Supplementary Online Material (SOM):

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

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SOM S1

The British geological, environmental, and archaeological framework for MIS 10–9–8

Purfleet preserves three fining-upward fluvial cycles laid down in an abandoned loop of the Thames, each containing a different archaeological signature (SOM Table 1). This sequence is seen across all the pits, but is most clearly represented at Greenlands Pit. The basal cycle (Beds 1–3) contains a non-handaxe signature correlated to MIS 10/9, the middle cycle (Beds 4–7) contains a handaxe assemblage correlated to MIS 9, while the upper cycle (Bed 8) shows the beginnings of prepared core technology (PCT) correlated to MIS 9/8. The base of the Purfleet sequence (Bed 1) marks a transition from cold climatic conditions at the end of MIS 10, shortly after down-cutting to this terrace level. The onset of temperate conditions is first signalled by the molluscs from Bed 3, with strong temperate signatures coming from Beds 4 (tidally laminated silty clay) and 5 (Greenlands Shell Bed). The laminated silty-clay of Bed 4 is thought to represent tidal sedimentation during a period of high sea level, although formaniferal evidence of salinity is muted (Schreve et al., 2002; cf. Hollin, 1977). Pollen from Bed 4 reflects the early temperate phase of the MIS 9e interglacial, dominated by mixed temperate woodland, rich in alder, spruce, and oak with nearby areas of open grassland that periodically became dominant (Bridgland et al., 2013); green frog indicates mean July temperatures of at least 15–17 °C. The laminated deposits at Globe Pit, Little Thurrock, which produced a rich core and flake signature from the lateral equivalent of Beds 1–3, have also been attributed to estuarine conditions during MIS 9 (Table 1; Bridgland, 1994; cf. Hollin, 1977).

The Greenlands Shell Bed at Purfleet (Bed 5) marks an increase in flow energy and the development of a sand flat, the limited terrestrial molluscan fauna indicating a mosaic of marsh or swamp close to the river channel, with grassland, scrub and woodland beyond (Schreve et al., 2002). The brackish mollusc *Paladilhia radigueli* suggests the continuation of high sea level, while the cyprinids demand high summer temperatures of at least 18 °C, in keeping with evidence from the equivalent MIS 9 sites of Hackney, in north-east London, and the long sequence at Cudmore Grove,

an estuarine site in a Thames tributary downstream in eastern Essex (Roe, 1994, 1999; Green et al., 2004; Bridgland, 2006; Roe et al., 2009). The mammalian assemblage from the Greenlands Shell Bed reflects fully interglacial conditions and a range of habitats that included deciduous woodland, grassland, riparian and aquatic environments (Schreve et al., 2002).

The Bluelands Gravel (Bed 6) from its coarser-grained character is suggested to have been deposited under cooling climatic conditions, possibly the transition from MIS 9e–d, rather than that between the end of MIS 9 and beginning of MIS 8 (Bridgland et al. 2013). The mammalian assemblage from this bed, which includes horse, is consistent with more open, cool conditions. Renewed warm conditions are signalled by the estuarine environment tentatively associated with Bed 7 (Schreve et al., 2002), which would therefore represent a second warm event with high sea-levels within MIS 9. The upper beds at Purfleet are typically decalcified and weathered, and have been attributed to the Botany Gravel (Bed 8). This gravel is better represented in the Botany Pit, 1 km to the west. A large PCT assemblage was recovered from the Botany Pit in the early 1960s and consists of simple prepared cores (White and Ashton, 2003). The correlation of the Botany Gravel with Purfleet (Greenlands Pit) allows attribution to late MIS 9 or early MIS 8 (Bridgland et al., 2013).

Several other sites can be related to the sequence at Purfleet. The well-known Lynch Hill Thames deposits at Stoke Newington, also attributed to MIS 9, have produced rich faunal and archaeological assemblages many of which were collected by Worthington G. Smith (Smith, 1894; Green et al., 2004). Up to three separate Acheulean horizons are present at Stoke Newington, the most important being the collection from the 'floor' in the Stoke Newington Sands. These have been argued on geological and biostratigraphical grounds to belong to an earlier part of MIS 9 (Green et al., 2004; Simon Lewis, personal communication, 2019), and it is probable that they are geologically contemporaneous with the Bluelands Gravels at Purfleet. Roe (1968) assigned the Acheulean handaxes from Stoke Newington to his Group I, point-dominated with ficrons and cleavers, although the high frequency of scrapers had earlier caused Smith to assign them to the Mousterian.

The later part of MIS 9 or one of the cool substages is probably found at Wolvercote, in the Upper Thames (Oxfordshire). This is the only other MIS 9 site to produce both environmental data and a rich archaeological assemblage, and the only site in the British Isles attributed by Roe (1968) to his handaxe Group III, characterized by 'slipper-shaped' plano-convex handaxes. Sediments directly overlying the main archaeological horizon (Bed 5) contained a cool-temperate mammalian assemblage (including *Palaeoloxodon antiquus*, *Stephanorhinus hemitoechus*, *Equus ferus* and *Bison priscus*), alongside 17 species of mollusc, 67 species of plants and mosses, and five coleopteran taxa (Bell, 1894, 1904; Blair, 1923; Sandford, 1924; Duigan, 1956). These environmental proxies included several species characteristic of highland or sub-alpine habitats, with the sparse pollen from Bed 5 showing a transition from pine-dominated forest to more open habitats (Briggs et al., 1985).

A further site, Cuxton in Kent, lies within terrace deposits of the River Medway, a south-bank tributary of the Lower Thames. Correlation with the Thames is hindered by a lack of deposits that are directly relatable, and the absence of biological remains in this part of the Medway Valley, but it has been attributed to MIS 9–8 on the basis of lithostratigraphy and OSL dating (Tester, 1965; Cruse, 1987; Bridgland, 2003; Wenban-Smith, 2004). Excavations by Tester in the 1960s exposed only the higher part of the fluvial sequence, finding an Acheulean assemblage (657 artifacts, including 199 handaxes) in fresh condition. Cruse's later excavations in deeper-channel exposures identified two separate artifact groups: a non-handaxe assemblage (*n* = 118) from a lower gravel and a handaxe assemblage (*n* = 102) from the upper gravel, separated by a depositional hiatus (Callow, in Cruse 1987). The different locations of these trenches in relation to the terrace formation may explain the differences in the archaeological remains each contains, the shallow sequences towards the edge of the terrace containing a conflated sequence that conceals the separation of handaxe and non-handaxe assemblages found in Cruse's section. Roe's (1968) analysis of 160 handaxes from Tester's excavations placed them in Group I (with cleavers). Six proto-Levallois cores and flakes were reported by Tester (1965) within the Acheulean assemblage, although these were questioned by Callow (in Cruse 1987), who was also hesitant to correlate the non-handaxe signature from Cuxton

with the Clactonian. Nonetheless, the archaeological sequence at Cuxton shows an intriguing similarity to the sequence of assemblages found at Purfleet.

The Corbets Tey terrace of the Lower Thames has produced significant assemblages from Lower Clapton and further sites in the Grays Thurrock area, while from the Lynch Hill terrace of the Middle Thames there are a rich series of sites from pits between Reading, Maidenhead and Burnham to the west of London, which include Baker's Farm, Furze Platt, Lent Rise, Grovelands Pit and Sonning. Many of the sites on the Corbets Tey-Lynch Hill terrace have shared archaeological characteristics with most of the handaxe assemblages attributed to Roe's (1968) Group I, while many contain elements of PCT. The middle terraces of other river systems have also been attributed to the MIS 10–9–8 climatic cycle (SOM Table 2). There are large collections from the tributaries of the former Solent River, such as East Howe Pit on the Terrace 8 of the Stour in Bournemouth, Warsash on Terrace 3 of the Test with upstream equivalents at Romsey and Dunbridge. There are several further sites in the catchment of the Ouse with Biddenham and Kempston, near Bedford, on Terrace 3 of the Great Ouse, and Barnham Heath on a middle terrace of the Little Ouse in Suffolk. Other sites in East Anglia include Keswick on the River Yare and Southacre on the Nar, both in Norfolk. Initial research by White and Bridgland (2018) indicates some similarities of the Solent and East Anglian assemblages with those in the Thames valley, although this is the subject of ongoing work.

SOM S2

Methodology for lithic analysis

The following attributes were recorded from all retouched flakes in line with the methodologies of Inizan et al. (1999) and Scott (2011).

Quantitative measurements

Length, width and thickness of flake tools, recorded in mm.

Elongation was calculated from these measurements by dividing width by length.

Length of retouch, recorded in mm.

Length of retouch was also calculated as a proportion of artifact length.

Qualitative observations

Typology: Flake tools were categorized (SOM Table 3) based on their characteristics. These categories allowed comparison to other sites both in Britain and Europe.

Position of retouch was recorded as an assessment of whether retouch was confined to one side of the artifact. Where only one side was retouched the relation to the dorsal surface was recorded (SOM Fig. S1):

- Direct—Retouch on the dorsal surface.
- Inverse—Retouch on the ventral surface.
- Alternate—Retouch on opposite edges on both faces.
- Bifacial—Retouch of both faces on the same edge.

Distribution of retouch was recorded as an assessment of whether the retouch was one sequence or unrelated ad hoc removals (SOM Fig. S2):

- Continuous

- Discontinuous

Regularity of retouch was recorded. While similar to distribution, this was an assessment of how uniform retouch was:

- Regular
- Irregular

Form of the retouched edge was recorded as an assessment of the shape the edge of the tool had been retouched into (SOM Fig. S3):

- Rectilinear
- Convex
- Concave
- Notch
- Denticulate

Invasiveness of retouch was recorded as an assessment of the extent the retouch on the surface of the flake tool (see SOM Fig. S4):

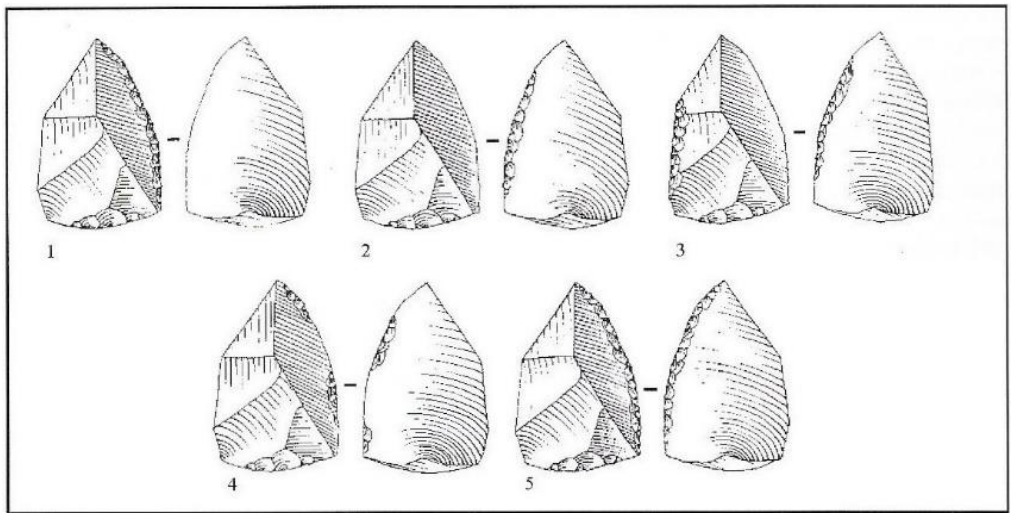
- Minimally invasive
- Semi-invasive
- Invasive

Location of retouch was recorded as an assessment of where the flakes had been retouched:

- Distal
- Left
- Right
- Multiple
- Proximal

To confidently identify Levallois flakes, the criteria used by Scott (2011) were followed:

- Hard hammer percussion.
- Large number of dorsal scars, possibly in a complex pattern.
- Removed from the surface rather than the volume of the core, making the flake relatively flat.
- Signs of distal and lateral convexities being controlled.
- May retain evidence of faceting or other methods of platform preparation.
- May retain evidence of deliberate convexity accentuation, including small peripheral flake scars.



SOM Figure S1. Position of retouch 1) direct, 2) inverse), 3) alternate, 4 and 5) bifacial (modified after Inizan et al., 1999 and Scott, 2011).

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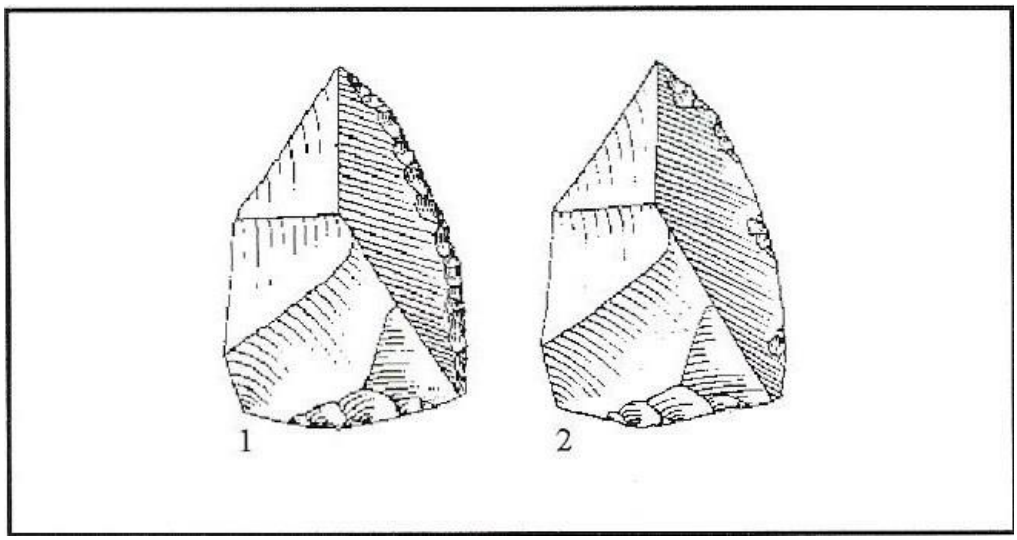
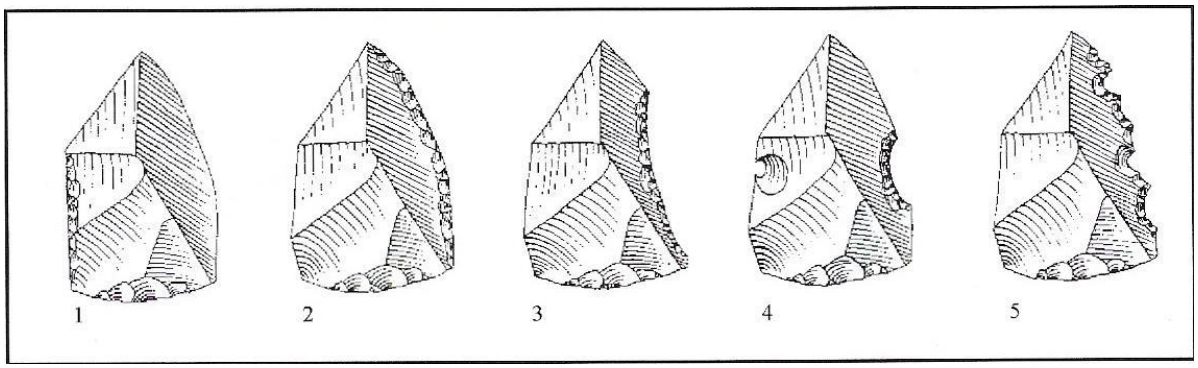
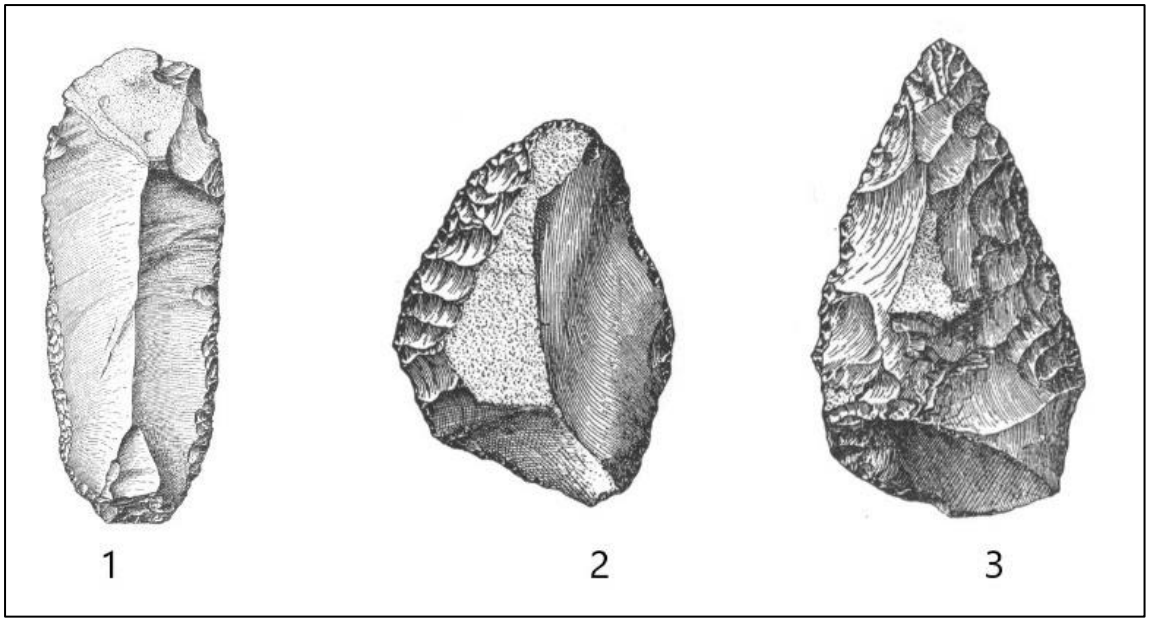


SOM Figure S2. Distribution of retouch 1) continuous and 2) discontinuous (modified after Inizan et al., 1999 and Scott, 2011).



SOM Figure S3. Form of retouch 1) rectilinear, 2) convex, 3) concave, 4) notch, and 5) denticulate (modified after Inizan et al., 1999 and Scott, 2011).



SOM Figure S4. Invasiveness of retouch 1) minimally invasive, 2) semi-invasive, and 3) invasive (modified after Kelley, 1937).

SOM Table 1

Summary of Purfleet sequence showing geology, archaeology, and environments (after Bridgland et al., 2013; White and Bridgland, 2018).

Bed #/name	Thickness	Archaeology	Pit	Environment
8. Botany Gravel	2 m	Proto-Levallois/Levallois	Greenlands, Bluelands, Botany	Cold?
7. Grey-brown silty clay, weathered	<0.75 m			Temperate?
6. Bluelands Gravel	Up to 6 m	Acheulean	Bluelands, Greenlands, Esso, Botany	Cold?
5. Greenlands Shell Bed	Up to 2 m	? a few flakes		Temperate. Contains an abundance of temperate shells, most articulated in life-position, as well as thermophilous fish and an interglacial mammalian fauna. A range of local marshland, woodland, and grassland, and slow-to fast-moving aquatic habitats are indicated, including a weak brackish influence.
4. Laminated Silty Clay	<0.25 m			Temperate. Possibly tidal sedimentation during high sea levels. Temperate ostracod, some with brackish tolerances. Mosaic open woodland with 70% temperate arboreal pollen including oak, ash, lime, elm, and spruce. Remains of green frog suggest mean July temperatures ~15–17°C.
3. Shelly Gravel	<0.75 m	Non-handaxe (cf. Clactonian)	Greenlands, Bluelands	Temperate
2. Little Thurrock Gravel	<0.4 m	Non-handaxe (cf. Clactonian)	Greenlands, Bluelands	Cold
1. Angular chalk rubble (Coombe Rock) lying on chalk	1 m	Non-handaxe (cf. Clactonian)	Greenlands, Bluelands	Cold

SOM Table 2

Summary of secondary context sites correlated to MIS 9.

System	Area	Sites	MIS	Archaeology	Context	Main collectors	References
Thames	Maidenhead	Pits in Furze Platt area including Cannoncourt Farm	10–9–8	Acheulean	Lynch Hill Terrace. 4 m of bedded gravel, overlain by a pebbly, silty clay.	Treacher, Lacaille	Wymer (1968); Bridgland (1994)
	Farnham Royal	Baker's Farm	10–9–8	Acheulean PCT	Lynch Hill Terrace. Similar to Furze Platt. Ill-sorted fluvial gravels overlying Reading beds. Artifacts associated with lowest part of stratified gravels.	Treacher, Lacaille	Wymer (1968)
	Burnham	Lent Rise	10–9–8	Acheulean PCT	Lynch Hill Terrace. Similar to Furze Platt. Ill-sorted but stratified gravel overlain by brickearth.	Lacaille	Wymer (1968)
	Reading	Grovelands Pit	10–9–8	Acheulean	Lynch Hill Terrace. Bluff gravel between the Lynch hill and Taplow terraces. 4 m of gravel underlain by sand and clay.	Treacher	Wymer (1968)

	Grays Thurrock		10–9–8	Acheulean	Related to the Lynch Hill/Corbets Tey formation, precise provenance of archaeology uncertain due to general provenance stated. Artifacts associated with thin deep-red seam of gravel.	W.G. Smith; Hinton and Kennard	Wymer (1968)
	Lower Clapton		10–9–8	Acheulean	Lynch Hill Terrace. Linked to Palaeolithic floor at Stoke Newington.	W.G. Smith	Bridgland (1994)
	Sonning	Sonning Railway Cutting	10–9–8	Acheulean PCT	Lynch Hill Terrace. Gravel removed during the widening of Great Western Railway. East end of the cutting, and therefore part of the Lynch Hill terrace.	Shrubsole; Treacher	Wymer (1999)
Kentish Stour	Sturry	Pits including Homersham's East and West	10–9–8	Acheulean	Terrace 2 of the Stour. 25 m Terrace. Loose, open framework gravel. Variable gravels with large scale cross bedding.	Rice; R. Smith	Bridgland et al. (1998a, b)

Solent	Bournemouth	East Howe, Brixey & Good's Pit, Redhill Common	10–9–8	Acheulean PCT	Stour Terrace 8. 19 m above the Stour.	Local collectors	Westaway et al. (2006)
	Dunbridge	Several pits covering two terraces	?	Acheulean PCT	Terrace 2/3 of the Test. Two gravel terraces: Upper Belbin Formation and a Lower Mottisont formation.	Local collectors; Harding and Bridgland	Harding et al. (2012); Davis et al. (2021)
	Romsey	Several pits	?	Acheulean ?	Terrace 4 of the Test ~41 m ordnance datum.	Local collectors	Davis et al. (2021)
	Warsash	Several pits	10–9–8	Acheulean PCT	Top of Terrace 3 of Test. Varying thickness of gravel across four pits (New, Park, Dykes, and Newbury). Split in Lower and Upper Warsash terraces.	Codrington; Draper; Mogridge	Westaway et al. (2006); Davis et al. (2016); Hatch et al. (2017)
Great Ouse	Biddenham/Kempston	Several pits	10–9–8	Acheulean PCT	Terrace 3 gravels, sands and silts 'Biddenham member', at 14.5–18 m ordnance datum. Archaeology associated with organic beds with rich temperate signatures.	W.G. Smith; Wyatt	Harding et al. (1991) Boreham et al. (2010)
Little Ouse	Barnham Heath	Newport's Pit	11–9	Acheulean PCT	6–8 m above the flood plain.	Brown	Wymer (1985)

					5.8 m of sandy gravels resting on disturbed chalk with archaeology coming from the base.		
Kennett	Kennett/Kentford	Station Pit	10–9–8	Acheulean	Terrace 3. 4–5 m of gravel well bedded gravel.	Wright and Whitaker	Boreham et al. (2010)
Nar	Southacre	Bartholomew's Hills Pit and Thorpe Gravel Pits	10–9–8	Acheulean PCT?	Terrace 4. Sandy cross bedded gravel, no distinction.	Sainty	Boreham et al. (2010)
Yare	Keswick		?	Acheulean PCT?	Yare Valley Gravel at 15 m above the river. Little detailed recording.	No formal work; Lawrence	Cranshaw (1983); Wymer (1985)

PCT = Prepared core technology.

SOM Table S3

Typological categories of flake tools.

Scrapers	Sidescraper
	Endscraper
	Convergent scrapers
	Doubled scrapers
Notches	
Denticulates	
Bifacially worked	
Miscellaneous	

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