Flake tools in the European Lower Paleolithic: A case study from MIS 9 Britain

Abstract

Studies of flake tools in the British Lower Paleolithic are rare, due to lower quantities of flake tools in comparison to handaxes and the perception that flake tool technology became more important in the succeeding Middle Paleolithic. In Britain, and Europe more broadly, MIS 9 (328– 301 ka) has been characterized as a period of technological transition due to the presence of early prepared core technology and the status of the period as the final interglacial prior to the onset of the Middle Paleolithic. It has been argued that the period demonstrates an increase in both the numbers and importance of flake tools, possibly showing emerging Middle Paleolithic behaviors. This paper presents the results of a technological examination of flake tools in Britain during MIS 9, focusing on 25 sites, including 15 assemblages previously recorded as having higher quantities of flake tools. We use these data to assess whether the flake tools of MIS 9 represent a transition towards the technology of the Middle Paleolithic. We consider factors including collection history, site formation, function, reduction, and cultural groups. We argue that in Britain the archaeological record of MIS 9 does not show an increase in the use of flake tools and demonstrates more continuity than change in relation to earlier periods of the Lower Paleolithic. There is a technological background of ad hoc retouch of simple flake tools with occasional evidence of more invasively retouched scrapers. Furthermore, aside from the introduction of Levallois technology, flake tools change little in the Early Middle Paleolithic. These results are contextualized within the broader evidence from Europe and comparisons to the longer sequences at key sites. We conclude that the major changes in technology began between MIS 13 and MIS 11 and these merely became cemented during MIS 9 and the following Middle Paleolithic.

Keywords: Middle Paleolithic; Acheulean; Levallois technology; Clactonian, Europe

1. Introduction

The emergence of the Middle Paleolithic has commonly been seen as indicating more sophisticated planning and behavior, reflecting enhanced cognitive skills (Gamble and Roebroeks, 1999; Scott, 2011; Hérisson et al., 2016; Malinsky-Buller 2016a, 2016b). Technological developments in stone tools can be seen in the beginnings of Levallois and other prepared core technologies, and it has also been argued with an increase in the use of flake tools (White and Jacobi, 2002; Scott, 2011; Hérisson et al., 2016; White and Bridgland, 2018; Moncel et al., 2020). But studies of the European Lower Paleolithic have tended to treat flake tools as something of an aside, especially within Acheulean contexts where handaxes have dominated research (Smith, 1894; Evans, 1897; Breuil, 1932; Kelley, 1937; Wymer, 1968, Roe, 1981; Wymer; 1985, McNabb, 2007; Pettitt and White, 2012). This attitude can be traced to the origins of the Acheulean as defined by de Mortillet, as an exclusively handaxe-based industry, with the use of flakes tools distinguishing the succeeding Mousterian epoch (de Mortillet 1867, 1869, 1872). It was in no small part due to Earnest d'Acy's (1878, 1894a, b) vocal and persistent claims that elements of the Mousterian, including flake tools, could be found within Acheulean assemblages, even at the type site, that de Mortillet (de Mortillet and de Mortillet, 1881; de Mortillet, 1883) decided that Saint-Acheul was 'impure' and abandoned the Acheulean altogether, replacing it with the Chellean, named after a new locality at Chelles-sur-Marne in the Seine Basin. When the Acheulean was re-introduced a decade later, it was as a transitional industry with both handaxes and flake tools (d'Ault Du Mesnil, 1889; de Mortillet 1891). When scraper-rich industries were described, for example those from Clacton-on-Sea (Warren 1923, 1958; Oakley and Leakey 1937) or High Lodge (Evans, 1897; Breuil, 1932), they generally lacked handaxes altogether, suggesting to contemporary workers that they were culturally and technologically more closely aligned with the Mousterian of the Middle Paleolithic rather than the Acheulean of the Lower Paleolithic. In the late 1930s, Harper Kelley (1937) felt it necessary to remind Lower Paleolithic archaeologists that flake tools were, in fact, an integral part of the Acheulean and had been for a long time. The situation is little better today, particularly in Britain, with flake tools

52 rarely being the focus of technological work, although some have argued that this is simply a
53 reflection of the British Acheulean record rather than a national fixation with handaxes (McNabb,
54 2007; Pettitt and White, 2012).

55 In fact, flake tools are found throughout the British Paleolithic including the earliest sites of
56 Happisburgh Site 3 and Pakefield, dating from over 800 ka and ca. 700 ka respectively (Parfitt et al*.,*
57 2005, 2010). There are few formal types, however, with flake tools often characterized by their
58 conservative nature, primarily being ad hoc, retouched flakes aimed at specific needs (Roe, 1981;
59 McNabb, 2007). While temporally and geographically ubiquitous, flake tools appear in low
60 frequencies in the British Lower Paleolithic and rarely meet the criterion of 100 specimens suggested
61 by Bordes (1961) as necessary for statistically significant analysis using his methodology for the
62 examination of Paleolithic technology. When flake tools are mentioned, they are often included as a
63 percentage of the total number of artifacts, or as short descriptions, although sites such as High
64 Lodge (MIS 13; Ashton and McNabb, 1992; Brumm and McLaren, 2011) and Hoxne (MIS 11a; Singer
65 et al., 1993; Ashton et al*.,* 2008) have attracted more detailed examination, mainly due to the more
66 invasive shaping of scrapers at those sites. Lev (1973) analyzed sites with over 50 flake tools but was
67 restricted by the chronological framework of the time, prior to the recognition of MIS 9 and MIS 7 in
68 the terrestrial record (Bassinot et al., 1994; Bridgland, 1994), and focused on assigning sites to the
69 Clactonian (non-handaxe), Acheulean (handaxe), and Mousterian cultures with little overarching
70 interpretation.

71 While the paucity of new studies of flake tools has made synthesis and interpretation
72 difficult, the identification of two further interglacials (MIS 9 and MIS 7) during the Middle
73 Pleistocene has revealed a number of chronological trends in the British record. Following the work
74 on the updated chronology, MIS 9 (328–301 ka) has been identified as the interglacial in which the
75 final Lower Paleolithic industries (both handaxe and non-handaxe) gradually gave way to more
76 Middle Paleolithic modes of technology and behavior, with MIS 8 and MIS 7 seeing the full

development of the Early Middle Paleolithic (EMP) characterized by the frequent use of classic Levallois technology (White and Jacobi, 2002; Scott, 2011).

Recent work (Bridgland and White, 2014, 2015, 2018, White et al., 2018, 2019) has suggested that the archaeological record of MIS 9 is further distinguished by a greater emphasis on the production of flake tools when compared to previous interglacials, as well as the appearance of more elaborate scrapers within the Acheulean (Pettitt and White, 2012; White and Bridgland, 2018). This interpretation was based entirely on Roe's (1968a) gazetteer, which listed only 18 Acheulean contexts (discrete layers of archaeological sites) containing greater than 50 flake tools (from a total of 3091 sites and findspots), with 15 of these argued to date to MIS 9 (Fig. 1). The trend towards a greater emphasis on the production of scrapers was suggested to show the long term and gradual development of Middle Paleolithic technologies and behaviors throughout MIS 9, culminating in, or accompanying, the appearance of prepared core technology (PCT) and rare appearance of Levallois at the end of the interglacial (White and Ashton, 2003). On the basis of the increased number of flake tools, and appearance of PCT, MIS 9 has been suggested to be the key period for understanding the beginnings of the Middle Paleolithic, a period that has been argued to show increased planning depth, improved hunting through technology and cooperation, and more strategic use of landscape (Kuhn, 2013; Moncel et al., 2020).

Figure 1 Here

The key to understanding the archaeology of MIS 9 in Britain lies in several well-studied sites situated on the Lynch Hill-Corbets Tey Formation of the Thames and its equivalents in the River Medway, south east England, which are river terrace aggradations dated to the climatic cycle MIS 10-9-8. Of particular importance are the MIS 9 interglacial deposits at Purfleet (Greenlands Pit) in east London (Table 1; Bridgland, 1994; Schreve et al., 2002; Bridgland et al., 2013), where there is a succession of a core and flake industry at the base, followed by a handaxe assemblage in the middle

beds and a PCT assemblage at the top. This sequence seems to be replicated at Cuxton on an equivalent terrace on the River Medway. This pattern from Purfleet and Cuxton forms a tentative framework for understanding the different assemblages from MIS 9 (see Supplementary Online Material [SOM] Table S1).

Table 1 Here.

Additional sites correlated with MIS 9 come from the catchments of the Thames, the former Solent River and several of the rivers in eastern England (SOM Table S2). Many of these collections were made in the late 19th and early 20th centuries from terrace gravels in the major rivers that are now suggested to have aggraded between MIS 10 and MIS 8, based on Bridgland's (1994, 2006) model of terrace formation. The absence of clear interglacial sediments within the terrace aggradations makes finer attribution difficult. In addition, the artifacts were mainly collected, rather than excavated, so precise contextual details are often lacking. But they form an important body of data as time-averaged assemblages from this age bracket (SOM S1). As it is probable that Britain was uninhabited during the coldest phases of MIS 10 and MIS 8, much of the record they contain is most likely to relate to the warmer part of the MIS 9 climatic cycle (White and Bridgland, 2018). For the purposes of this paper, the shorthand of 'MIS 9' is used for sites that come from terraces that aggraded between MIS 10 to MIS 8 and we argue that as time-averaged assemblages they are a representative sample of sites and activities that took place in the river system at that time.

Although some assemblages have been subject to fluvial edge damage, in the Thames the assemblages generally form coherent collections of material with few notable differences in condition (Bridgland, 1994; White et al*.,* 2018). It has been demonstrated that reworking from higher into lower terraces is a problem with Solent assemblages (Ashton and Hosfield, 2010; Davis, 2013;

126 Davis et al., 2021b), as well as terrace sites in some parts of eastern England (Boreham et al., 2010).
127 Thus, greater caution is adopted here regarding their interpretation, compared to more securely
128 provenanced sites.

129 In this paper, we present the results of a new study which re-recorded and re-examined flake
130 tools from over 20 British sites attributed to MIS 9. We characterized the prevalence and technology
131 of the flake tools of MIS 9 Britain. We then assessed how MIS 9 fits with other evidence from the
132 period spanning MIS 13–MIS 7, examining any chronological or technological trends. Furthermore,
133 we examined whether the evidence from Britain can be considered to be characteristic of the
134 European Lower and Middle Palaeolithic. Our work set out to answer the following research
135 questions:

136 1. Was there a rise in the number of flake tools during MIS 9, suggesting an increase in their
137 use?
138 2. Was there an increase in the elaboration of scraper forms in MIS 9 compared to earlier parts
139 of the Lower Paleolithic?
140 3. If there is an increase in either the number of flake tools, or their elaboration, can this
141 increase be linked to the beginnings and/or increase of PCT during the period, as part of a
142 trend towards Middle Paleolithic technologies and behaviors?

143 Answering these research questions will contribute to debates about the emergence of the Middle
144 Paleolithic and the development of improved cognitive abilities in hominins , by examining whether
145 increased flake- tool use was part of wider behavioral changes.

146 **2. Material and methods**

147 *2.1. Materials*

148 We initially undertook a literature search to identify sites that had yielded assemblages with
149 large numbers of flake-tools (>50), or were referred to as yielding distinctive flake tools, that dated

to the MIS 10–9–8 climatic cycle. Fifteen 'scraper rich' sites dated to MIS 9 were listed by White and Bridgland (2018), and a further 10 were identified through the gazetteers and databases of Roe (1968a) and Wymer (1993, 1996, 1997). This resulted in 25 assemblages that met the criteria for inclusion as shown in Table 2.

These assemblages were then physically examined (see section *2.3. Methods*, below), identifying 606 flake tools from across the 25 sites, although only small numbers were available for first-hand study from Keswick, Southacre, and Lower Clapton, due to limited access to certain museum collections. Therefore, we relied on the following sources (Sainty and Watson, 1944; Roe, 1981; Macrae, 1999; Wymer, 1985, 1999; McNabb, 2007) to make qualitative comparisons between Lower Clapton, Keswick, and Southacre, and the sites physically studied.

Table 2 Here

2.2. Collection bias

Collection bias at these sites is a problem due to the favored collection of more distinctive items, such as handaxes or more elaborate flake tools. Most sites were predominantly monitored by well-respected antiquarians, such as Llewellyn Treacher and Armand Lacaille at Baker's Farm, Furze Platt, Grovelands Pit, and Lent Rise, in the Reading to Maidenhead area (Treacher, 1904; Lacaille, 1940, 1942, 1960). Worthington Smith was mainly responsible for the collections in east London from Stoke Newington, Lower Clapton and Grays, as well as the Bedfordshire sites of Kempston and Biddenham (Smith, 1894). These workers were generally assiduous in their recovery, although at times they also relied on local laborers to augment their collections (Harris et al., 2019). Generally, Treacher, Lacaille, and Smith collected more cores and flakes than their contemporaries, recognizing their importance and subsequently identifying more flake tools (though not always accurately), which may be one reason why a number of MIS 9 sites have higher numbers of flake tools attributed to them (Hosfield, 2009; Roe, 2009; Harris et al*.,* 2019).

This potential problem is exacerbated by the fact that apart from work done at Purfleet (Greenlands Pit; Schreve et al*.,* 2002; Bridgland et al*.,* 2013) and Cuxton (Cruse, 1987; Wenban-Smith, 2004), little modern work has been undertaken on MIS 9 sites. The lack of modern excavations of primary context sites has allowed outdated ideas to remain unchallenged and reports by Roe (1968a, 1981) and Wymer (1968, 1985) have been overly relied upon in recent syntheses (Pettitt and White 2012), which is no longer the case for the more recent analyses of MIS 11 assemblages (Wymer and Singer, 1993; Conway et al*.,* 1996; Ashton et al*.,* 1998; White and Plunkett 2004; Ashton et al. 2005), or those from MIS 8–7 EMP sites (Scott, 2011).

One way to assess potential overrepresentation of flake tools is to use the excavated assemblages from Cuxton (Cruse), Globe Pit, and Purfleet (Greenlands and Botany Pits) as a baseline for the relative proportions of unmodified flakes to retouched flakes expected in excavated and therefore less biased assemblages. At these baseline sites, the percentage of flakes that have been retouched ranges from ~1 to 8%. Of the 21 collected assemblages, six have similarly low percentages, under 10%, while 10 show >10%–<20% flake tools. The sites of Warsash, Grovelands Pit, Sturry, and Lower Clapton all have higher percentages (23–43%) and should be interpreted more cautiously, but we conclude based on these baseline percentages that flakes and flake tools are not dramatically overrepresented at many sites and that they can thus be used to assess the relative frequency of flake tools in MIS 9 sites in Britain. Those sites with a higher proportion of flake tools than expected likely show the preferential collection of these artifacts, similar to that of handaxes.

A further measure of collecting bias may be shown by the percentage of flake tools with invasive retouch, as they are also more likely to have been selectively collected (Table 2). Notably, the four excavated assemblages all have relatively low percentages of fine scrapers, between 0 and 10%. It should also be noted that they are all non-handaxe or PCT assemblages, which may be important if there is a link between flake tool manufacture and handaxe manufacture.

2.3. Methods

Flake tools are defined here as flake blanks that have been modified into tools through retouch or edge modification (Tixier, 1974; Inizan et al., 1999). All MIS 9 flake tools were recorded using the following methods. At a basic level, flake tools were divided into scrapers, notches, and denticulates. Scrapers were further subdivided into single sidescrapers, endscrapers, convergent scrapers, or double scrapers (SOM Table S3). The distinction between flake handaxes, unifacial flake handaxes, and convergent scrapers is a grey area of classification with a judgement being based on extent, location, and character of retouch. Due to the arbitrary nature of the distinction between a unifacial flake handaxe and a more invasively retouched convergent scraper, we grouped these together, while bifacially worked flake tools were grouped separately. Basic measurements of length, width, and thickness were taken to provide a minimum estimate of flake blank size. The length of retouch was also measured to evaluate the extent of retouch relative to the entire flake blank. These measurements were incorporated in our assessment of elaboration in scraper form (Research Question 2, see below).

Incorporating the above descriptive elements and metrics of Bordes' (1961) typology, we focused on a more technological analysis as used by Inizan et al. (1999) and Scott (2011), which uses qualitative observations (see SOM S2) to understand the technological process behind the production of flake tools rather than just the static end shape. The technological approaches of Inizan et al. (1999) and Scott (2011)—by design—do not lend themselves to statistical analysis and seek to answer different questions compared to older methods such as Bordes (1961). Emphasis was placed on qualitative factors involving the characteristics of the retouch to examine more nuanced variation beyond proportions and metrics (Andrefsky, 1998). Based on our examination of the artifacts, we recorded the following attributes of retouch for each flake tool: distribution, form, position, regularity, location, and degree of invasiveness (Tixier, 1974; Inizan et al.,1999; Scott, 2011; SOM S2). We paid particular attention to the invasiveness of retouch, as this is a key element of flake tools that are considered more 'elegant', such as those from High Lodge (Ashton, 1992), compared

to those usually found in the Lower Paleolithic. Elegant flake tools have been argued previously to be characteristic of some MIS 9 assemblages (White and Bridgland, 2018).

To test whether there was an increase in the number of flake tools during MIS 9 compared to previous periods (Research Question 1), we assessed the proportion of flake tools in the MIS 9 assemblages to evaluate whether those cited by White and Bridgland (2018), taken from Roe (1968a), are accurate when studied in more depth and with modern methods. As Roe's (1968a) original identifications included a high proportion of flakes that were classed as being retouched due to natural edge damage, careful attention was paid to ensure that all flake tools contained genuine retouch following the methodologies of Baumler (1995), Andrefsky (1998), and Inizan et al. (1999), who also put more emphasis on how flake tools were manufactured rather than on the dimensions of the finished product

We conducted a preliminary assessment of the increase in the number of flake tools within MIS 9 (Research Question 1) by comparing the non-handaxe, handaxe, and PCT assemblages. To determine if any longer-term trends could be identified in the numbers of flake tools compared to previous periods, we compared our data to assemblages both preceding and following MIS 9 based on published sources (Wymer, 1964; Singer et al., 1973; Ashton, 1992; Wymer 1993; Ashton and McNabb, 1996; Ashton et al.,1998, 2005; Pope, 2002, White and Plunkett 2004; Gowlett et al. 2005; Scott, 2011; Aldhouse–Green et al., 2012).

Identifying an 'elaboration' in scraper form (Research Question 2) is prone to subjective assessment. To minimize subjectivity, we assessed elaboration based on a select number of attributes listed above, which we defined as being indicative of 'refined scrapers'. These include quantitative measurements of tool length, retouch length, and the ratio of retouch length to tool length, and qualitative attributes of retouch invasiveness, regularity of retouch, and the percentage of more complex forms (double, convergent, and bifacial scrapers) in scrapers.

Whether the potential increase in flake-tool use was connected to either Levallois or PCT (Research Question 3) was evaluated through the identification of these technologies using the discipline-standard criteria in Europe of Boëda (1986, 1995) and Scott (2011; SOM S2), which primarily focuses on evidence for the organization and preparation of cores to produce products. This was done to test for any difference between Acheulean assemblages and those with Middle Paleolithic characteristics. Botany Pit (Purfleet) was used as a baseline, as the only major PCT site from MIS 9.

3. Results

We present a complete summary of the flake-tool study to provide an overall understanding of the British flake tool assemblages and to aid comparisons in future work. We elaborate on data that are pertinent to addressing the three main research questions within each section.

3.1. Prevalence of flake tools

Based on our study, the numbers of flake tools reported by Roe (1968a) and by Wymer's English Rivers Project (Wymer, 1993, 1996, 1997), and cited in White and Bridgland (2018), are overestimates, which can be attributed largely to Roe (1968a). Different understandings of 'flake tool' and 'retouched flake' in the older literature, combined with overoptimistic identifications, has resulted in the misclassification of naturally damaged unmodified flakes as flake tools.

Of the 25 assemblages, only three sites actually yielded 50 or more flake tools: Botany Pit, Stoke Newington (from two separate areas), and Grovelands Pit, making comparisons between sites difficult (Table 2). For the Thames catchment, only Cuxton (Tester Collection), Sturry, Botany Pit, Stoke Newington, Furze Platt, Grovelands Pit, and Baker's Farm contain >25 flake tools. In eastern England, Biddenham, Kempston, and Kentford also contain >25 flake tools, as does Warsash in the Solent. Eight of the sites, including Purfleet (Greenlands Pit), contain <10 flake tools and therefore contribute little due to their low numbers. Furthermore, the actual number of flake tools present at

a site depends mostly on the total sample size of flakes and flake tools, without any clear increase in their relative frequency (Fig. 2).

Figure 2 Here

3.2. Technology and typology of flake tools

General observations Despite low numbers and low frequencies, British MIS 9 flake tool assemblages are dominated by scrapers, with percentages generally varying between 75 and 95% (Table 3). Most are sidescrapers (21.4–75%) with lower quantities of endscrapers (0–30.8%), double scrapers (0–20%) and convergent scrapers (0–18.5%). The remaining tools are mainly notches and denticulates.

Based on the size of flake tools there are few differences between the assemblages, with the mean length of flake tools from assemblages mainly varying between 70–90 mm and mean width between 60–80 mm (Table 4). This variation likely reflects the influence of shape and/or size of the local raw materials on the size of the resulting flakes. There is no clear trend of increased elongation of flake tools compared to regular flakes (Table 5). The flake tools from Sturry and Kentford are slightly more elongated, but this could be due to differences in core technology or raw material. While unretouched flakes at these two sites are not notably elongated, as one might expect if raw material shape were the main factor (Table 5), there are some differences in the technology with both sites showing less focus on distal retouch to create endscrapers, and more emphasis on lateral reduction as shown in the location of retouch (Table 6). This focus on the lateral edges possibly contributes to the small increase in elongation. There is little observable difference in the length of retouched edges among the sites (mean = 77.8 mm, range = 48.1–105.5 mm), which again probably relates to the size of available flint resources. On average, flake tools are larger than regular flakes at

all sites other than Barnham Heath and Kempston, potentially indicating the selection of larger flake blanks to retouch (Tables 4 and 5; Fig 3).

Tables 3–6 here

Figure 3 Here

Table 6 summarizes the characteristics of the retouch. Again, few differences in technology can be detected between assemblages. Assemblages are usually characterized by semi-invasive (28.2–90%), continuous (74.6–100%), regular retouch (34–71.4%), with convex edges (53.8–92.9%), although more invasive retouch is evident at the handaxe sites of Biddenham, Grovelands Pit, Lower Clapton, Stoke Newington, and Warsash (see below). The location of retouch is consistently to the margins and proximal, forming sidescrapers and endscrapers, with little pattern in the variation between sites: flake tools have often simply been retouched on the longest edge. Perhaps unsurprisingly, sites showing higher proportions of flake tools with multiple retouched edges also show more invasive retouch: at Biddenham, 23.8% of flake tools are retouched on multiple edges and these make up a large proportion of the 43.3% of flake tools that are invasively retouched. Similarly, at Lower Clapton, 42.9% of flake tools are both invasively retouched and retouched on multiple edges, indicating a connection between these two attributes. Differences between the three types of assemblage are examined below.

Non-handaxe assemblages Three assemblages from the Thames or its tributaries, all belong to the earlier part of MIS 9, and are characterized by core and flake working and the absence of handaxes. At Cuxton (Cruse collection) and Purfleet, the assemblages lie stratigraphically below those with handaxes, while the assemblage from Globe Pit in Thurrock occurs alone. Only the Cruse assemblage from Cuxton contains enough flake tools to be included in Tables 3, 4, and 6. All three assemblages have been excavated so they should, in theory, not be subject to the biases associated with collected assemblages.

There are only 19 flake tools in total. There are few characteristics which separate them from the flake tools found in handaxe assemblages, the majority of which are scrapers with additional notches and denticulates (Table 3). This agrees with McNabb's (1992, 2007) observation that there is a lack of distinction in core and flake technology between non-handaxe and handaxe assemblages. The only possible distinctions are the generally shorter retouched edges and the comparative rarity of invasively retouched flake tools in non-handaxe assemblages (Table 6); there is just one example of a semi-invasive convergent scraper from the non-handaxe layer at Cuxton, but most of the tools show simple retouch.

Handaxe assemblages Twenty-one assemblages that contain handaxes have been assigned to MIS 9, although six of these have very low numbers of flake tools. At least 12 of these sites can be attributed to handaxe Group I of Roe (1968b), characterized by ficron handaxes and cleavers and more pointed forms overall (Table 2). As with the other assemblages, the majority of the flake tools (Tables 3 and 6) consist of simple ad hoc retouch to create side scrapers, notches, and denticulates. Any increase in the proportion of flakes tools compared to the non-handaxe sites could be due to the effects of collection rather than excavation as all of the non-handaxe assemblages were excavated, as opposed to the collected nature of the majority of the handaxe sites (White and Bridgland, 2018). Most of the flake tools appear to be typical of the Lower Paleolithic, being simply retouched to create ad hoc tools with no evidence of PCT, which is similar to the older non-handaxes industries of Cuxton (Cruse Collection) and Globe Pit.

However, more invasively retouched flake tools are present and seem to characterize the handaxe assemblages. Other than Grays Thurrock, the handaxe sites all yielded between 15.5–53.6% invasive flake tools, compared to 10.0% of the core and flake assemblage at Cuxton, and 6.1% of the PCT assemblage at Botany Pit, Purfleet (Table 6). Many assemblages yielded over 35% invasive retouch including Biddenham, Grovelands Pit, Kempston, Lower Clapton, Stoke Newington, and Warsash. The handaxe assemblages also have complex forms including convergent scrapers,

346 unifacial handaxes (the difference between these two categories being largely typological) and
347 bifacially worked flake tools, which were absent in core and flake and PCT assemblages (with the
348 exception of one convergent scraper at Cuxton which was semi-invasively retouched (Figs. 4 and 5;
349 Table 6). The highest proportions are found at Grovelands Pit, Biddenham, Kempston, Dunbridge,
350 and Stoke Newington, showing elaboration in flake tool forms along with the invasiveness and
351 regularity of retouch (Table 6). Additionally, both Grovelands Pit (with adjacent McIlroy's Pit) and
352 Dunbridge show large flake tools with longer retouched edges. Many of the sites, including
353 Grovelands Pit and Stoke Newington, were previously described as having Mousterian flake tools
354 (Shrubsole, 1906; Smith, 1915; Warren, 1942; Wymer, 1968; Roe, 1981), suggesting more of a focus
355 on flake tools. The sites at East Howe, Lower Clapton, Sturry, and Romsey lack assemblages that are
356 large enough, or of a secure enough archaeological context, to accurately characterize. Nonetheless,
357 they show similarities to the other MIS 9 handaxe sites detailed above. Sites in the Solent also
358 showed lower numbers of flake tools than previously recorded in Roe (1968a), Dunbridge and
359 Warsash both containing examples of invasively retouched flake tools including unifacial handaxes.

360 Figures 4 and 5

361 In addition to the sites examined in this study, other handaxe sites that have been correlated
362 to MIS 9 contain examples of elaborate flake tools (Fig. 6). For example, rescue excavations in 1975
363 in South Woodford, northeast London, recovered a small assemblage from channel sediments
364 interpreted as equivalent to the Corbets Tey terrace of the Thames and probably dating to MIS 9
365 (White et al., 1998). This assemblage includes three handaxes, two of which are pointed, together
366 with a large invasively retouched flake interpreted as a unifacial handaxe. At Whitlingham in Norfolk,
367 fluvial sediments of the River Yare yielded a handaxe assemblage attributed to Group I of Roe
368 (1968b), including a large unifacial cleaver. The dating of Whitlingham is less secure than the sites
369 included in the current study, but it most likely dates to MIS 9 (White and Bridgland, 2018),

especially considering the similarities to other Group I assemblages correlated to MIS 9. The assemblage also includes a number of invasively retouched scrapers.

Figure 6 here.

Scrapers from handaxe sites or from contexts containing handaxes at multi-layered sites show some elaboration of flake tools during MIS 9 (Research Question 2) being larger with longer retouched edges and a greater proportion of the artifacts retouched (Table 7; Fig 7). This indicates more extensive retouching, a practice further suggested by the increase in the amount of flake tools that have been invasively retouched. Scraper retouch within handaxe assemblages is also more regular and controlled than seen in the core and flake and PCT assemblages. This is also reflected by an increase in the proportion of complex forms most notably convergent scrapers; the most intensively retouched convergent scrapers are sometimes indistinguishable from flake handaxes.

Table 7 Here

Figure 7 Here

Prepared core technology assemblages Prepared core technology is very rare in most assemblages examined here and it is usually not clear whether there is intermixing between two distinct periods. The exceptions are the small assemblages from Purfleet (Greenlands Pit) and Cuxton, a distinct assemblage from Barnham Heath and the considerably larger assemblage from Purfleet (Botany Pit).

Despite the abundance of PCT at Botany Pit, the flake tools show no evidence of being made on PCT products, seemingly showing the lack of a link between increases in the number or elaboration of flake tools and PCT (Research Question 3). Table 3 and Figure 3 demonstrate that the higher numbers of flake tools at Botany Pit reflect the larger assemblage and flake tools are not represented at a higher proportion than other sites. The flake tools from Botany Pit do tend to be on flakes from the larger end of the range, but not as large as those produced by PCT (Table 8). The elongation of flake tools from Botany Pit is more similar to flake tools from handaxe sites (Table 5),

394 rather than diagnostic of PCT products (Table 8). This is true of all of the PCT assemblages included in
395 this study, with the exception of Barnham Heath, where the cores are generally smaller than the
396 flakes, probably due to collection biases for large flakes. However, accurate identification of flakes
397 produced from such prepared cores is difficult. The technology is characterized by simple
398 preparation of the platforms so the flakes lack any faceting, while the flaking surfaces are worked in
399 a variety of ways but often less intensely, resulting in flakes with unremarkable and simple dorsal
400 scar patterns (White and Ashton, 2003). The resulting flakes are difficult to distinguish from any
401 other Lower Paleolithic core technology, and this probably explains the lack of flake tools that are
402 diagnostically linked to PCT at Botany Pit. While one flake handaxe is present, a large proportion of
403 the flake tools are irregularly retouched (48.2%) into simple side scrapers, endscrapers, notches, and
404 denticulates, and 42.1% have only minimal retouch (Table 6). The site lacks the bifacially retouched,
405 convergent, and unifacial flake tools associated with the earlier handaxe assemblages during MIS 9.
406 There is a similar paucity of refined scrapers in the laterally equivalent archaeological contexts of the
407 Botany Gravel at Bluelands and Greenlands Pits (Palmer, 1975).

408

409 Cuxton shows no direct connection between flake tools and PCT. While ~15% show invasive
410 retouch, the site is dominated by side scrapers (53.1%), often with minor retouch. Barnham Heath
411 has the second largest PCT assemblage (*n* = 20), and it is important to note that these are in fresher
412 condition than the considerably abraded handaxes from the site, but from the mixed condition of
413 the flake tools it is not clear with which technology they are associated (see SOM). The flake tools
414 themselves are unremarkable and as with Botany Pit there is no bifacial retouch, or convergent and
415 unifacial flake tools. For all other sites there is only one example of a direct link between PCT and
416 flake tools, namely the handaxe site of Sonning which has an invasively retouched convergent
417 scraper made on a Levallois flake (Fig. 5). Overall scrapers those from PCT sites have lower levels of
418 elaboration on average than handaxe sites from MIS 9 (Table 7; Fig 7).

Table 8 here.

4. Discussion

The results of the study shed light on the three questions we initially proposed. First, genuine flake tools are much lower in number than previously suggested (Research Question 1), as evidenced by the difference between the number of flake tools examine compared to Roe's (1968a) counts (Table 2). To more fully address Research Question 1, the flake tools of MIS 9 are discussed within the British context below to identify any long-term trends that precede and/or follow MIS 9. Second, while there is little evidence for large numbers of flake tools at MIS 9 sites, there does appear to be evidence for more the elaborate scrapers (Research Question 2). However, these forms seem to relate to handaxe assemblages, as demonstrated in Table 7 which shows the examination of scrapers from the MIS 9 assemblages. Despite problems of selective collecting, there does seem to be correspondence between Roe's Group I assemblages and an elaboration in scraper form and unifacial handaxes, which is supported by similarity in the condition of Group I handaxes and the flake tools at many of the sites examined. Whether these flake tools show an increase in elaboration compared to previous periods will be discussed below. Lastly, despite evidence of early PCT during MIS 9, the idea that this is linked to an increase in flake tool numbers or their elaboration is unsupported (Research Question 3). There is no evidence in either the technology or blank selection that PCT products were being extensively retouched into flake tools, or that there was an increase in the proportion of flake tools linked to the beginnings of the Middle Paleolithic.

Other conclusions can also be drawn. There is no obvious distinction in the technology or frequency of flake tools between the sites in different geographical areas, other than that all the core and flake assemblages thus far identified are all in the Lower Thames, as is Botany Pit, the only PCT assemblage to be clearly associated with flake tools. Within the handaxe assemblages the characteristics of the flake tools are similar among the three areas of the Thames, Solent, and

444 eastern England, each containing assemblages attributed to Roe's Group I with characteristic ficron
445 handaxes. More detailed analysis is currently underway (Dale) on the handaxe assemblages, which is
446 beginning to identify possible regional differences between the Thames and Solent catchments using
447 morphometrics and assignment to Roe's groups.

448 The only temporal pattern that can be recognized within the flake tools is in the Thames,
449 where the core and flake, handaxe, and PCT assemblages are stratigraphically related at Purfleet,
450 and probably Cuxton, although the relationship between handaxes and PCT is not clear at a number
451 of other sites. These assemblages suggest that the core and flake and the PCT assemblages are
452 characterized by simple ad hoc scrapers, denticulates, and notches, whereas most assemblages
453 associated with handaxes are augmented by more elaborate scraper production with invasive
454 retouch. Although this may also be a characteristic of the Solent and eastern England assemblages,
455 there is too much intermixing of artifacts and uncertainty of contexts to be sure of the association
456 between more elaborate scrapers and handaxes in these areas.

457 The beginnings of the Middle Paleolithic in Europe is marked by the widespread use of PCT
458 and Levallois technology, together with a suggested increase in the use of flake tools (Roe, 1981;
459 Gamble and Roebroeks, 1999; White and Jacobi, 2002; Monnier, 2006; Scott, 2011 Malinsky-Buller,
460 2016a). It has been suggested that these characteristics may in part be related to the production of
461 more carefully shaped flake blanks and tools with the intention of hafting (Villa et al., 2009; Hardy et
462 al., 2013; Rots, 2013; Iovita and Katsuhiro, 2016; Picin, 2018; Moncel et al., 2020), and this is an area
463 that should be examined in future studies. It has also been suggested that more occasional use of
464 PCT can be identified in the Lower Paleolithic from MIS 12 to MIS 9 and that there is a trend towards
465 increased flake-tool usage (Lamotte and Tuffreau, 2016; Moncel et al., 2020). The data from this
466 study has shown that in Britain there is little evidence for an increase in the use of flake tools during
467 MIS 9, although there is an increase in elaboration of flake tool form in association with handaxe
468 assemblages during the middle part of the interglacial associated with Stoke Newington and other

Roe (1968b) Group I handaxe assemblages. But this is not evident at the end of the interglacial in the higher layers at Purfleet. To investigate longer-term trends in flake tools, below we compare the record from MIS 9 with earlier and later periods in Britain to further address research questions 1 and 3.

4.1. Flake tool technology in Britain from MIS 13 to MIS 7

For the periods prior to, and after MIS 9, there are no clear trends in flake tool production. Most sites, even when collected rather than excavated, have between 2–8% of flake tools (Table 9). This level of variation can easily be accounted for by slight differences in the range of tasks undertaken at different sites. This is almost certainly the case for Pontnewydd, as a result of being the only cave site (Aldhouse-Green et al., 2012). Flake tools are found at all sites, and the variety of flake tools is consistent throughout with scrapers, denticulates and notches. There might be a slight increase in percentages of flake tools for non-handaxe sites, but this is not particularly marked (Table 9). Only in two assemblages, High Lodge (Bed C) (Fig. 8; Brumm and McLaren, 2011; Davis et al., 2021a) and Hoxne (Upper Industry) (Fig. 9; Wymer and Singer, 1993), was more attention paid to the form of scraper production with more invasive retouch and more elaborate forms, but they date to MIS 13 and MIS 11a respectively, and do not form part of a wider trend. During MIS 11c, despite other differences in technology, all the flake tools are characterized by ad hoc scrapers, denticulates, and notches, with little evidence of more elaborate forms (Davis and Ashton, 2019).

There is no evidence of a significant change during the EMP. While Baker's Hole shows large Levallois flakes being shaped into flake tools, some of which resemble handaxes, most EMP sites show only modest percentages of flake tools. In addition, there is little evidence of elaborate flake tools, with most remaining ad hoc tools. These results support the findings of this study that there is no marked increase in flake tools during MIS 9 (Research Question 1), or that there is an increase in flake tools associated with PCT and the emergence of the Middle Paleolithic (Research Question 3).

Table 9 Here

Figures 8-9 here

4.2. Changes and trends across Europe during MIS 9

The record from Britain can be compared to a series of sites in neighboring mainland Europe, some of which have long sequences and are ideal for identifying changes or long-term trends in technology and tool use (Table 10). In order to assess whether the results of this study fit the broader European context a number of sites from the period in mainland Europe are examined below to offer comparison.

Table 10 Here

Menez-Dregan in Brittany has deposits dating from MIS 12 to 8. Due to the rarity of handaxes it is one of several sites that were termed 'Colombanian', but are now regarded as a local expression of the Acheulean , with the low numbers (sometimes absence) of handaxes being attributed to the difficulty of working local raw material and the variable use of the cave (Monnier and Molines, 1993; Ravon et al*.,* 2016a, b, 2022; Ravon, 2019), Similar to the British record the flake tools generally consist of ad hoc modifications to flake edges and are dominated by denticulates with lower quantities of notches and scrapers. While layers 9 to 7 (MIS 12–10) have higher proportions of flake tools (1.7–6.2%), there is a significant drop in the proportion in layers 6 to 5a (0.8–2.8%), which date to MIS 9 (Table 10). The relative numbers of scrapers vary in the MIS 9 levels, with somewhat higher proportions in layers 5c', 5c and 5b'. Layers 4c and 4ab have been attributed to MIS 8 with the first signs of the Middle Paleolithic based primarily on evidence of several discoidal cores, although Levallois is absent. The proportion of flake tools in Layer 4 remains low (1.6–2.6%)

with no marked difference to preceding levels (Layers 5–6, 0.8–2.8%), which is suggested to be due to a slight shift in cave use, rather than technological change. Similar to the British record what can be observed is an absence of a clear trend to increased flake tool use during the EMP.

Another French site, Soucy, further demonstrates that while there is a lack of temporal trends flake tools are often linked to handaxe manufacture. Soucy has nine occupation sites within floodplain deposits of the river Yonne that have been dated to MIS 9 (Lhomme, 2007). The sites are spatially and stratigraphically separated, but represent a series of different activity areas on the floodplain. The background signature is of handaxe manufacture and use with ad hoc production of notches, denticulates, scrapers, and other marginally retouched flakes, often associated with butchered bone (Table 10). Most site variation probably relates to different activities, with two of the smaller assemblages lacking handaxes (Soucy 6 and 2). Where there is evidence of handaxe manufacture there is an increase in scrapers and the quality of the retouch, while Soucy 5 (Level I) shows handaxe manufacturing flakes being used for flake tools. In Soucy 3 Level P, flake tools included convergent scrapers and more invasive, regular retouch. Soucy 1 showed a spatial separation between flake tools and handaxes, giving a glimpse of how sites were structured in the landscape. Soucy is important because it provides short glimpses of activity within a finite landscape, which is concordant with the variation to be expected from a single population over a short period of time. It is very different to the time-averaged assemblages from Britain, but shares many of the same features of flake tool production with generally ad hoc forms, occasionally supplemented by more elaborate scraper production.

The lack of a progressive trend can be noted at several sites in the Somme Valley around Amiens that date from MIS 12 to 9, all with handaxes and flake tools, with the MIS 12 site of Cagny-la-Garenne showing the early use of PCT (Lamotte and Tuffreau, 2016). The later sites of Ferme de l'Epinette (MIS 10), Cagny-l'Epinette (MIS 10/9), and Revelles and Gentelles (both MIS 9) show little change in technology, other than the rarity or absence of PCT. The flake tools are dominated by

notches (24.5–28.9%) and denticulates (16.9–22.8%), and, more rarely, scrapers (8.7–14.7%; Lamotte and Tuffreau, 2016). Convergent scrapers are occasionally evident during MIS 9.

Orgnac 3, a cave site in Ardeche, France, preserves a detailed record of the transition from MIS 9 to MIS 8 (Moncel et al*.,* 2012). The relative proportion of handaxes decreases through the sequence from 1.7% (Level 7) to 0.01% (Level 1), while early occasional PCT becomes the predominant technology in the highest levels (Moncel et al., 2012). Nevertheless, the proportion (6.2–24%) and types of flake tool is variable, mainly dependent on the function of the site (Moncel et al., 2012), and not a progressive change in technology. Scrapers predominate over denticulates and notches throughout, but more invasive retouch is evident in the lower levels, and more marginal retouch and lower proportions of flake tools characterize the assemblages towards the top.

Elsewhere in Europe there is also no trend linking the beginnings of the EMP and an increase in either flake tool numbers or elaboration. The cave of Gran Dolina at Atapuerca, Spain, is the richest of the archaeological sites dating to MIS 9, with TD10.1 at the top of the sequence showing the beginnings of the transition to the Middle Paleolithic (de Lombera-Hermida et al*.,* 2020). Early signs of PCT are known from Lower TD 10.1 and Upper TD 10.1. Lower TD 10.1 has more invasive retouch to create convergent scrapers and side scrapers, while Upper 10.1 has more ad hoc expedient retouch with a higher level of denticulates, accompanied by a decrease in handaxes.

In Belgium the sites of Kesselt-Op de Schans and Mesvin IV also show that lack of an increase in flake tools Kesselt-Op de Schans dates to MIS 9/8 and is characterized by early PCT and full Levallois (Van Baelen, 2017). Only 13 flake tools could be identified, three scrapers, one with semi-invasive retouch*,* and 10 ad hoc retouched flakes. Mesvin IV also dates to early MIS 8 and contains a mixture of PCT and handaxes (Ryssaert, 2006). Flake tools make up ca. 2% of the assemblage, just under half being minimally worked scrapers. Some of the Levallois flakes also have minimal retouch.

Most MIS 7 archaeological assemblages have been classified as Early Middle Paleolithic mainly due to the widespread establishment of Levallois technology by this time. Although the

568 introduction of this technology unites these assemblages, there is still considerable variation. Some
569 assemblages include handaxes, such as La Cotte de St Brelade (level 5; Callow and Cornford, 1986),
570 Pucheuil (A/C; Delagnes and Ropars, 1996), Gentelles (upper levels; Tuffreau et al., 2008), and Osiers
571 à Bapaume (Tuffreau, 1976; Koelher, 2008), while at other sites there is a complete absence of this
572 technology such as Maastricht-Belvedere (Roebroeks et al., 1992; De Loecker, 2006), Biache-Saint-
573 Vaast (Boëda, 1986), and Therdonne (Hérisson, 2007). The flake tool assemblages also vary, but
574 most consist of marginally retouched denticulates, notches, and scrapers with little difference from
575 preceding periods. However, some sites do show the use of Levallois flakes, either through marginal
576 retouch, or more intriguingly at Pucheuil and Therdonne, through the truncation and thinning of
577 Levallois flakes and points, possibly for hafting.

578

579 *4.3. Flake tool production across Britain and Europe during the Lower Paleolithic*

580 The evidence of flake tool production in Britain during the Lower Paleolithic, as shown in this
581 study and the comparisons to previous work, is entirely concordant with that of mainland western
582 Europe. The underlying technology is of marginal retouch to convenient edges to produce simple
583 scrapers, denticulates, and notches, probably produced expeditiously as needs arose. This form of
584 production extends from the earliest sites in northern Europe, such as Happisburgh Site 3 and
585 Pakefield (Parfitt et al., 2005, 2010), to those at the end of the period, including Orgnac 3, Gran
586 Dolina TD10.1 and Cuxton, and appears to extend into the EMP. It can also be observed beyond the
587 traditional European Acheulean region, in central and south-eastern Europe, where handaxes are
588 rare or absent (Rocca et al., 2016). Along with the early Mode I sites in western Europe and core and
589 flake assemblages in MIS 11 and MIS 9, these sites demonstrate that flake tool usage is part of a
590 wider Lower Paleolithic technology, with or without handaxes.

591 In addition to this base technology, comparison to previous studies show there is
592 occasionally evidence of more complex flake tool production, which seems to reflect short-term,

593 localized innovation of slightly different traditions of practice. Examples of this occur in MIS 13 at
594 High Lodge (Bed C), Hoxne Upper Industry in MIS 11a, and also in some of the MIS 9 assemblages
595 such as Stoke Newington, Soucy 3 and Gran Dolina TD10.1. From this study the evidence shows that
596 in Britain during MIS 9, sites with evidence for the increased importance of flake tools appear to be
597 associated with handaxe production, which may also be the case for other assemblages in Europe.

598 During the EMP across Europe there is occasional use of Levallois flakes for flake tools,
599 usually with marginal retouch, which is rare in the MIS 9 sites directly studied here. There is also
600 evidence of the truncation and thinning of the butts of Levallois products, which have been
601 suggested to be preparation for hafting. It is often stated that hafting of tools would lead to
602 standardization in tool form (Bar-Yosef and Kuhn, 1999; Tomasso and Rots, 2018), but this is only
603 occasionally evident in the EMP of western Europe, and probably limited to Levallois points and
604 flakes rather than other flake tools. Related to the development of hafting is the issue of
605 resharpening and reprovisioning of tools (Dibble, 1987, 1995; Scott, 2011), which is more likely to
606 occur when there has been significant time investment in creating and securing a tool handle. The ad
607 hoc nature and lack of standardization in most flake tools in both the Lower Paleolithic and EMP
608 suggests that resharpening was rare and that hafting was only beginning to be used in the EMP.

609 The function of flake tools has been a long-term topic of discussion, but with few clear
610 relationships between tool form and activity (Keeley, 1980, 1993; Newcomer et al., 1986; Bamforth,
611 1988; Mitchell, 1996; 1997). It has been suggested that the scrapers at High Lodge and Hoxne
612 indicated early hide working and possible clothing and shelter, but there has been no use-wear
613 analysis to support this (Ashton, 2015; Davis and Ashton, 2019). Pettitt and White (2012) further
614 suggested that changes in wider behavioral and societal changes, including increased hide working
615 and developments in clothing, could have caused an increase in flake tools in Britain during MIS 9.
616 There is no use-wear analysis to support these suggestions and little support is found in this study,
617 which shows no discernible increase in the importance of flake tools or of scrapers during the Lower

618 Paleolithic, other than short-lived, localized elaboration in some forms as seen at High Lodge and
619 Hoxne.

620 The lack of evidence of a temporal increase in flake tools in the British record poses the
621 question of why more elaborate scrapers seem to appear at specific sites, or in particular regions
622 and periods, but seem to be only short-lived traditions of manufacture. For High Lodge (MIS 13) it
623 has been suggested in the absence of handaxes the invasively retouched and shaped scrapers took
624 on some of the social resonance that is often attributed to handaxes (Ashton and Davis, 2021). For
625 MIS 9 it seems that the more elaborate scrapers are usually associated with Roe's handaxe Group I.
626 This group includes the remarkable ficrons that epitomize ideas on the wider meaning and purpose
627 of handaxes, beyond the purely functional (Gamble, 1999; Kohn and Mithen, 1999; Wenban-Smith,
628 2004; Westaway et al., 2006; Spikins, 2012; Bridgland and White, 2014, 2015; Davis et al., 2016;
629 Hosfield et al*.,* 2018; White and Foulds, 2018; White et al. 2018; 2019). Ficrons are the most visible
630 form of material culture expressed in stone and it is suggested here that the elaborate scrapers also
631 reflect groups in Britain who expressed their shared traditions through these scraper forms
632 alongside specific handaxes during MIS 9.

633 Unfortunately, we lack contextual evidence for the majority of sites in Britain during MIS 9,
634 making interpretation of flake tools, including their function, difficult. By contrast, in the Levant
635 evidence of more elaborate flake tools usage in the Lower Paleolithic can be observed at Qesem
636 cave, Israel (ca. 420–200ka) where it is linked to local circumstances such as changes in fauna,
637 hominin culture (Acheulo-Yabrudian Cultural Complex), fire use, and meat processing (Karkanas et
638 al*.,* 2007; Barkai et al., 2017; Agam and Zupancich, 2020). In Britain. the understanding of short-lived
639 traditions of increased flake tool use could be obscured by the lack of this level of contextual
640 evidence.

641 Finally, in this study, we have shown that there is no long-term evolutionary trend in flake-
642 tool production through the Lower Paleolithic into the EMP in Britain, and this appears to also fit the

643 evidence across Europe. This has ramifications for how why think of behavioral change during the
644 Lower-Middle Paleolithic transition. Although the Lower-Middle Paleolithic transition has been
645 argued to show important changes in hominin behavior (Gamble and Roebroeks, 1999; Scott, 2011;
646 Hérisson et al., 2016; Malinsky-Buller 2016a, 2016b), many of the apparent innovations, and
647 advances in cognitive ability, had already been developed and practiced in the preceding Lower
648 Paleolithic, providing an underlying body of technological knowledge that became far more widely
649 established in the Middle Paleolithic. These technological developments included improved hunting
650 (Roberts, 1996a, b; Roberts and Parfitt, 1999; Pope et al*.,* 2020), wood and bone working (Warren,
651 1911; Thieme, 1997, 2003, 2005; Villa et al., 2021), fire-use (Gowlett et al. 2005; Roebroeks and Villa,
652 2011; Ravon et al., 2016a, b), and preferential use of caves (de Lumley and Barsky, 2004; Molines et
653 al., 2005; Ollé et al., 2016; Ravon 2018). Possibly the biggest change, as seen in the British evidence,
654 was expression through material culture as glimpsed through handaxe form and occasionally in the
655 elaboration of scrapers. These innovations were becoming established from 500 ka and perhaps
656 represent a more significant threshold in hominin behavior and cognitive development than the
657 Lower to Middle Paleolithic transition, which shows a more gradual change consolidating previous
658 innovations (Moncel et al*.,* 2020)

659

660 **5. Conclusions**

661 In this study, we find little evidence to support the idea that there was an increase in the
662 importance of flake tools during MIS 9. We have demonstrated that the character of flake tools
663 shows more continuity than change. Any increase in the elaboration of flake tools of MIS 9 cannot
664 be tied to the beginnings of PCT and this is also true of the EMP. Instead, elaborately retouched flake
665 tools are connected to sites with substantial handaxe production, and often in the complete absence
666 of PCT, as in the cases of Stoke Newington, Grovelands Pit, and Furze Platt. Despite being dominated
667 by PCT, Botany Pit shows a lower proportion of flake tools, and with less elaboration, than

Grovelands, Biddenham, and Kempston. When compared to the wider Lower-Middle Paleolithic, a background of expedient ad hoc technology can be observed at most sites, with more invasively retouched flake tools often found within sites with handaxes.

Despite the difficulties associated with working with old collections, both regional and chronological patterns are beginning to emerge in the British record. Further work may be able to relate these to other patterns in handaxes (White et al., 2018; 2019) or changes in technology during the EMP (Scott, 2011). A wider analysis of flake tools from all periods may also be able to expand on this work and determine whether changes in flake tools can be identified when compared to Roe's (1968b) handaxe groups. Further excavations are essential in getting more representative assemblages from key sites, and this would help provide further context to the flake tools, which could be crucial to fully understand differences in function and type. To assess the function of flake tools new assemblages that have potential for use-wear, would be invaluable, as they are lacking in the current sample. The patterns observed in the British record can be observed in mainland Europe, including the lack of an increase in both the elaboration and proportion of flake tools during the EMP and the production of elaborate flake tools by Acheulean populations. The lack of previous work has hindered our knowledge of flake tools during the Lower Paleolithic, and it is important to ensure that, rather than being treated as epiphenomena, they are studied as part of the wider technology of the British Lower Paleolithic.

Acknowledgments

We would like to thank the staff at the British Museum, The Higgins Bedford, The Pitt Rivers Museum, Oxford Natural History Museum, Cambridge Archaeology and Anthropology Museum, Reading Museum, Hampshire Cultural Trust, Sedgewick Museum, Portsmouth Museum and Danielle Schreve at Royal Holloway for access to collections and assistance with data collection. We are grateful to Chris Orton for the production of Figure 1. We are

grateful for the helpful comments and suggestions made by the reviewers and editors that have helped improve this paper. The research and writing of this paper were undertaken while A.R. and L.D. were funded by the Arts and Humanities Research Council, through the Northern Bridge Doctoral Training Programme and Collaborative Doctoral Partnership, respectively.

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Figure captions

Figure 1. Map showing the main sites referenced in the text: a) overview of Britain; b) insert of the Thames and East Anglia; c) European sites used for comparison.

Figure 2. Percentage of flake tools as a proportion of the total number of flakes and flake tools: a) proportion of flake tools at MIS 9 sites; b) proportion of flake tools at sites with >10 flake tools; c) overall proportion of flake tools by assemblage type.

Figure 3. Size comparison between flakes and flake tools: a) length b) width c) elaboration. On average flake tools are larger than unretouched flakes which could show blank selection.

Figure 4. Scrapers from British MIS 9 sites: a) Warsash; b) Lower Clapton; c) Keswick; d) Stoke Newington.

Figure 5. Scrapers from British MIS 9 sites: 1, 3, 4, and 7) Grovelands Pit, Berkshire; 2) Sonning, Oxfordshire; 5 and 8) Kentford, Suffolk; 6) Baker's Farm, Buckinghamshire; 9) Cannoncourt Pit, Furze Platt, Berkshire. (1–4 and 7 after Wymer 1968; 5 and 8 after Wymer 1985. 4 and 9 after Lacaille 1940).

Figure 6. Unifacial and partly bifacial flake 'cleavers'. Top: Whitlingham, Norfolk. Bottom: South Woodford, London Borough of Redbridge. Note the localized battering on the ventral bulbar surface of the South Woodford specimen (after Wymer 1985).

Figure 7. Elaboration of scrapers from MIS 9 sites. Comparison of features indicative of 'refined scrapers': complex forms, invasive retouch and regular retouch, split by assemblage type. When compared flake tools from handaxe assemblages from MIS 9 show higher degrees of elaboration than other assemblage types.

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1124 **Figure 8**. Scrapers from the clayey-silts (Bed C) High Lodge, Suffolk (after Ashton et al., 1992).

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1126 **Figure 9**. Scrapers from the Upper Industry Hoxne, Suffolk (after Wymer, 1985).

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