industry.

<u>Beeches Pit</u> The nearby site of Beeches Pit lies 10 km southwest of Barnham (Fig. 1; Whitaker et al., 1891; Kerney, 1976; Gowlett et al., 2005; Preece et al., 2006, 2007; Voinchet et al., 2015). The sequence abuts a low Chalk bluff with Anglian glacial sediments overlain by spring-fed silts and tufaceous clays. The sequence is correlated with Barnham through the molluscan fauna, in particular the change in dominance from *Discus ruderatus* to *Discus rotundatus* at the HoII/HoIII boundary (Fig. 5; Preece and Penkman, 2005). The artifact assemblage probably dates to this or soon after this boundary and has abundant evidence of handaxe manufacture (Assemblage Type 5). There are only six handaxes in the assemblage, of which four are ovate in form, while two are more irregular bifacial tools. The site also has good evidence of fire-use with a series of hearths associated with burnt artifacts (Gowlett et al., 2005).

<u>Clacton and Swanscombe</u> There are two major sites in the Lower Thames Valley that date to MIS 11—Clacton and Swanscombe—being part of the Boyn Hill/Orsett Heath Terrace formation (Bridgland, 1994; Penkman et al., 2011). At Clacton, a channel of the former Thames is infilled with fluvial 'freshwater

beds' and overlying estuary beds (Figs. 1; Warren, 1912, 1923, 1951; Oakley and Leakey, 1937; Pike and Godwin, 1953; Singer et al., 1973; Bridgland et al., 1999). The archaeological assemblages have been collected and excavated from the fluvial sands and gravels, consisting of cores, flakes and flake tools, but no handaxes (Assemblage Type 4; McNabb, 1992, 2007). The palynology and molluscan biostratigraphy suggest that the upper part of the fluvial sequence correlates with the Hoxnian pollen zones of late HoII or early HoIII, with the lithic assemblages probably assigned to HoIIb-HoIIc (Fig. 5; White et al., 2013) The site is also well-known for the wooden spear found by Hazeldine Warren in 1911 (Warren, 1911; Oakley et al., 1977).

Molluscan biostratigraphy suggests that the freshwater beds at Clacton correlate with Phase I of the Swanscombe sequence (Figs. 1 and 5), which is composed of the Lower Gravel and Lower Loam and contains assemblages of cores and flakes without handaxes (Assemblage Type 4; Smith and Dewey, 1913; Swanscombe Committee, 1938; Ovey, 1964; Bridgland, 1994; Conway et al., 1996). Phase II is composed of the fluvial Middle Gravels, which have been attributed to HoIII and HoIV (Fig. 5). They contain a markedly different assemblage of pointed handaxes, which are often quite small with unworked butts and chronologically are part of Assemblage Type 5 (Figs. 7D, E). Phase III is a complex series of slope and alluvial sediments that may correlate with MIS 11b and 11a (White et al., 2013). Most of the Phase III sediments are devoid of artifacts, other than the Upper Loam, which contains a small assemblage of ovate handaxes, often with a twisted profile, and as they are stratigraphically higher and typologically distinct from the pointed handaxes of the Middle Gravels, have been allocated to Assemblage Type 6 (White et al., 2019). The Upper Loam is argued to correlate with similar deposits above Boyn Hill/Orsett Heath gravels at the nearby sites of Dartford Heath (Wansunt Loam) and Greenhithe (Stoney Loam), both of which also contain twisted ovate handaxes (Figs. 1, 5 and 8; White et al., 1995, 2019; White et al., 2013).

<u>Hoxne</u> The two excavated assemblages from Hoxne post-date the Hoxnian lake beds, coming from overlying fluvial and colluvial sediments, attributed to MIS 11a (Figs. 1 and 5; Frere 1797; Evans et al., 1896; West, 1956; Turner, 1970; Singer et al., 1993; Ashton et al., 2008). The 'Lower Industry' is dominated by the manufacture of handaxes of generally ovate form, while the 'Upper Industry' has several pointed handaxes and a significant component of invasively-flaked scrapers. From the old collections White et al. (2019) record four twisted ovates, although their stratigraphic context is not clear. These might also be attributable to Assemblage Type 6.

<u>Other Hoxnian sites</u> There are two additional East Anglian sites with assemblages probably attributable to Type 5, but recovered in the earlier years of the subject. Foxhall Road, Ipswich, was meticulously excavated by Nina Layard from 1903–1905 (Fig. 1; Layard, 1904, 1906). She recovered an artifact assemblage in primary context from grey clays that includes seven twisted ovates from a small assemblage of 18 handaxes. The remaining 11 handaxes are a variety of forms (White and Plunkett, 2004). Recent reassessment interprets the clays as Hoxnian lake beds above Anglian glacial sediments and unpublished OSL dates of 416 ± 36 ka and 434 ± 54 ka support a Hoxnian attribution (see White et al., 2019). Also potentially belonging to Assemblage Type 5 are the handaxe assemblages from Hitchin, Hertfordshire (Fig. 1). They were collected in the late 19th and early 20th centuries and are in a range of conditions with a mix of both pointed and ovate forms, some with twisted profiles (Shipton and White, 2020). Some seem to have come from lacustrine clays, although most were clearly described as coming from gravel above the clays, beneath 'brickearth' (Reid, 1897; Bloom, 1934). More recent geological and palynological work interprets the site as Hoxnian lake beds above Anglian glacial sediments with attribution of the lake beds to HoI and HoII, and an overlying chara-marl to HoIIc (West 1956; Boreham and Gibbard, 1995). The 'brickearths' have been interpreted as a combination of colluvial, fluvial and aeolian deposits.

In the Thames Valley there are numerous sites and find-spot records of artifacts from gravels of the Orsett Heath/Boyn Hill terrace formation, broadly dating from MIS 12 to 10. One of the two largest assemblages is from Chadwell St Mary, 7 km downstream from Swanscombe, but on the north side of the current Thames valley (Fig. 1). There were several gravel pits, which between them yielded at least 126 handaxes. The majority are in fresh to slightly abraded condition, generally pointed in form and notably similar to those from Swanscombe (Roe, 1968; Wymer, 1985). The other main assemblage in Boyn Hill gravels is 60 km upstream at the adjacent gravel quarries of Cooper's and Deverill's Pits, near East Burnham (Fig. 1; Lacaille, 1939; Wymer 1968). Almost 300 handaxes are recorded, which are predominantly pointed in form. Unfortunately, there is little detail on the precise context of the Chadwell St Mary, or the Burnham assemblages other than fluvial sand and gravel, but they provide a time-averaged reflection of handaxe production in other parts of the Thames Valley, probably during MIS 11 and from their similarity to those from the Middle Gravels at Swanscombe, the majority might be attributable to Assemblage Type 5.

<u>Summary of MIS 11 archaeological record</u> Improved geological and biostratigraphical resolution of the British MIS 11 records allow the recognition of three distinct assemblage types, one of which might be further divided geographically into two regions (Fig. 7; Table 3). The first phase is represented by Assemblage Type 4 lacking handaxes, dating to the first half of the Hoxnian interglacial (MIS 11c, pollen zone HoII). The assemblages include those from Clacton, Swanscombe Lower Gravel and Lower Loam, and Barnham grey silts and clays.

Assemblage Type 5 is represented by several assemblages with handaxes that are attributed to the second part of the Hoxnian interglacial (MIS 11c, pollen zone HoIII). In East Anglia the assemblages are often characterized by ovate handaxes, some with twisted profiles (e.g., Barnham paleosol and Elveden). Beeches Pit can also be attributed to this category, where the small handaxe assemblage is predominantly composed of ovates. These assemblages are termed Type 5a. Some of the assemblages from Hitchin and Foxhall Road possibly fall into this category, but too little is known about their stratigraphic positions within the respective sequences to be clear (Shipton and White, 2020). It is notable that both sites include twisted ovates in their assemblages.

At least one site in the Thames Valley, the assemblages from the Swanscombe Middle Gravels, can also be assigned to Assemblage Type 5. But the handaxes are markedly different from those in the East Anglian sites, being typically small, pointed in form with cortical butts (Shipton and White, 2020). Raw material does not appear to have been a limiting factor as the assemblages also include larger handaxes, which adhere to the same pointed plan-form. The assemblages are termed Type 5b. Other assemblages that might be attributed to this sub-type are the collections from Chadwell St Mary and possibly East Burnham, though both sites have poor age constraints.

Assemblage Type 6 is attributed to MIS 11a, where there are three assemblages that lie in deposits above the Boyn Hill/Orsett terrace gravels, from Swanscombe Upper Loam, Greenhithe Stoney Loam and Dartford Wansunt Loam, which all contain distinctive twisted ovates. The four twisted ovates from Hoxne might also form part of this group of assemblages. It has been suggested that these assemblages indicate some form of cultural continuity with the twisted ovate assemblages in Assemblage Type 5a (White et al., 2019). If this is the case, then it is probable that this form of handaxe manufacture was maintained further south beyond Britain, as it seems unlikely that humans would have survived in Britain during the cold climate of MIS 11b.

### *3.3. Assessment of British Assemblage Types*

Improved resolution of the dating and correlation of British sites, together with reanalysis of the archaeological assemblages suggests that there may be at least six assemblage types with distinctive artifacts that can be separated chronologically from MIS 15 to MIS 11. The typological distinctions are based on: 1. The presence or absence of handaxes; 2. Differences in the morphology of the handaxes; 3. The form of scrapers; and 4. Differences in condition between assemblages. The interpretation of the typological divisions is reliant on the strength of the chronological separation between the assemblages, and whether they can be shown to be persistent over discrete periods of time. If so demonstrated, they are unlikely to be the result of raw materials, function or stochastic variation (cf. Binford, 1972, 1973; Isaac, 1972; Ashton and McNabb, 1994; White, 1998b), but representative of culturally distinct groups.

For the Bytham assemblages, the time distinction between Assemblage Types 1 and 2 is based on the absence of Type 1 at High Lodge, together with differences in condition at Warren Hill, Maidscross Hill and Brandon Fields. At these latter sites, the Type 1 assemblages are more rolled, stained and less patinated than Type 2, and are therefore argued to have had a longer taphonomic history. If they form a coherent assemblage, their minimum age is that of the Timworth Terrace, which is attributed to MIS 14. It is suggested here that they were reworked from MIS 15 land-surfaces, based on the interpretation that MIS 14 would have been too cold for human habitation. As a cold period, MIS 14 seems to have been relatively muted, compared to MIS 16 and MIS 12 (Candy et al., 2015), so the strength of this interpretation will need to be a reassessed in future work. For the moment it remains a reasonable assessment in terms of what is known of human climatic tolerances in the early Middle Pleistocene (Parfitt et al., 2010; Hosfield, 2020).

The stratigraphic relationship between Assemblage Types 2 and 3 can be demonstrated at High Lodge, but the extent of the time separation is less clear. One interpretation might be that the absence of handaxes in Beds B and C was due to a different functional use of the area over a short time span. Of importance is the persistence of the core, flake and scraper industry through the accumulation of the 2-m thickness of these beds without any hint of handaxes or manufacturing flakes. The length of time represented by the 2-m thickness of the clayey-silts is difficult to assess, but must be measurable in centuries, if not millennia. The introduction of handaxes may have been quite rapid without any obvious transitional phase from scraper to handaxe production. In some areas, the surface of Bed C has a series of shallow, silt-filled runnels (Bed D), which refitting shows contain artifacts from Bed C. Both Beds C and D are overlain by the silt and sands of Bed E. Although there is an erosional contact, there is no clear evidence of a major hiatus, but rather a transition to increased waterflow, as initially represented by Bed D and then becoming more persistent in Bed E. The persistence of the Type 2 assemblage followed by the rapid introduction of Type 3 handaxe technology, suggests that the change in material culture did not develop at the site, but instead represents a new population arriving in the region towards the end of MIS 13. The material culture of Type 3 seems to correspond certainly with Boxgrove and possibly other sites in southern and eastern England.

The stratigraphic relationship of Assemblage Types 4, 5 and 6 can be demonstrated at Swanscombe. The 2-m thick Lower Gravels and 1 m of Lower Loam both contain Type 4. Importantly, the Lower Gravels provide a time-averaged assemblage, which reflects persistent activity in the area in the earlier part of MIS 11c, and this continues into the primary context Lower Loam. The overlying Middle Gravels with a thickness of over 2 m, also provide a time-averaged assemblage, but this time with handaxes of Type 5 during the middle part of MIS 11c. Although there could be a short erosional hiatus between the Lower Loam and the Middle Gravels, the introduction of handaxe technology appears to be rapid, without any intervening phases. The time interval between Type 4 and Type 5 is also brief between the in situ assemblages at Barnham. Both Swanscombe and Barnham can be correlated through biostratigraphy with Clacton, Elveden and Beeches Pit, which supports the time relationship between the assemblages and patterns on a regional scale (Fig. 5). The rapid turnover in material culture is most easily explained as a new population arriving in Britain during the middle part of MIS 11c. The possible regional differences between the Type 5 assemblages, might suggest more than one population arrival, but this is discussed further below.

The Type 6 assemblages with twisted ovate handaxes date to MIS 11a with a clear time separation with the preceding MIS 11c. Twisted ovates also occur in some of the Type 5 assemblages during MIS 11c in East Anglia, but it is not clear whether this shows continuity in occupation through the relatively cold period of MIS 11b, or whether there was a retreat further south and then repopulation by the same group in MIS 11a (see White et al., 2019 for full discussion).

On the basis of the chronological patterning, it is suggested that Assemblage Types 1 to 6 represent a succession of phases of occupation of Britain by groups with different material cultures and fulfills the expectations of the Cultural Mosaic Model. There is little evidence of in situ development in the lithic assemblages, and therefore it is argued that the assemblages reflect groups that entered Britain from mainland Europe. To understand more fully the British sequence of repopulation events it is necessary to understand the nature of the European record and whether the Cultural Mosaic Model might be applicable on a European scale. This is assessed in the discussion below.

## 4. Discussion

### 4.1. *European record*

The British assemblages show a series of discrete assemblage types, some with varied forms of handaxe or flake tools, or marked by the absence of any bifacial technology. There is no real pattern in typological or technological development, other than the somewhat crude handaxes that seem to characterize MIS 15. This section briefly reviews whether there are clearer large-scale patterns in the record for mainland Europe, or whether there is similar regional variation in the lithic assemblages through this period.

Moving from the regional to the continental scale immediately throws up the problem of correlation between sites over much larger geographical areas, often with different geological frameworks and a variety of dating methods. Long sequences in several cave sites, help to show variation in a single location, while a more regional picture has been constructed for some areas. Papers by Moncel et al. (2015), Rocca et al. (2016), Villa et al. (2016), and Davis and Ashton (2019) provide useful reviews of the major sites, which are summarized in Table 4. There seem to be some overarching patterns, such as the first persistent appearance of handaxe assemblages being from c. 700 to 600 ka at la Noira and Moulin Quignon in France, and Notarchirico in Italy (Moncel et al., 2013, 2020; Pereira et al., 2015; Antoine et al., 2019). Of note is the soft-hammer use for handaxe manufacture at la Noira in early MIS 16, in contrast to Moulin Quignon and Notarchirico with a similar age, or the MIS 15 (Type 1) assemblages in Britain, where the handaxes were made by hard-hammer and relatively crude. There is no clear development in the improvement of handaxe manufacture at these early sites, and it is clear from this and later evidence, that crude forms do not provide an indication of age (White, 1998b; de Lumley et al., 2015; Ravon et al., 2019, submitted).

A further pattern is the comparatively late occupation of north-eastern Europe from MIS 11 and the apparent absence of handaxes in these regions, such as at Bilzingsleben and Schöningen in Germany which were dependent on glacially derived Baltic flint (Rocca et al., 2016). The lack of biface technology is almost certainly due to poor quality raw materials in these north-eastern areas. Elsewhere the absence or low numbers of handaxes can also at times be attributed to poor raw materials, such as the MIS 11 site of Terra Amata, in southern France (de Lumley et al., 2015), or through the long MS 12-8 sequence at Menez-Dregan in western France (Monnier et al., 1996; Ravon et al., 2016a, b, submitted). However, raw materials are not the only explanation; at Caune de l'Arago in southern France the different archaeological levels show marked variation from MIS 14 to 12. The most obvious difference is the presence or absence of handaxes, but there is also variation in the morphology of handaxes when present and scrapers between levels (de Lumley and Barsky, 2004; Barsky and de Lumley, 2010; Barsky, 2013).

There is similar variation in the sequence at Notarchirico in Italy with alternation in levels with the presence or absence of handaxes, dating to MIS 16 (Lefèvre et al., 2010; Pereira et al., 2015; Moncel et al., 2020). By contrast the MIS 12 site of Fontana Ranuccio, southeast of Rome, contains a small assemblage of handaxes, but two of which were made on elephant bone (Boschian and Saccà, 2015; Zutovski and Barkai, 2016). To the northwest of Rome, along the via Aurelia, within a small region there is marked variation in the lithic assemblages (Villa et al., 2016). The lower level at Torre in Pietra, attributed to MIS 10 (Anzidei and Bulgarelli, 2015), contains handaxes of varied form mainly made of limestone, while the MIS 9 site of Castel di Guido also has handaxes, but manufactured on elephant bone (Boschian and Saccà, 2015; Zutovski and Barkai, 2016). The neighboring site of La Polledrara di Cecanibbio is also dated to MIS 9, but by contrast has no handaxes, just simple retouched flakes with several bone tools (Milli and Palombo, 2005; Pereira et al., 2017). In this region, there appears to a fragmentation of the archaeological signatures with little clear patterning in time or space.

In the Iberian Peninsula, the various assemblages from the Atapuerca sites illustrate the variation within one locale that date from MIS 12 to 7 (Gran Dolina, TD10, and Galeria, GII and GIII; Mosquera et al., 2013; Ollé et al., 2013, 2016; Demuro et al., 2014; García-Medrano et al., 2014, 2015). Much of the variation between the different caves is attributed to site function, with varying quantities of handaxes and flake tools on a variety of raw materials. There is also a shift towards Middle Paleolithic technologies from MIS 9, as shown in TD10.

The European lithic record from the main sites shows widespread typological and technological variation with no clear patterning either geographically or through time. The evidence does however conform to the expectations of the Cultural Mosaic Model with small-scale variation in the record, with at least some variation attributable to the specific circumstances of the sites. Importantly, large-scale patterns in time and space are difficult to identify through the period.

### *4.2. Developing the Cultural Mosaic Model*

The evidence from Britain and possibly from the rest of Europe conforms, at least, to the expectations of the 'Cultural Mosaic Model' (Fig. 9; Ashton, 2018; Davis and Ashton, 2019). To expand on the basic model, it proposes that much of the variation in material culture reflects localized situations, where social groups in stable environments became habituated within limited territories and sets of resources. The resources—lithic raw materials in the case of stone tools—influenced the development of material culture and behavior, which over several generations and effective knowledge transfer became embedded within the social group, leading to niche construction and enculturation of a territory (Laland and O'Brien, 2010). Fueling the mosaic could have been the human propensity for conformity (Claidière and Whiten, 2012; Shipton and White, 2020). The dual processes of informational conformity, whereby a visibly successful practice was followed, and normative conformity, where social pressures or rules encouraged particular behaviors, could have led to distinct cultural groups. An important effect of normative conformity is that an increase in group size leads to intra-group homogeneity and inter-group diversity (Claidière and Whiten, 2012). Across Middle Pleistocene Europe, the expectation would be a mosaic of cultural variation dependent on social group size, territory size and interaction between groups (Fig. 9).

Interaction could have been dependent on numerous factors, but might arguably have increased during times of environmental change when groups are likely to have enlarged foraging areas or moved territories in response to shifts in vegetation and other resources. Increased interaction could have benefitted the maintenance of existing technologies through group social pressures (see discussion of normative behavior below), but also improved the chances of successful establishment of innovative methods and ideas (Nowell and White, 2010). The biggest triggers for environmental change were the episodic shifts in climate through this period, particularly the glacial extremes, when large areas of northern Europe are likely to have been uninhabitable. Large population movements, extinctions and repopulation events—the sinks and sources of Dennell et al. (2011)—could have helped to maintain the underlying knowledge base, which included production of efficient stone, bone and wooden tools, effective food procurement, and possibly hide-working, clothing and shelter production, and fire-use.

While support for the model requires further investigation and testing, it does provide a framework in which to understand the variation in tool form, which accommodates local factors in influencing outcomes, but also a system for understanding how knowledge is transferred at the generational, millennial and larger time scales. There is also support from recent research of the hominin record, where the traditional bifold division into *Homo heidelbergensis* and *H. neanderthalensis* has been viewed by some researchers as difficult to sustain (Dennell et al., 2011; Stringer, 2011, 2012; Arsuarga et al., 2014; Manzi, 2016; Daura et al., 2017; Galway-Witham et al., 2019).

An important interpretation put forward by Dennell et al. (2011) to understand the European hominin record uses the concept of demes, denoting geographic, interbreeding subdivisions of a species (see also Howell, 1999). This approach fits well with the Cultural Mosaic Model. The latter would suggest that stable populations would have reduced gene-flow between groups and so enhancing selection for traits that benefit adaptation to a particular environment, or environmental evolution. This process could have been enhanced through cultural evolution where specific cultural systems can have an important impact on selection (Henrich, 2015). For Middle Pleistocene Europe, this could have involved diet and food processing methods with selection of beneficial enzymes or selection for physical traits that benefited food acquisition, such as hunting techniques. The expectation would be that the dual processes of environmental and cultural evolution could have led over millennial time periods to distinct variations (or demes) in the hominin populations of Europe.

### *4.3. British population dynamics*

Britain provides an unusual circumstance for exploring the model. As a ‘cul-de-sac’ of Europe, it was probably a ‘sink’ region for population with frequent occupation, extinction or abandonment (Dennell et al., 2011). Although there was a permanent link to mainland Europe through this period, the land-bridge would have been less than 300 km across during MIS 13, or considerably less during MIS 11. On a European scale, this would have diminished the chances of populations entering Britain. If large enough populations arrived then they likely could have thrived during warm, stable conditions, but any cooling or environmental change would have put the populations under stress, particularly with reduced contact with neighboring groups in mainland Europe. The effect may have resulted in relatively short-term visits prior to abandonment or extinction, a circumstance that would have been considerably exacerbated during cold climate.

The advantage of what we argue to be a punctuated record is the opportunity to recognize individual population incursions that can be defined by a distinctive material culture. For MIS 11 they can be recognized as incursions of a few thousand years or potentially much less. The same may be true for the pre-MIS 12 record. Therefore, in Britain we may have individual 'snapshots' of the much larger 'photomontage' of Europe with the potential to understand the dynamics of population movement in relation to environmental change. As Britain was a peninsula with a relatively narrow isthmus, it also provides the opportunity to examine group dynamics and population densities within clearly defined limits.

Little can be said for the pre-MIS 12 record, other than both Assemblage Types 2 and 3 were associated with interglacial environments. At High Lodge there was probably little time gap between groups with Type 2 assemblages and the arrival of groups with Type 3, which with the evidence from Boxgrove seems to have been towards the end of the interglacial. It is not clear what triggered the arrival of either group. The considerably wider distribution of Assemblage Type 3 might suggest a more successful and sustained occupation.

More can be suggested for the MIS 11 record. The arrival of a population with the Type 4 assemblage can be understood in the context of climate warming towards the beginning of the interglacial and an expansion of European populations. The groups represented by Type 5 assemblages seem to have arrived at the HoII/HoIII boundary. It has been suggested that this might correspond with the non-arboreal pollen phase (Ashton et al., 2016), which seems to have been a rapid, widespread deforestation event recognized across northern Europe (Diehl and Sirocko, 2007; Candy et al., 2014). Whether the cause was volcanic eruption or meteor strikes as has been suggested (Candy et al., 2014), such an environmental catastrophe would inevitably have led to population instability and movement, with one possible effect being the arrival of new populations in Britain. There is no evidence for populations in MIS 11b in Britain, but there seems to be the arrival of groups with Assemblage Type 6 as climate warmed in MIS 11a. As indicated above, White et al. (2019) have suggested a cultural connection between populations with Types 5a and 6, perhaps with a retreat out of Britain during MIS 11b.

The most intriguing pattern is of Assemblage Types 5a and 5b, distributed in East Anglia and the Thames Valley respectively, representing groups that are contemporary as far as the resolution of the pollen record allows. It has been suggested that they could reflect group territories (Davis and Ashton, 2019; White et al., 2019; Shipton and White, 2020). Biological parameters for likely territory size can be deduced from ethnographic literature on recent foragers in similar environments. Limits on population density are largely determined by the biological productivity of the area and the technological ability to convert biomass into edible food. On the assumption that recent foragers are more efficient at converting biomass into edible foods, then they should provide an upper limit to population density in any specific biome. Trying to find recent or historically recorded foragers in biomes that are analogous to southern Britain is difficult, though two groups recorded by Binford (2001) in southwestern British Colombia occupy quite similar climatic and vegetational zones—the Nlaka'pamux and Ulkatcho peoples (formerly Thompson and Alkatcho groups, respectively). They traditionally lived in largely forested landscapes and hunted large, medium and small mammals, as well as fish. Binford gives their population densities as 7.5 and 33 people /100 $km^2$, respectively. Using Wobst's (1974) estimate of a biologically viable population of 175 people (an interbreeding population of several subgroups), these groups would require areas of 2333 $km^2$ and 530 $km^2$, respectively. For comparison, the sites in central East Anglia encompass an area of approximately 2500 $km^2$, while a 20 km wide swathe along the 65 km between sites in the Thames Valley encompasses 1300 $km^2$. Acknowledging all the problems of ethnographic analogy, these figures still illustrate that the East Anglian sites and those in the Thames Valley provide reasonable territories for groups of 175 modern foragers, and could be realistic for Middle Pleistocene hunter-gatherers.

The only other evidence of territory size can be derived from raw material studies with the import of exotic rocks. With the ubiquitous availability of Cretaceous flint over large parts of southern and eastern England, examples in Britain are few; at Waverley Wood flint handaxes were brought over 60 km from East Anglia into the Midlands in MIS 13 (Keen et al., 2006), while at Wolvercote during MIS 9 flint was brought from c. 25 km away from the Chilterns (Ashton, 2001). In France at Caune de l'Arago raw material was brought in from over 30 km between MIS 14 to 12 (Barsky, 2013), while at Menez-Dregan 'glossy sandstone' was consistently transported 20 km from MIS 11 through to MIS 9 (Ravon, 2017, 2018). At Ambrona in Spain, flint was also brought in from 20 km away during MIS 11 (Santonja et al., 2018). The overall similarity of the distances seems to reflect quite localized territories of perhaps 30 km radius and generally fits with the interpretation of the East Anglian and Thames Valley groups.

### *4.4. Material culture, society and adaptation to northern latitudes*

There has been much discussion of hominin adaptation to northern environments involving their technological ability to cope with long, cold winters through thermal buffering and improved hunting, seasonality or physical adaptation (Roebroeks, 2001, 2006; Parfitt et al., 2010; Dennell et al., 2011; Ashton and Lewis, 2012; Ashton, 2015; Hosfield, 2016, 2020). While the social structure of groups has been recognized as important (Gamble, 1996, 1999; Roebroeks, 2001, 2006; Gamble et al., 2014) and the introduction of handaxes has been suggested to reflect 'behavioral plasticity' (Hosfield and Cole, 2018), there have still been problems in finding archaeological data that can test the theoretical requirements of maintaining effective social networks and territories in northerly environments.

As a generalization, in more northerly environments mammalian territory sizes increase, resources become more segregated and consequently human forager territories increase with more reliance on hunting (Kelley, 1995; Roebroeks, 2001, 2006; Hosfield, 2016). Other interrelated factors will also play a role, such as precipitation, dominant vegetation (deciduous/coniferous woodland, grasslands, wetlands or ecotonal environments), seasonal variation, terrain and altitude (Hosfield, 2020). But overall, more northerly latitudes have less biomass that can be converted to food and therefore sustain human populations at lower densities. Ecotonal environments, such as river valleys, lakes and coasts, provide a greater range of resources and therefore reduce territory size (Ashton et al., 2006; Hosfield, 2016, 2020).

For Middle Pleistocene hunter-gatherers, operating over extended territories could have been a challenge. It can be seen as a balance between maintaining a viable population, but having the technological abilities to exploit food resources over territories within which social networks were still effective. The starting point is the minimum biologically viable population of about 175 people (Wobst, 1974). This also corresponds approximately with the Dunbar Number (1998) of 150 people, which is the average number of social relationships that can be effectively maintained with modern humans. As the number of social relationships seems to directly correlate with brain size, it is argued that late Middle Pleistocene populations would have been able to maintain a similar number of relationships (Roebroeks, 2001; Dunbar, 2003; Gamble et al., 2014). The effective limit for Middle Pleistocene hunter-gatherers was where social ties were on the verge of breaking down over extended distances. The segregation of resources in increasingly northern latitudes would therefore have been a real boundary to sustainable occupation.

So how strong were the social bonds and networks of Middle Pleistocene hominins? As suggested above, there is good evidence for hunting and exploitation of medium to large-sized mammals for example, horse at Boxgrove, bison at Atapuerca TD10.2, and elephant at Ambrona and Guado St Nicola (Roberts and Parfitt, 1999; Peretto et al., 2016; Zutovski and Barkai, 2016; Rodríguez-Hidalgoa et al., 2017; Santonja et al., 2018). Given the skills involved, a requisite for success must have involved cooperation, communication and probably language (Frison, 1998; Roebroeks, 2001). This is reinforced by the ethnographic record where large game hunting corresponds with larger group cooperation (Kelly, 1995). Furthermore, it has been suggested that with large mammal predation, meat-sharing would reduce the risk of famine or feast and be an evolutionary advantage (Winterhalder and Smith, 2000). As expressed by Roebroeks: "Hunting made food sharing necessary, while food sharing made hunting feasible" (2001: 450).

Hunting, efficient food processing, tool manufacture and many other technologies would make high-fidelity learning and knowledge transfer essential for future survival. Evident changes in the life history of hominins with shortened infancies, longer childhood and juvenile stages, and extended life after the menopause, would have benefited learning processes (Bogin and Smith, 1996; Rosas et al., 1999; Bermúdez de Castro et al., 2003; Krovitz et al., 2003; Nowell and White, 2010; Hosfield and Cole, 2018). The longer childhood and juvenile stages would have provided additional time for learning more complex technological and social skills. Although younger weaning would have led to shorter intervals between births, it would have been balanced by the availability of older siblings and grandparents to help with child-rearing. These more complex relationships are reflected by evidence of care and support for disabled young and elderly from Atapuerca (Gracia et al., 2009; Bonmati et al., 2010).

Henrich (2004) has also argued that larger group sizes would reduce the risk of imperfect learning, particularly of complex processes. Effective knowledge transfer becomes an imperative where techniques have evolved to the point of being 'cumulative culture', when the reasons for processes are beyond the knowledge of individuals or groups, but part of the tradition of the group (Henrich, 2015). It would seem that the level of technology that is demonstrable at least by 500 ka, and probably earlier, required socially connected groups for a number of reasons, which included breeding, cooperative hunting, meat-sharing and effective systems of knowledge transfer through high fidelity learning. The evidence from Britain in MIS 11c provides a glimpse of how culturally distinct groups might have operated within broadly defined territories and if correctly interpreted is the first archaeological evidence to support the more theoretical models of group sizes within the range of 150–200 people.

The two British assemblage types in East Anglia and the Thames Valley have been recognized because of their distinctive material cultures, expressed through handaxes. Finding these differences in handaxe technology and morphology is highly useful for archaeologists, but is there a much deeper importance to the expression of difference? There has been extensive debate about the social, rather than functional, implications of handaxes and the additional meanings that they acquired as longer-term possessions of either individuals or groups in the negotiation of relationships (Gamble, 1999; Kohn and Mithen, 1999; Pope and Roberts, 2005; Porr, 2005; Machin et al., 2007; Spikins, 2012; Ashton, 2015). At the group level they would have been one of the many elements of material culture that provided identity, reinforced through conformity and successful knowledge transfer over generations. Detailed study of the Boxgrove assemblage shows high fidelity imitation over a few generations, where despite raw material breakage, the plan-form was still retained (Garcia-Medrano et al., 2019). Other elements of material culture are far less durable, but objects of wood or bone could have also fulfilled this role, as well as purely visual displays of group identity and possibly language (Porr, 2005; McNabb, 2012; Ashton, 2015).

We therefore propose that by 500 ka social cohesion in human populations had developed through the agency of material culture to a critical turning point, whereby culturally distinctive objects provided a means to identify with others in the group. Together with language and less visible social practices, material culture provided bonds that were critical for group cohesion. The stronger the bonds, the more resilient the group and the better able to extend territories. It was therefore distinctions in culture, visible though material culture, that was a critical element for enabling foraging groups to expand successfully into northern Europe with more dispersed resources and larger territories from c. 500 ka. Strong social cohesion ensured effective systems of knowledge transfer, strong cooperation for food acquisition and sharing, as well as sustainable breeding (Fig. 10).

## 5. Conclusions: cultural mosaics and the Acheulean package in Europe

The archaeological evidence shows an expansion of populations in Europe from c. 500 ka and possibly earlier. The expansion is often associated with a range of technologies from efficient hunting, possible hide-working, fire-use and more elaborate tools made with wood, bone and stone. Variation in the lithic record suggests that small-scale cultural groups were creating distinctive material cultures that were successfully transferred through generations to create cultural traditions at a local scale. The local scale may also be reflected in the demes suggested by Dennell et al. (2011) in the hominin record. But knowledge transfer and probably gene-exchange also operated on a broader scale, primarily driven by periodic changes in environment and climate with population expansion and possibly retreat. While this enabled the maintenance of a common foundation of technological expertise and knowledge, it also fragmented the smaller scale cultural traditions that we get glimpses of in the archaeological record.

The timing of the more sustained occupation of Europe, particularly the north, can be seen as a series of interconnected circumstances. The MPT had set the scene by 700 ka with the increase in the duration and temperature extremes in the oscillations of the climate record. It had the effect of longer periods of warm stable climate, allowing more sustained occupation of the north, but also increased disruption during cold periods, encouraging maintenance and transmission of ideas and increased gene flow (Dennell et al., 2011). In addition, by 500 ka hominin brain size had approached modern levels with an expansion in the neocortex and enabling the effective maintenance of larger social groups. At the same time, we can see the development of distinctive material cultures that acted as social cement, improving cohesion within groups as a demonstration of kinship and maintenance of a breeding population. The strengthened social bonds enabled expansion of territory sizes and therefore more resilient occupation of northern latitudes. In our view, the Acheulean package or techno-complex, was underpinned by the enabling force of social cohesion, for which distinctive, small-scale material cultures played a critical role. We suggest that the Cultural Mosaic Model provides a framework for interpreting the variation in lithic assemblages and a structure for understanding the underlying social systems in Middle Pleistocene Europe. Future testing of the model depends on refined chronologies elsewhere in Europe where distinctive typological signatures can be isolated in space and time, but shown to be persistent within a region.

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## Figure legends

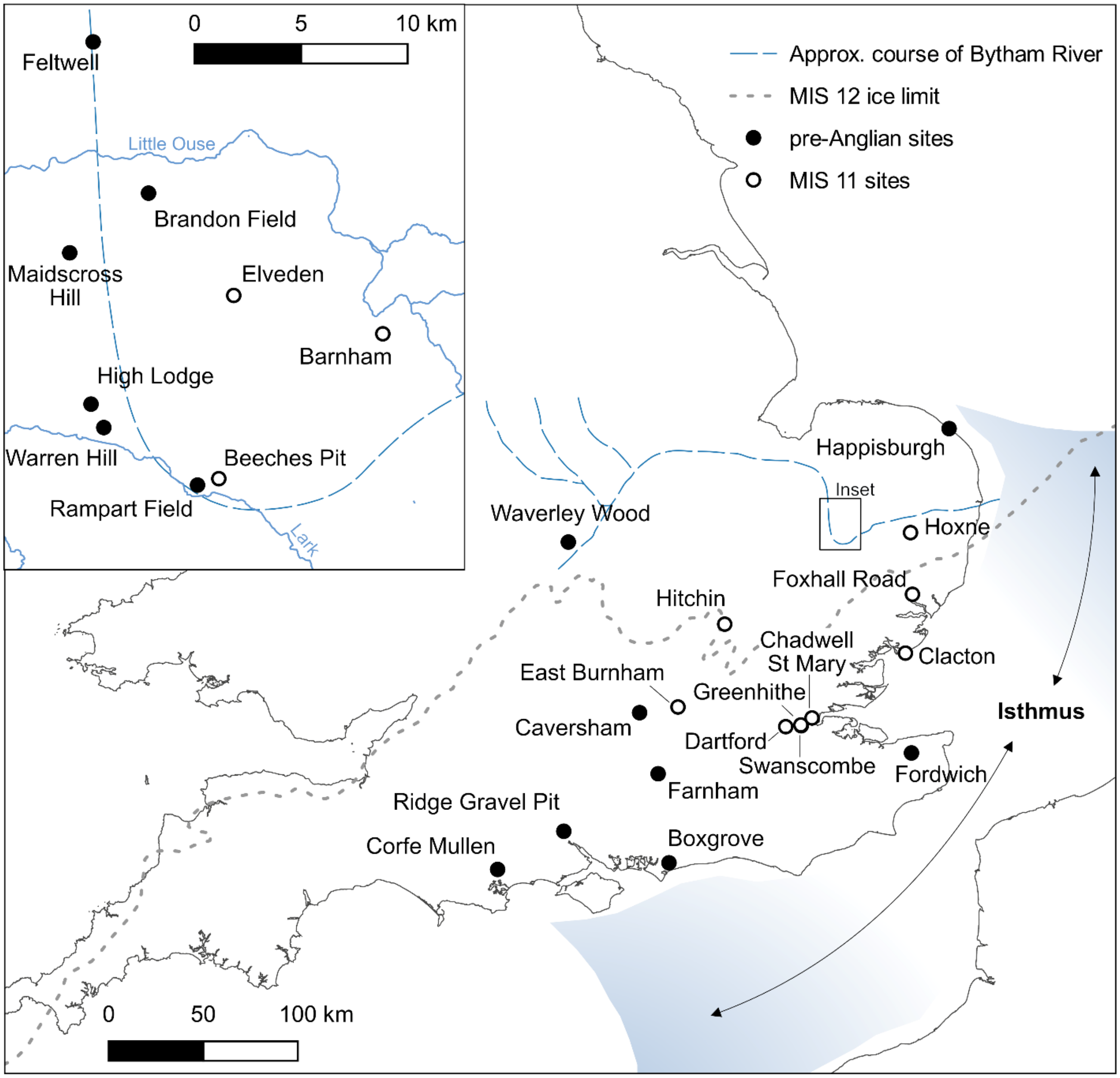


**Figure 1**. Map of southern Britain showing British sites discussed in this paper.

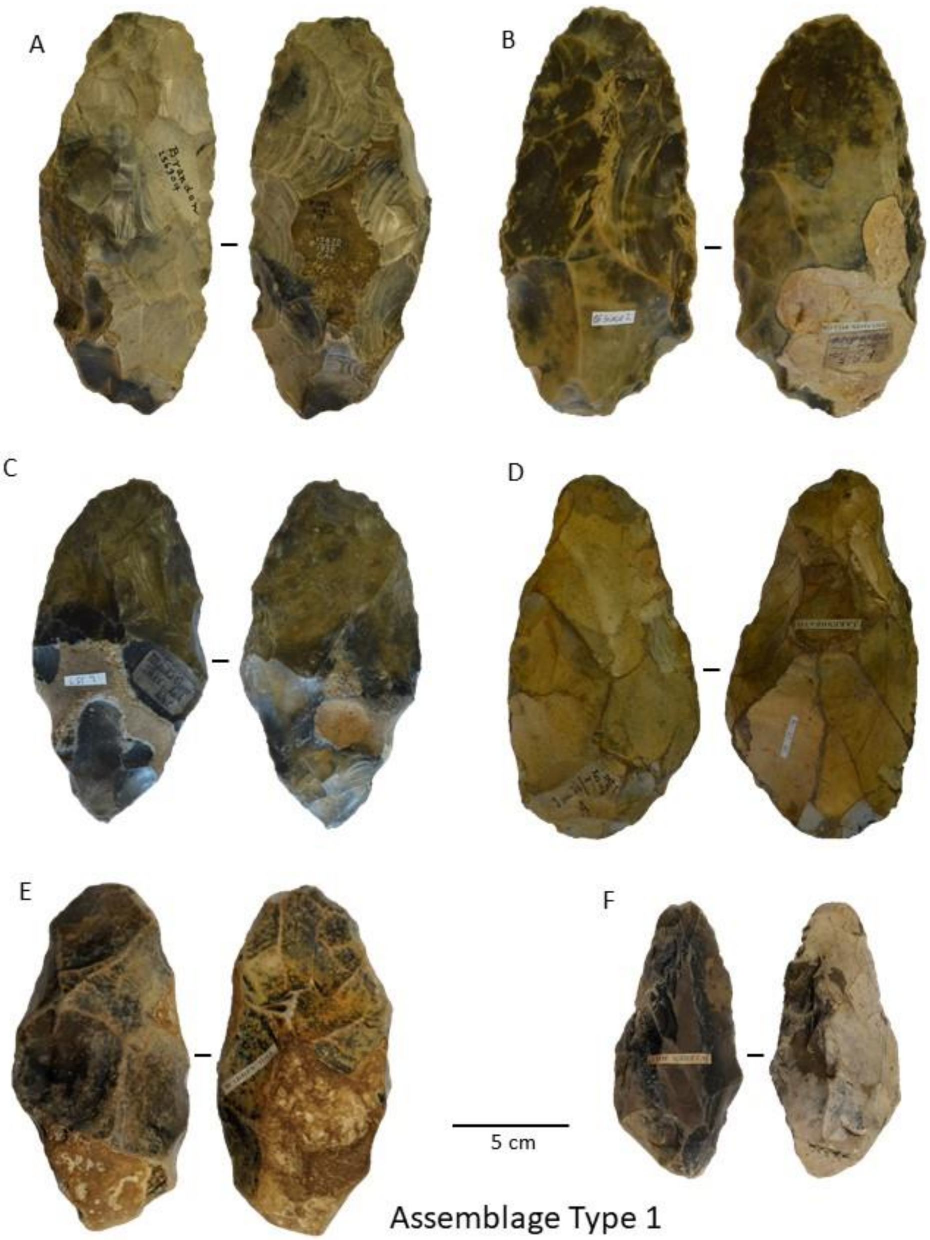


**Figure** 2. Assemblage Type 1 handaxes. A–B) Brandon Fields. C–D) Maidscross Hill. E–F) Warren Hill.


**Figure 3**. Assemblage Type 2 scrapers. A) Maidscross Hill. B–C) Warren Hill. D–E) High Lodge.

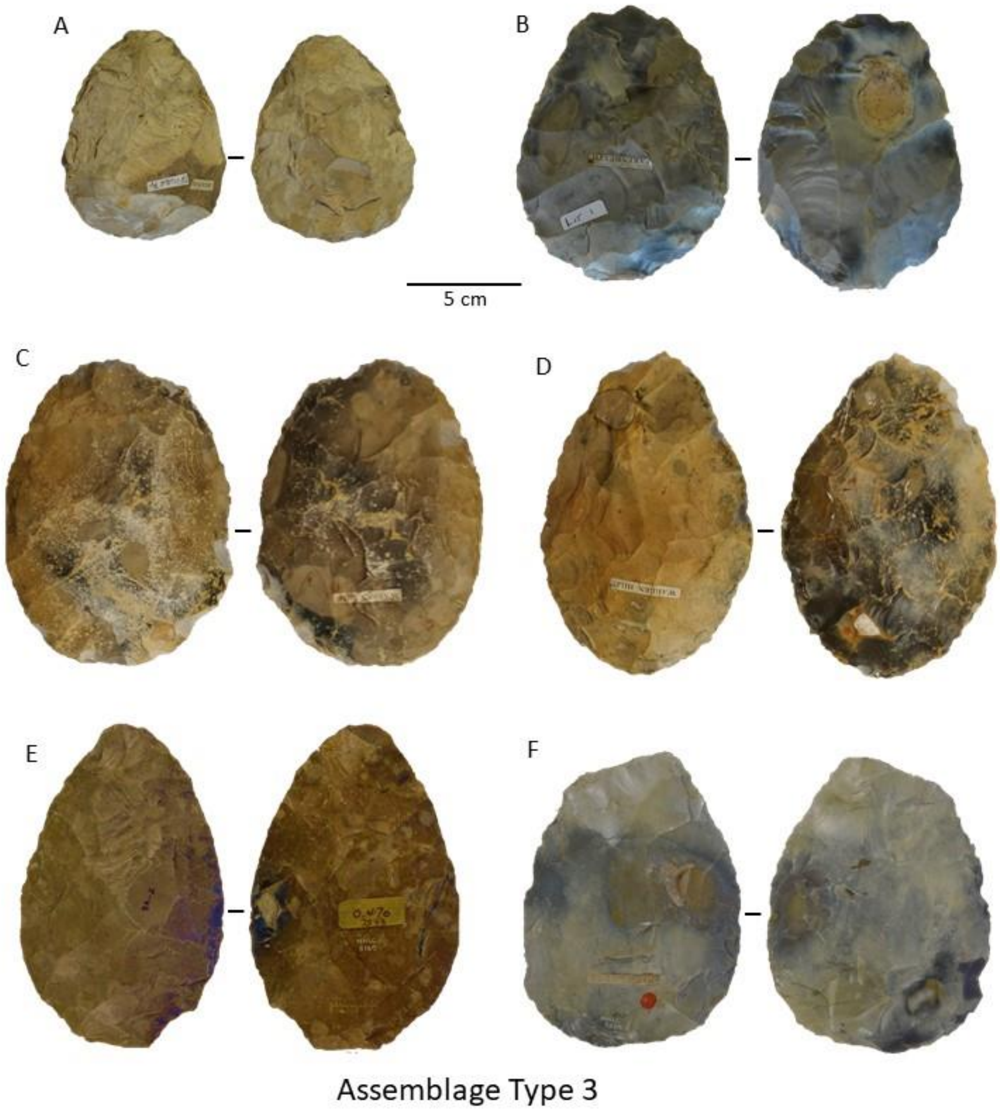


**Figure 4**. Assemblage Type 3 handaxes. A) Brandon Fields. B) Maidscross Hill. C–D) Warren Hill. E–F) High Lodge.

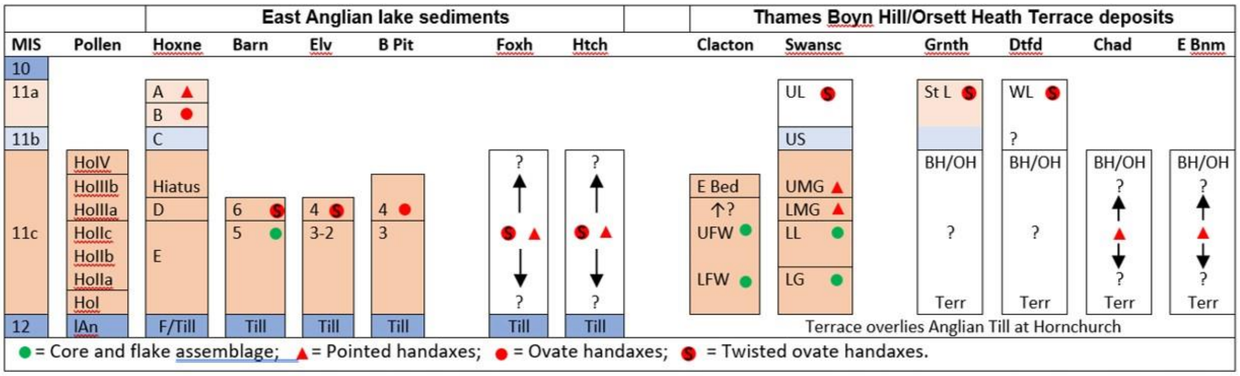


**Figure 5**. Suggested correlation of British MIS 11 sites. The pink and light blue shaded horizons have biostratigraphic data to support correlation based on Preece and Penkman (2005), Preece et al., (2007), Ashton et al. (2008, 2016) and White et al. (2013). Key to sites: Barn = Barnham; Elv = Elveden; B Pit = Beeches Pit; Foxh = Foxhall Road; Htch = Hitchin; Swansc = Swanscombe; Grnth = Greenhithe; Dtfd = Dartford; Chad = Chadwell St Mary; E Bnm = East Burnham. Key to deposits: E Bed = Estuarine Bed; LFW = Lower Freshwater Bed; UFW = Upper Freshwater Bed; LG = Lower Gravel; LL = Lower Loam; LMG = Lower Middle Gravel; UMG = Upper Middle Gravel; US = Upper Sand; UL = Upper Loam; BH/OH Terr = Boyn Hill/Orsett Heath Terrace; St L = Stoney Loam; WL = Wansunt Loam.

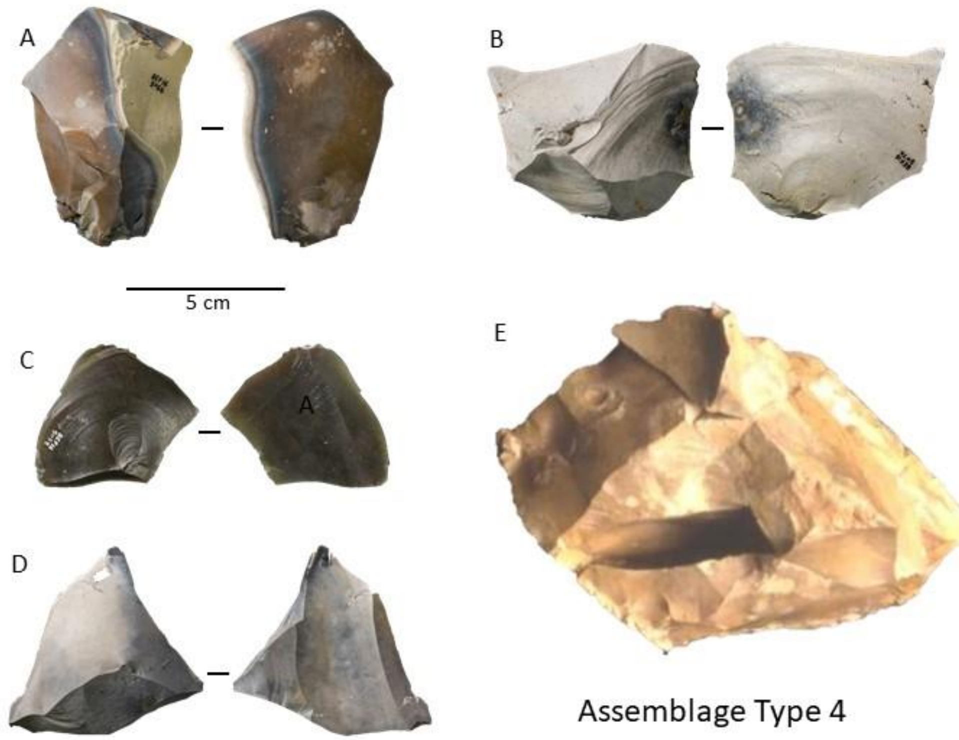


**Figure 6**. Assemblage Type 4 from Barnham. A–D) Hard hammer flakes from Area III. E) Refitting core and flakes from Area I, excavated by John Wymer 1979.

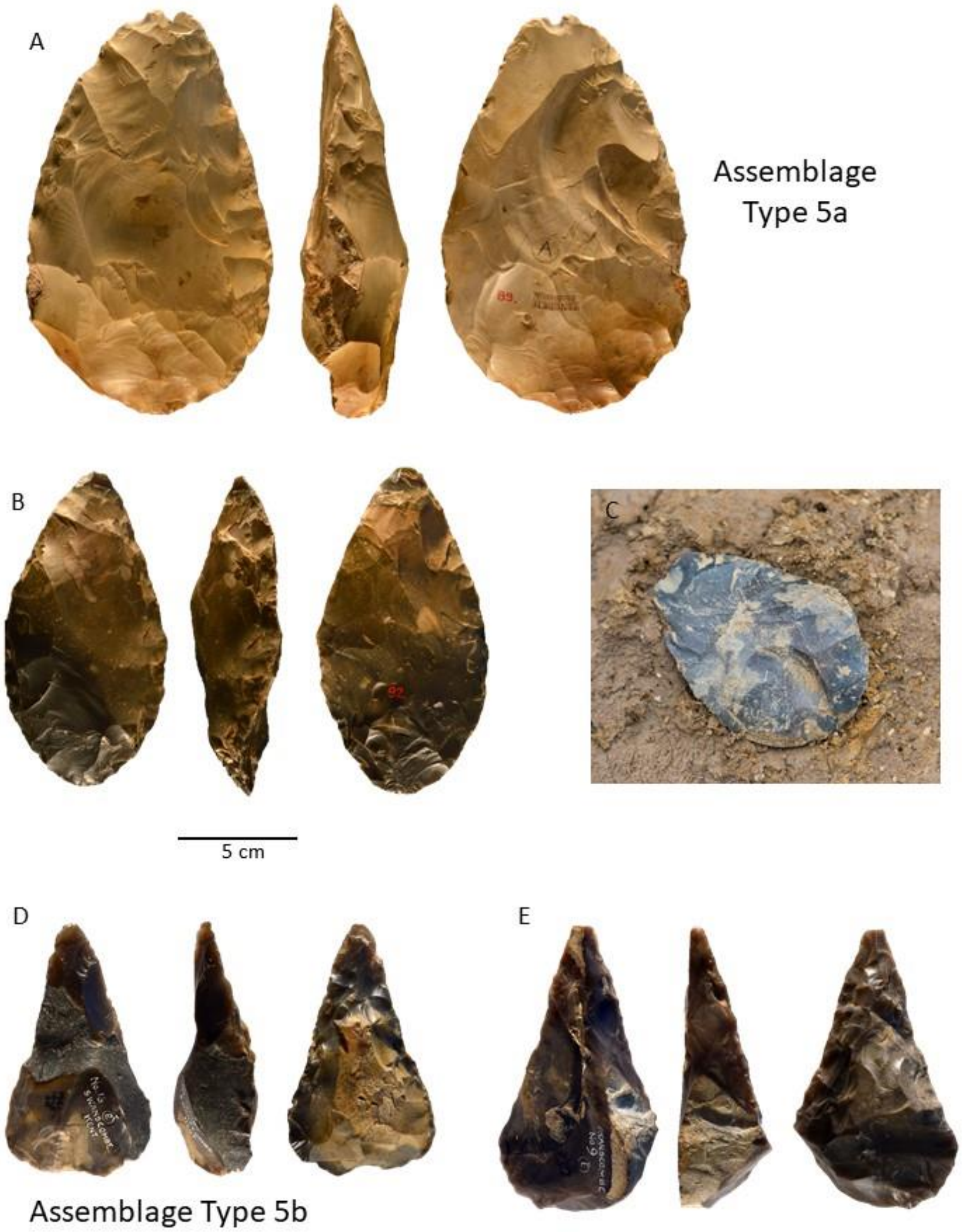


**Figure 7**. Assemblage Type 5 handaxes. A–B) Type 5a from Elveden. C) Type 5a from recent excavation at Barnham. D–E) Type 5b from Middle Gravels at Swanscombe.

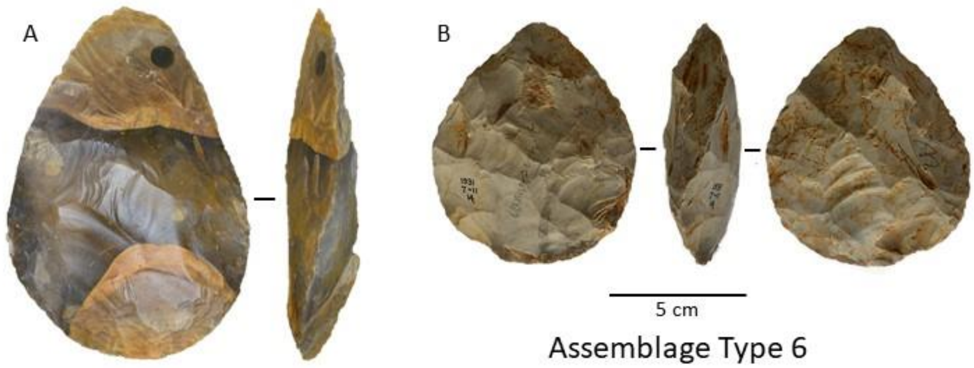


**Figure 8**. Assemblage Type 6 handaxes. A) Greenhithe. B) Wansunt Pit, Dartford.

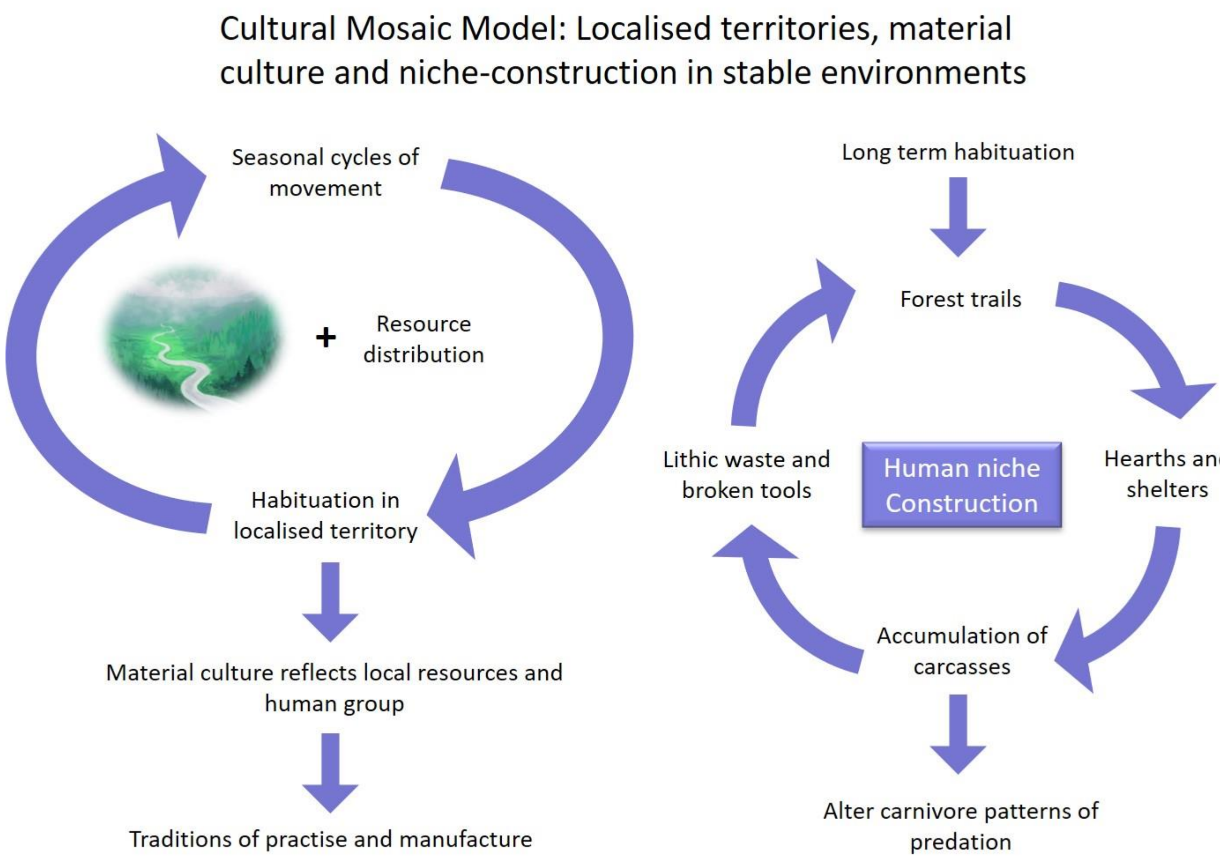


**Figure 9**. Model of localized development of group material culture through resource use and habituation within a landscape during stable environments. Long-term habituation can lead to niche construction and acculturation of the landscape.

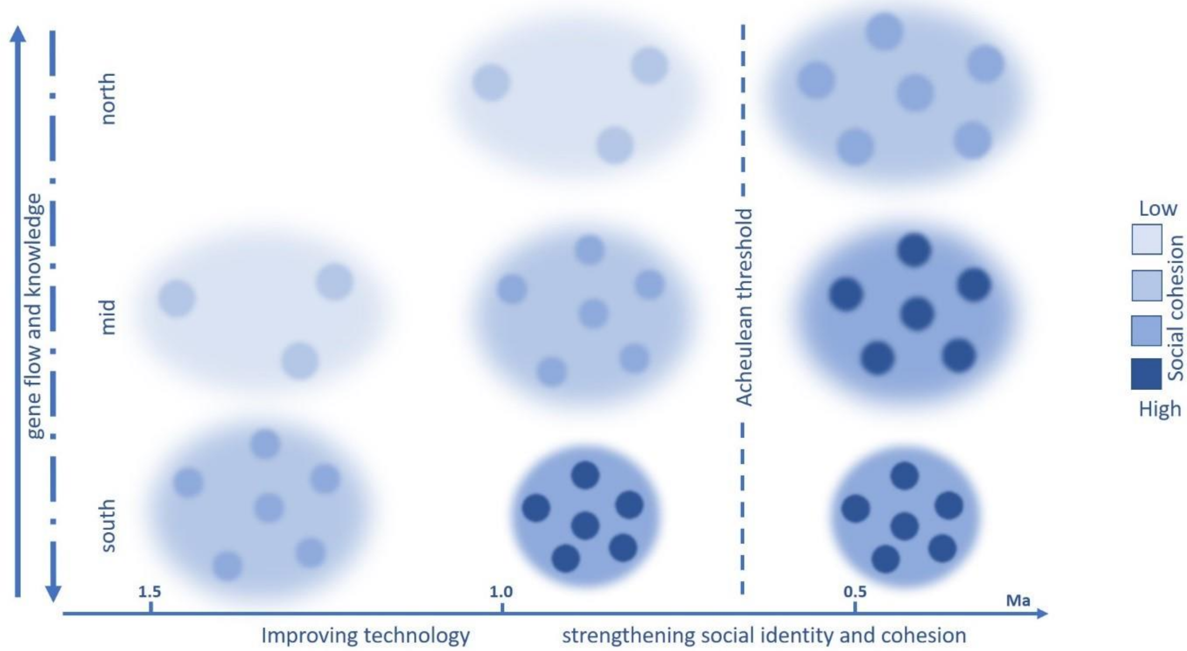


**Figure 10**. Model of social cohesion of human groups at c. 1.5, 1.0 and 0.5 Ma according to southern, mid and northern latitudes in Europe. Large circles represent the territories of sustainable, interbreeding groups with populations of c. 150 with smaller circles representing sub-groups. The more segregated food resources in more northerly areas require larger territories, weakening social cohesion. The model suggests that by 0.5 Ma social cohesion was strengthened through material culture, which is the turning point for sustainable occupation of northern Europe during temperate climate. Shifts in climate produced population movement with expansion, retreat or extinction, but also created a circumstance for gene-flow and knowledge transfer.

**Table 1**

Interpretation of Bytham River archaeological assemblages in the Breckland. High, medium and low indicate relative importance within each assemblage.

| Deposits | Age | Assemblage origin | Assemblage 1 (crude, rolled) | Assemblage 2 (scrapers) | Assemblage 3 (ovate, fresh) |
|---|---|---|---|---|---|
| Warren Hill | MIS 12 | Derived from MIS 13 | | Medium | High |
| | | Derived from MIS 15 | Medium | | |
| High Lodge | MIS 13 | In situ Bed E | | | High |
| | | In situ Bed C | | High | |
| Timworth T | MIS 14 | Derived from overlying MIS 13 | | Low | Medium |
| | | Derived from MIS 15 | High | | |

**Table 2**

Summary of Assemblage Types 1 to 3 showing general characteristics, sites, suggested attribution to Marine Isotope Stage (MIS), and classification of handaxe group by Roe (1968).

| Assemblage | General characteristics | Sites | Possible additional sites | MIS | Roe (1968) handaxe Group |
|---|---|---|---|---|---|
| Type 1 | Thick, crude handaxes made with hard-hammer working | Brandon Fields (rolled)<br>Maidscross Hill (rolled)<br>Warren Hill (rolled) | Farnham Terrace A<br>Fordwich<br>Corfe Mullen (rolled)<br>Ridge Gravel Pit (rolled)<br>Black Park Terrace (rolled) | MIS 15 | Group V |
| Type 2 | Hard-hammer flakes with invasively-retouched scrapers, often on more than one edge | High Lodge (Beds B and C)<br>Brandon Fields (less rolled)<br>Maidscross Hill (less rolled)<br>Warren Hill (less rolled) | | Mid-late MIS 13 | |
| Type 3 | Ovate and cordiforms in shape, soft-hammer working, little cortex retention, frequent tranchet finish to tip | High Lodge (Bed E)<br>Brandon Fields (less rolled)<br>Maidscross Hill (less rolled)<br>Warren Hill (less rolled)<br>Boxgrove | Feltwell<br>Waverley Wood<br>Happisburgh Site 1<br>Corfe Mullen (fresh)<br>Ridge Gravel Pit (fresh)<br>Black Park Terrace (fresh) | Late MIS 13 | Group VII |

**Table 3**

Summary of Assemblage Types 4 to 6 showing general characteristics, sites, suggested attribution to the Marine Isotope substage (MIS) and Hoxnian pollen zone, classification of handaxe group by Roe (1968).

| Assemblage | General characteristics | Sites | Possible additional sites | MIS (Pollen zone) | Roe (1968) handaxe Group |
|---|---|---|---|---|---|
| Type 4 | Core and flake industry with simple flake tools | Clacton<br>Swanscombe (LG, LL)<br>Barnham (GSC) | | MIS 11c (HoII) | |
| Type 5a | Predominantly ovate handaxes, many with twisted edge profiles | Elveden<br>Barnham (Pal) | Beeches Pit<br>Foxhall Road<br>Hitchin | MIS 11c (HoIII) | Group VI |
| Type 5b | Predominantly pointed handaxes, often small with thick, cortical butts | Swanscombe (LMG)<br>Swanscombe (UMG) | Chadwell St Mary<br>East Burnham | MIS 11c (HoIII) | Group II |
| Type 6 | Twisted ovate handaxes | Swanscombe (UL)<br>Greenhithe (Stoney Loam)<br>Dartford (Wansunt Loam) | Hoxne | MIS 11a | Group VI |

For Barnham: GSC = Grey silts and clays, Pal = Paleosol; For Swanscombe: LG = Lower Gravel, LL = Lower Loam, LMG = Lower Middle Gravel, UMG = Upper Middle Gravel, UL = Upper Loam.

**Table 4**

Summary of principal European sites with age attribution, open-air or cave, presence of handaxes, elaborate scrapers, non-lithic technologies, and main references.

| Age (MIS) | Site | Open/ cave | Handaxes | Elaborate scrapers | Non-lithic technologies | Main references |
|---|---|---|---|---|---|---|
| **Northwest** | | | | | | |
| MIS 16 | La Noira (a) | Open | SH handaxes | | | Moncel et al., 2013 |
| MIS 16 | Moulin Quignon | Open | HH handaxes | | | Antoine et al., 2019 |
| MIS 15 | Brandon Fields | Open | HH handaxes | | | Moncel et al., 2015; Davis et al., 2021 |
| MIS 13 | High Lodge | Open | SH handaxes (Bed E) No: (Bed C) | Yes (C) | | Ashton et al., 1992 |
| MIS 13 | Boxgrove | Open | SH handaxes | | Bone tools | Roberts and Parfitt, 1999 |
| MIS 12 | Cagny-la-Garenne | Open | SH handaxes | | | Moncel et al., 2015; Lamotte and Tuffreau, 2001 |
| MIS 12–11 | Menez-Dregan (levels 9-8) | Cave | Rare handaxes some levels | | Fire | Ravon et al., 2019, submitted |
| MIS 12–11 | Grande Vallée | | SH handaxes | Rare | | Herisson et al., 2012, 2016 |
| MIS 11 | Clacton | Open | No | | Wooden spear | Warren, 1911; Singer et al., 1973 |
| MIS 11 | Barnham | Open | SH handaxes: (unit 6) No: (unit 5) | | Fire? | Ashton et al., 1998, 2016 |
| MIS 11 | Swanscombe | Open | SH handaxes (Upper Loam, Middle Gravel) No: (Lower Gravel) | | | Wymer, 1968; Conway et al., 1996; White et al., 2013 |
| MIS 11 | Beeches Pit | Open | SH handaxes | | Fire | Gowlett et al., 2005; Preece et al., 2006 |
| MIS 11/10 | Ferme de l'Epinette | Open | SH handaxes | | | Moncel et al., 2015; Lamotte and Tuffreau, 2001 |
| MIS 10–9 | Menez-Dregan (levels 7–5) | Cave | Rare handaxes some levels | | Fire | Ravon et al., 2019, submitted |
| **Southwest** | | | | | | |
| MIS14–12 | Caune de l'Arago | Cave | Handaxes some levels (P, G, F, E and D) | Yes (J, H, G and F) | | de Lumley and Barsky, 2004; Barsky, 2013 |
| MIS 11 | Gruta da Aroeira | Cave | SH handaxes | | Fire | Daura et al., 2017; Sanz et al., 2020 |
| MIS 11 | Ambrona | Open | SH handaxes | | | Santonja et al., 2017 |
| MIS 11/10 | Terra Amata | Open | Occasional crude handaxes | | Fire | de Lumley et al., 2015 |
| MIS 12/11 | Galeria GII | Cave | Varying form and | | | Ollé et al., 2013, 2016; Garcia |
| MIS 12/11 | TD10.2-4 | Cave | number of handaxes in | | | Medrano et al., 2015 |
| MIS 10/9 | Galeria GIII | Cave | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| MIS 10/9 | TD10.1 | Cave | different levels related to site function | | | |
| **Southeast** | | | | | | |
| MIS 16 | Notarchirico | Open | HH handaxes some levels | | | Moncel et al., 2020 |
| MIS 16/15 | Isernia | Open | No | | | Gallotti and Peretto, 2015 |
| MIS 14 | Korolevo VI | Open | No | Yes | | Koulakovska et al., 2010 |
| MIS 12 | Marathousa 1 | Open | No | | Bone tools | Tourloukis et al., 2018 |
| MIS 12 | Fontana Ranuccio | Open | Handaxes including on elephant bone | | | Segre Naldini et al. 2009 |
| MIS 10 | Torre in Pietro | Open | Crude handaxes | | | Villa et al., 2016 |
| MIS 9 | Castel di Guido | Open | Handaxes, including on elephant bone | | Bone tools | Boschian and Sacca, 2015; Villa et al., 2016 |
| MIS 9 | La Polledrara di Cecanibbio | Open | No | | | Anzidei et al., 2012; Anzidei and Bulgarelli, 2015; Pereira et al., 2017 |
| **Northeast** | | | | | | |
| MIS 11? | Bilzingsleben | Open | No | | Bone tools | Mania, 1995; Pasda, 2012 |
| MIS 9 | Schöningen | Open | No | | Bone tools<br>Wooden tools | Schoch et al., 2015; Serangeli and Conard, 2015; van Kolfschoten et al., 2015 |

SH = Soft-hammer handaxe manufacture; HH = Hard-hammer handaxe manufacture.