Journal of Paleolithic Archaeology (2024) 7:13
https://doi.org/10.1007/s41982-024-00177-z

RESEARCH

# Making a U-turn on the Purfleet Interchange: Stone Tool Technology in Marine Isotope Stage 9 Britain and the Emergence of the Middle Palaeolithic in Europe

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Accepted: 6 April 2024


## Abstract

This paper re-examines earlier Palaeolithic core technology from British sites assigned to MIS 11, 9, and 7 using primarily a chaîne opératoire approach, with the objective of better understanding the earliest occurrence and distribution of Levallois and other prepared-core technologies across the Old World. Contrary to previous interpretations (White and Ashton in *Current Anthropology, 44*: 598–609, 2003), we find no evidence for a true Levallois concept in MIS 11 or MIS 9 in Britain. Cores previously described as 'simple prepared cores' or 'proto-Levallois' cores show neither evidence of core management nor predetermination of the resulting flakes. They can instead be explained as the coincidental result of a simpler technological scheme aimed at exploiting the largest surface area of a core, thereby maximising the size of the flakes produced from it. This may be a more widespread practice, or a local solution derived from existing principles. Levallois appears fully formed in Britain during terminal MIS 8/initial MIS 7. Consequently, Britain does not provide evidence for an in situ evolution of Levallois, rather we argue it was introduced by new settlers after a glacial abandonment: the solution to the emergence and significance of Levallois lies in southern Europe, the Levant and Africa.

**Keywords** Levallois · Simple prepared cores · Hierarchically worked cores · Lower-Middle Palaeolithic transition · Europe · Africa · Western Asia

## Introduction

One of the rare near-consensuses amongst Palaeolithic archaeologists is that the appearance of Levallois technology in Europe from ~320 ka (MIS 9) marks the beginning of the Middle Palaeolithic (e.g., Ronen (1982); Gamble and Roebroeks (1999); Scott, 2011; Hérisson et al., 2016a; Malinsky-Buller, 2016a, 2016b). In this marker role, Levallois also serves as proxy for a range of inferred behavioural changes we have come to associate with this transition, such as more intensive and mono-specific hunting practices, more complex composite technologies, wider-ranging mobility patterns, and more strategically organised use of the landscape (Hopkinson, 2007; Moncel et al., 2011, 2012, 2020; Fontana et al., 2013). There is far less agreement, however, on precisely what these changes signify in terms of human demography, dispersal, and settlement during the late Middle Pleistocene.

The past quarter-century has seen an intensification of research into the Lower-Middle Palaeolithic transition, with continuing debate on whether the appearance of Levallois marks independent technological developments among indigenous Eurasian and African populations (White & Ashton, 2003; Moncel et al., 2011, 2012; Malinsky-Buller, 2016b), or whether it registers the incursion of new technologies, practices, and peoples from Africa (Foley & Lahr, 1997; Lahr & Foley, 1998; Zaidner & Weinstein-Evron,

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Published online: 10 May 2024

2020). In other words, whether Levallois is a technology of convergence, with common roots in the Acheulean and multiple geographical origins, or a unique formula with a single African provenance, which spread via dispersal or diffusion to other parts of the Old World (Foley & Lahr, 1997; White et al., 2011). While it is now indisputable that sophisticated prepared-core technologies were in use in Africa from 1.1 Ma (McNabb and Beaumont, 2012; Li et al., 2017), with full Levallois in large form appearing by 400 ka (Shipton, 2022), the question of technological convergence remains (Eren et al., 2018).

The ~ 320-ka (MIS 9) site at Purfleet (Essex), England, has played a pivotal role in these discussions, arguably providing evidence for the local emergence of 'simple prepared cores' (hereafter SPC, aka 'proto-Levallois') and 'precocious' early Levallois from pre-existing technologies, an entire glacial period before full Levallois became widespread across Europe in terminal MIS 8 to early MIS 7, and at the outer fringes of Europe in relation to Africa (White & Ashton, 2003; Scott & Ashton, 2011). Here, we take a fresh look at the significance of the Purfleet artefacts in British and European contexts through a new and detailed technological study of core reduction at 14 sites from the MIS 9 'Purfleet' interglacial (Bridgland et al., 2013; Rawlinson, 2021). We compare these to core technologies from British sites dating to MIS 11 and 7. We aim to clarify the nature and definition of the Purfleet core technology, examine its wider occurrence, and determine its relationship to similar core technologies and to Levallois.

## When Is Levallois Not Levallois?

The term Levallois was first applied to describe a singular assemblage of flakes from a pit near Levallois-Perret, Paris (Reboux, 1867), although it was only later that Levallois cores were recognised and named as the primary source of such flakes (Spurrell, 1883; de Mortillet, 1891). Since the beginning of the 20th Century (Commont, 1909), Levallois has been used to describe a variety of flakes and cores that were united not only by form but by the technological method used to produce them, viz, careful pre-shaping of the parent core that enabled the knapper to remove one or more 'target' flakes of a predetermined shape and size. While the degree of standardisation (a different concept to predetermination) achieved by these methods was questioned (Dibble, 1989) and problems of inter-analyst variance a cause of concern (Perpére, 1986), the notion that Levallois cores were deliberately shaped with the intention of exercising prior control over the form of the target flake/s remains the majority understanding (contra Dibble, 1989; Moore & Perston, 2016).

Predetermination is central to the modern conceptualisation of Levallois provided by Boëda (1986, 1988). For Boëda, Levallois is a way of managing the volume of a core geared towards controlling the form of the flakes produced from one of its surfaces. It depends on six technological and volumetric criteria (Fig. 1), all of which must be present for the technological system to be regarded as Levallois. Within the overarching Levallois concept, Boëda recognised two principal methods of exploitation: recurrent, whereby several target flakes were removed from each flaking surface; and lineal or preferential, in which the flaking surface was designed to produce a single target flake. Flaking surfaces could be dressed using several preparatory methods (centripetal, convergent, unipolar, bipolar and Nubian/distal divergent) and configured to yield a range of flat flake forms for hafting, retouching, and use (ovoid, rectangular, pointed, blade-like), but all conform to the same overarching Levallois concept. Such approaches require the analyst to 'read' the life-history of the core from its flake scars, and to infer from this the knowledge, know-how, and intentions of the original knapper (see Schlanger, 1996). It is deliberately non-quantitative, although attempts have been made to quantify it (Clarkson, 2010). The earliest known cores that fully conform to Boëda's Levallois concept are found in an Acheulean context in the Kapthurin Formation, Kenya, dated by tephrochronology to ~ 400 ka (Tryon et al., 2006; Blegen et al., 2018; Shipton, 2022).

Levallois is one of several knapping systems that fall within the wider 'Mode 3' family of lithic technologies (Clark, 1969, 32), in which the knappers aimed 'first and foremost at producing flake tools, and to this end [went] to particular trouble to prepare cores from which they could be struck in a finished fashion'. These include the Victoria West technique of South Africa (Jansen, 1926), targeted at the production of large right-side-struck flakes for cleavers and handaxes, and the Tachengit-Tabelbala technique from the NW Sahara region, specifically designed to produce preformed sharp-edge cleavers, similarly side-struck but predominantly from the left rather than the right (Shipton, 2019). In conception, preparation and sometimes in form these are comparable to Levallois, but their precise execution differs because the flakes are side-struck (wider than they are long), rather than end-struck (longer than they are wide) (Criterion 5). Such formalised large flake-blank production methods have long been considered an integral part of the African Acheulean (van Riet Lowe, 1945; Sharon, 2007) and are much older than Levallois, with the earliest Victoria West examples found in Acheulean contexts at Canteen Koppie and Wonderwerk Cave Strata 10, South Africa, in deposits dated to between ~ 1 and 0.8 Ma (Beaumont & Vogel, 2006; McNabb and Beaumont, 2012; Chazan, 2015; Li et al., 2017; Shaar et al., 2021), with Tachengit-Tabelbala

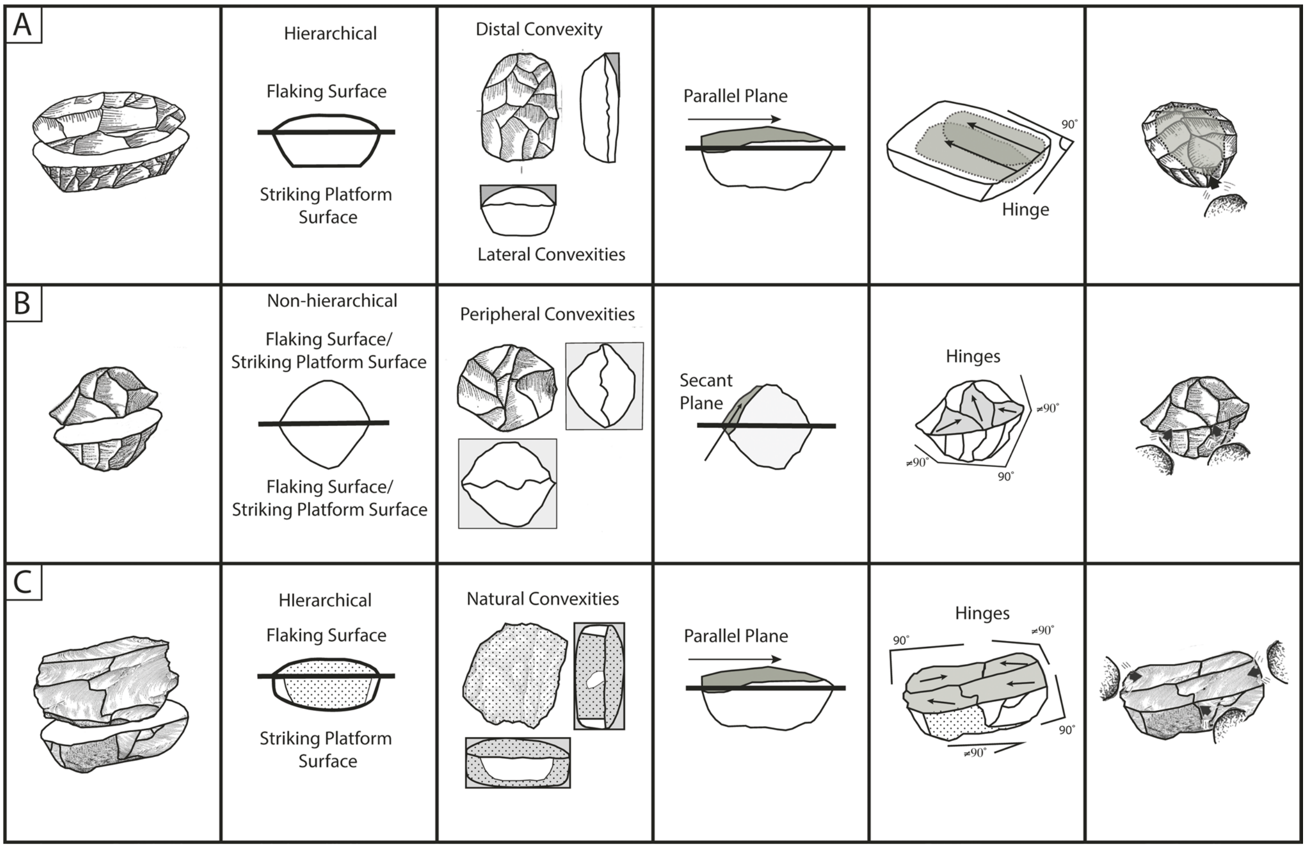


**Fig. 1** Schematic diagram showing the volumetric concepts involved in **A** Levallois, **B** Discoidal, and **C** Hierarchically Worked Cores. Boëda's six criteria for full Levallois (**A**) are from left to right: (1) two surfaces with single plane of intersection; (2) flaked hierarchically with distinct striking platform(s) and flaked surface; (3) control of convexity on flaking surface; (4) flaking surface usually parallel to plane of intersection; (5) hinge perpendicular to long-axis of percussion; (6) hard hammer percussion

appearing ~ 1 Ma as part of the 'second' Acheulean in northwest Africa (Gallotti et al., 2021).

Another knapping system often considered to fall into Mode 3 in terms of core exploitation is that represented at Purfleet, which has been variously termed proto-Levallois (Wymer, 1968), reduced-Levallois (Roe, 1981) and simple prepared cores (White & Ashton, 2003). A similar technology has been described from a number of European and western Asian locations, where it has likewise been given a variety of names: Levallois sensu lato (Callow, 1976), recurrent non-Levallois (Ameloot-van der Heijden, 1993), central surface cores (Barzilai et al., 2006), preferential surface debitage (Zaidner, 2014), discoids sensu lato (Mourre, 2003; Peretto et al., 2016), and hierarchical discoids (Clarkson, 2007; Bustos-Pérez et al., 2023). Malinksy-Buller (2016b) has proposed the umbrella term *hierarchically worked cores* to capture the essence of this technology, isolating the differential treatment of two surfaces across a plane of intersection without any management of the surfaces (Criterion 3) as the key for identification (Fig. 1). This type of technology is also found at Rietputs, South Africa, as early as 1.3 Ma and sporadically across Eurasia from ~ 750 ka (Leader et al., 2017), with an apparent increase in the frequency of use after MIS 9. The key technological characteristics are shown diagrammatically in Fig. 1C.

For present purposes, we retain the term we (White & Ashton, 2003) originally used to define the Purfleet and other British cores: 'simple prepared cores' (hereafter SPC). This technology is also characterised by cores with two main volumes separate by a plane, intersecting at a flat angle, typically exhibiting little or no preparation and maintenance of convexities; they have previously been considered to be hierarchical. It is the character of this technology and its relationship to classic Levallois and other European technological systems generally termed 'hierarchically-worked cores' that forms the main subject of this paper.

## Materials and Methods

A database of lithic reduction systems was compiled for 29 British assemblages, 13 from MIS 9, 11 from MIS 11, and five from MIS 7 (see Table 1 and SOM 1). Data for MIS 7 assemblages was taken from Scott, 2011, MIS 9 assemblages from Rawlinson, 2021, while MIS 11 materials were re-examined by the authors for the purposes of this paper.

Sites were selected on the basis of a secure context, a well constrained age, a known collection history, and being predominantly in fresh condition (Table 1 and references therein). Included in this list are several assemblages known to contain SPC and frequently mentioned in the developing MIS 9 archaeological narrative (Roe, 1981; Wymer, 1999; White & Ashton, 2003; Pettitt & White, 2012; Bolton, 2015; White & Bridgland, 2018; Rawlinson, 2021), but which are known to be deficient in one or more of the above selection criteria. They have been initially included for any information that can be gleaned for discussion but have not been incorporated into our interpretations because of problems of collection bias, or issues over context and age.

As the principal aim of this study is to understand the processes and technological concepts underlying core reduction during MIS 9, our main method involved reconstructing the technological biographies of each core following the chaîne opératoire approach of Boëda (1986, 1988, 1995). Each core was thus examined and assigned to one of the systems of earlier Palaeolithic debitage outlined by Boëda (see Fig. 1). Cores that conformed to all six of Boëda's technological criteria for Levallois, with evidence of predetermination of the target flakes, were classified as Levallois. Methods of exploitation (lineal, recurrent) and preparatory working on the flaking surfaces were also recorded. Cores that conformed to Boëda's definition of a discoidal core, i.e., showing non-hierarchical working on both sides of a plane intersection and a steep flaking angle, were classed as discoidal. Cores conforming to the description of hierarchically worked cores given above and in Fig. 1C were classed accordingly, and their chaîne opératoire interrogated in detail.

For the purposes of this paper, cores worked by Boëda's 'Trifacial' and 'Clactonian' systems of debitage and those belonging to the 'Chopper' system of façonnage were subsumed under the category of 'Single and Migrating Platform Core' (SMPC). These systems all involve similar simple methods and techniques applied in a more or less intensive fashion to irregularly shaped blocks, and their classification can vary widely between analysts. The aim of this combined system is to remove flakes from an abstract volume by identifying or creating and then exploiting suitable platforms, directing force through a secant plane, using a basic suite of parallel and alternating removals. There is no operational hierarchy, no control over the shape of the core or the morphology of the flakes, and no maintenance of platforms, with new platforms often sought or created on another part of the core upon exhaustion of existing ones. These cores tend to come in all shapes and sizes, their form largely depending on the morphology of the original nodule and the methods used by the knapper to exploit them, the latter aimed at optimising the potential of the nodule in either the quantity or size of flakes produced. Choppers were included as SMPCs because refitting groups at High Lodge (Ashton et al., 1992) show that some choppers were by-products of intensive and sustained alternate flaking and perhaps not the primary target (although they might nonetheless have later been reworked and used). The question of whether these 'choppers' are cores or tools has a long history of debate across several continents (Breuil, 1932; Warren, 1932; Toth, 1985; White, 2023), with Wymer (1968) adopting the neutral term 'chopper-core' to sidestep the issue. No examples of the Quina, Hummal, or Rocourt chaînes opératoire were identified, so these are not defined here.

The conceptual approach of Boëda has been criticised as being over reliant on non-reproducible observations (e.g. Bar-Yosef and Van Peer, 2009; Monnier and Missal, 2014), although we would still argue that it is the most powerful tool for understanding technological process. However, to complement the chaînes opératoire approach, quantitative data was also recorded for cores and flakes. For cores, maximum length, width, and thickness were measured, orientated according to the longest axis or the main axis of flaking, from which indexes for elongation (width/length) and flattening (thickness/width) were produced. The number of scars and their technological configuration were counted along with the percentage of residual cortex, to gain a relative estimate of the complexity and intensity of core preparation. For flakes, there were difficulties in distinguishing the knapping process from which they were derived, with very few clear Levallois products. Therefore, all flakes were measured with axial length, width, and thickness from which elongation (W/L) was derived. This quantitative data from the MIS 9 sites was compared to Levallois cores and flakes from the main MIS 7 sites, which was based on Scott (2011).

## Results

### Chronological Distribution of Technological Systems

Table 1 shows a summary of the chaîne opératoire present in all 29 assemblages in our sample. Single/migrating platform cores are present at almost all sites regardless of age,

**Table 1** Site, context, age, and technological summary for 29 British Middle Pleistocene lithic assemblages. (TF = Terrace Formation. BH-OH = Boyn Hill-Orsett Heath. LH-CT = Lynch Hill-Corbets Tey)

| Site | Context | Age | Flakes | Flake Tools | Handaxes | SMPC/ Chopper Core | Dis-coidal Cores | Simple Prepared Cores | Leval-lois Cores | Levallois flakes | Key Refs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Clacton on Sea, Essex (Warren Collection) | Fluvial Gravel BH-OH TF | MIS 11c | 774 | 65 | 0 | 84 | 20 | 5 | 1 | 0 | Singer et al. (1973); Bridgland (1994); White et al. (2023) |
| Swanscombe Barnfield Pit (Waechter Excava-tions) | Lower Gravel BH-OH TF | MIS 11c | 871 | 69 | 1 | 45 | 2 | 4 | 1 | 0 | Ashton and McNabb (1996); Bridgland (1994); White et al. (2013) |
| Swanscombe, Barnfield Pit (Wymer) | Middle Gravel BH-OH TF | MIS 11c | 18,346 | 88 | 199 | 32 | 2 | 2 | 1 | 0 | Wymer (1964); Bridgland (1994) |
| Swanscombe, Barnfield Pit (Marston A, D) | Middle Gravel BH-OH TF | MIS 11c | 1000s | 10s | ~900 | 68 | 7 | 4 | 1 | 0 | Wymer (1964); Bridgland (1994) |
| Foxhall Road, Ipswich | Fluvial sand and gravel | MIS 11c | 152 | 7 | 36 | 17 | 1 | 1 | 0 | 0 | White and Plunkett (2004); White et al. (2019) |
| Bowmans' Lodge | Gravel, BH-OH TF | MIS 11c | 35 | 12 | 29 | 72 | 1 | 2 | 0 | 0 | Bridgland (1994); Tester (1951); Wymer (1968) |
| Barnham, Area I, Suf-folk | Fluvial silt | MIS 11c | 600 | 30 | 0 | 24 | 2 | 1 | 0 | 0 | Ashton et al. (1998), Ashton et al. (2016)) |
| Barnham, Area I, Suf-folk | Cobble Band | MIS 11c | 428 | 16 | 1 | 40 | 0 | 4 | 0 | 0 | Ashton et al., (1998, 2016) |
| Elveden, Suffolk (BM excavations) | Gravel and Black Clay | MIS 11c | 1084 | 10 | 12 | 32 | 2 | 0 | 0 | 0 | Ashton et al. (2005) |
| Hoxne, Suffolk (Wymer excavations) | Lower Industry | MIS 11a | 715 | 9 | 13 + | 11 | 1 | 0 | 0 | 0 | Singer et al. (1993); Ashton et al. (2008) |
| Red Barns, West Sussex | Grey Loam | MIS 11–9 | 1943 | 5 | 19 | 3 | 0 | 1 | 0 | 0 | Wenban-Smith et al. (2000) |
| Globe Pit, Little Thur-rock | Bluelands Gravel, LH-CT TF | MIS 10–9 | 551 | 4 | 2 | 9 | 1 | 0 | 0 | 0 | Wymer (1985); Bridgland and Harding (1993); Conway (1996) |
| Stoke Newington, London | Gravel, LH-CT TF | MS 9 | 481 | 50 | 232 | 13 | 0 | 0 | 0 | 0 | Wymer (1968); Green et al., (2004, 2006) |
| Wolvercote | Gravel, LH-CT TF | MIS 9 | ~80 | 7 | 78 | 3 | 0 | 0 | 0 | 0 | Tyldesley (1986); Wymer (1968); Roe (1968); Bridgland (1994) |
| Baker's Farm, Slough | Gravel, LH-CT TF | MIS 9–8 | 259 | 47 | 239 | 3 | 0 | 3 | 0 | 1 | Wymer (1968); Bridgland (1994) |
| Purfleet, Botany Pit | Botany Gravel, LH-CT TF | MIS 9–8 | 458 | 114 | ~12 | 160 | 3 | 131 | 3 | 5 | Bridgland et al. (2013); White and Ashton (2003); Wymer (1968, 1985) |

**Table 1** (continued)

| Site | Context | Age | Flakes | Flake Tools | Handaxes | SMPC/ Chopper Core | Dis-coidal Cores | Simple Prepared Cores | Leval-lois Cores | Levallois flakes | Key Refs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Furze Platt, Cannoncourt Farm Pit, Maidenhead | Gravel, LH-CT TF | MIS 9–8 | 324 | 32 | 500 | 2 | 0 | 0 | 0 | 1 | Wymer (1968); Roe (1981); Bridgland (1994); Dale (2022) |
| Lent Rise, Burnham | Gravel, LH-CT TF | MIS 9–8 | 120 | 18 | 108 | 1 | 0 | 1 | 0 | 0 | Wymer (1968); Bridgland (1994) |
| Sonning Railway Cutting | Gravel, LH-CT TF | MIS 9–8 | 23 | 6 | 13 | 1 | 0 | 2 | 0 | 0 | Wymer (1968); Bridgland (1994) |
| Cuxton, Tester Collection | Medway Terrace Gravel | MIS 9–8 | 429 | 32 | 177 | 23 | 0 | 3 | 0 | 0 | Tester (1965); Cruse et al. (1987); Bridgland (2006) |
| Barnham Heath, Suffolk | Little Ouse Terrace 2 & 3 | MIS 9–7 | 308 | 16 | 83 | 32 | 0 | 14 | 3 | 2 | Wymer, 1985, Davis et al. in prep |
| Biddenham, Bedfordshire | Great Ouse Terrace 3 | MIS 9–8 | 517 | 47 | 109 | 8 | 5 | 12 | 1 | 2 | Harding et al. (1991); Wymer (1999) |
| Kempston, Beds | Great Ouse Terrace 3 | MIS 9–8 | 125 | 27 | 120 | 5 | 0 | 3 | 0 | 0 | Wymer (1999); Luke (2007) |
| Dunbridge, Station Pit | Test | MIS 9–8 | 117 | 15 | 97 | 14 | 0 | 4 | 0 | 0 | Harding et al. (2012); Davis et al. (2021); Dale (2022) |
| Baker's Hole Northfleet | Coombe Rock Taplow-Mucking TF | Late MIS 8 | 100s | 19 | 0 | 0 | 0 | 0 | 19 | 108 | Scott (2011) |
| West Thurrock | Basal Gravel Taplow-Mucking TF | Late MIS 8 | 171 | 2 | 2 | 0 | 0 | 0 | 5 | 23 | Schreve et al. (2006) |
| Ebbsfleet Channel | Lower Fluvial deposits Taplow-Mucking TF | 7 | 339 | 26 | 2 | 6 | 0 | 0 | 18 | 48 | Scott (2011) |
| Crayford, Stoneham's Pit | Lower Brickearth, Taplow-Mucking TF | 7 | 100+ | ? | 0 | 1 | 1 | 0 | 5 | 9 | Kennard (1944); Scott (2011) |
| Creffield Road, NW London | Top of gravel under brickearth, Taplow-Mucking TF | 7 | 182 | 30 | 0 | 2 | 0 | 0 | 15 | 123 | Brown (1887); Scott (2011) |

underlining the fact that minimally structured applications of parallel and alternate flaking represent the basic building blocks of lithic technology (Forestier, 1993; White, 2000). Flake tools are similarly found at all sites but there is no linear increase in the importance or craftsmanship of flake tools over time, and no explosion in scraper production in MIS 9 (cf. White & Bridgland, 2018; Rawlinson et al., 2022).

Discoidal cores occur in small numbers in 44% of British earlier Palaeolithic assemblages, with only Clacton having > 10 examples. SPC of the type found at Purfleet and argued to represent an emergent form of Levallois (Wymer, 1968; Roe, 1981; White & Ashton, 2003) are found in small numbers at eight of 11 assemblages from MIS 11, and eight of 13 MIS 9 sites, but have not been identified in MIS 7. Two cores from the terminal MIS 8 deposits at West Thurrock (Warren Collection) have been compared with Purfleet (Schreve et al., 2006), but these represent little more than individual sequences of alternate flaking, with a short parallel episode to create a platform along the short axis, followed by a longer parallel sequence along the longest axis of a nodule. Only at Purfleet (131 of 297), Biddenham (12 of 26), and Barnham Heath (14 of 49) do SPCs form a major component of the assemblages.

True Levallois forms the dominant, and often only, mode of reduction in all MIS 8–7 assemblages, but is virtually absent prior to this date, beyond isolated examples of morphologically Levallois-like cores from MIS 11 contexts at Swanscombe and Clacton, and MIS 9 locations at Purfleet ($n = 3$ of 297) and Biddenham ($n = 1$ of 26). At Barnham Heath, the few true Levallois cores ($n = 3$ of 49) are likely to be from the MIS 7 deposits in the northern part of the locale (see below). Levallois flakes are absent from MIS 11 and occur as only individual finds or as a very small percentage of the total at Barnham Heath and the above MIS 9 locations, with single examples also reported at Furze Platt and Baker's Farm. It is worth noting that, while these last two sites have both yielded large and well-studied handaxe assemblages, the general lack of cores is understood to be due to collector bias by Llewellyn Treacher (Cranshaw, 1983). The few in the collections were saved from all those he ignored precisely because they were different and 'Middle Palaeolithic' in type. Similar biases clearly exist in the small sample ($n = 3$) of SPC from Baker's Farm, which also have the distinction of being the largest in our sample (Table 4). While cores are rare even in more recent investigations (Harding & Bridgland, 1999), these examples have survived probably because they were large, which was Treacher's particular penchant, not because they were representative. A similar argument can be forwarded for Sonning, where the small collection of cores and flakes consists of metrically larger pieces than those from other sites (Table 4).

## Metrical Characteristics

Summary metrics for MIS 9 cores and flakes are presented in Tables 2, 3, 4, 5 and 6, alongside Levallois cores and Levallois flakes from the main MIS 7 sites. While there are differences between SPC and other cores in terms of length, width, and thickness, the direction of this variation is unpredictable, with average SMPC sometimes larger than SPC, and sometimes smaller. Only flatness appears to be consistent with SPC on average flatter than their SMPC counterparts.

Intra-assemblage comparison of SPC and SPMC at Purfleet, Biddenham, and Barnham Heath was conducted using a two-tailed Student's $t$ test (see SOM 2). The results indicate a statistically significant difference in core thickness between SMPC and SPC at both Purfleet and Barnham Heath ($t(296) = 3.41$, $p = 0.001$ and $t(48) = 2.86$, $p = 0.007$, respectively). This is not observed at Biddenham, however, where no significant differences between the two core types were apparent across any of the recorded metrics. Significant differences between the length ($t(48) = 2.74$, $p = 0.009$) and flatness ($t(48) = 3.01$, $p = 0.004$) of the two core types was also observed for the Barnham Heath assemblage. These differences may be explained by taphonomic and/or collector issues (see below). Otherwise, there does not appear to be a statistically significant difference in core flatness at Purfleet or Biddenham, suggesting that, where present, observed variation in core flatness may be driven by high variability in overall core thickness.

Maximum flake dimensions are dependent on the typical size of the local raw materials and are variable across MIS 9 sites, with mean lengths ranging from 55 to 95 mm. There is also little evidence that this method produced more laminar flakes, with the mean elongation of flakes from MIS 9 contexts showing that width and length were more or less equal.

The length data for the Purfleet flakes appears to show slight bimodality, with peaks at 60 mm and 80 mm. Whether this reflects the products of two core types or not, there is still too much metrical overlap and too little technological difference to identify them with any confidence (Fig. 2). A similar distribution is seen at Cuxton and Biddenham, although it is absent from Barnham Heath, where the flakes are on average larger than from other sites and, as noted above, almost certainly suffer from biases in taphonomy and/or their collection. Testing for multimodality using the *modetest* function within the *multimode* R package (Ameijeiras-Alonso et al., 2021) indicates that in all cases the presence of multiple modes can be rejected as not statistically significant and the distributions should be considered unimodal (see OSM).

A comparison of means of the MIS 9 SPC and MIS 7 Levallois cores using a Student's $t$ test shows that there is no statistically significant difference in width and

**Table 2** Technological data for all SPC and Levallois cores from MIS 9 and MIS 7 assemblages (Rawlinson, 2021; Scott, 2011)

| Site | n | Flaking Surface Configuration | | | | Method of exploitation | | | # [preferential?] removals | | | | Product | | | Striking surface | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unip | Bip | Cent | Conv | Lin | Rec | Unex | 0 | 1 | 2 | 3 | Flake | Point | Un-expl | Prox | Prox + Dist | One edge | Two sides | Three sides | All | None |
| MIS 9 | | | | | | | | | | | | | | | | | | | | | | |
| Purfleet | 134 | 43.3 | 11.2 | 44.8 | 0.7 | 78.4 | 13.4 | 8.2 | 8.2 | 79.1 | 11.9 | 0.7 | 91 | 0.7 | 8.2 | 41.8 | 32.1 | 0 | 14.9 | 2.2 | 8.2 | 0.7 |
| Baker's Farm | 3 | 0 | 33.3 | 66.6 | 0 | 66.6 | 0 | 33.3 | 33.3 | 66.6 | 0 | 0 | 66.6 | 0 | 33.3 | 0 | 0 | 0 | 0 | 33.3 | 66.6 | 0 |
| Cuxton (Tester) | 4 | 0 | 25 | 75 | 0 | 50 | 25 | 25 | 25 | 50 | 25 | 0 | 75 | 0 | 25 | 0 | 75 | 0 | 0 | 25 | 0 | 0 |
| Sonning | 2 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Barnham Heath | 17 | 11.8 | 35.3 | 47.1 | 5.9 | 70.6 | 0 | 29.4 | 29.4 | 70.6 | 0 | 0 | 64.7 | 5.9 | 29.4 | 11.8 | 11.8 | 0 | 11.8 | 17.6 | 47.1 | 0 |
| Biddenham | 13 | 0 | 38.5 | 61.5 | 0 | 84.6 | 7.7 | 7.7 | 7.7 | 84.6 | 7.7 | 0 | 92.3 | 0 | 7.7 | 7.7 | 30.8 | 7.7 | 7.7 | 23.1 | 23.1 | 0 |
| Kempston | 3 | 0 | 0 | 100 | 0 | 66.6 | 0 | 33.3 | 0 | 66.6 | 33.3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Dunbridge | 4 | 25 | 75 | 0 | 0 | 50 | 0 | 50 | 50 | 50 | 0 | 0 | 50 | 0 | 50 | 25 | 75 | 0 | 0 | 0 | 0 | 0 |
| MIS 7 sites | | ? | | | Con/unip | | | | Levallois products from final flaking surface? | | | | | | Other | | | | | | | |
| Bakers Hole | 19 | | 5.3 | 89.5 | 5.3 | 52.6 | 21.0 | 26.3 | 26.3 | 52.6 | 10.5 | 10.5 | 86.4 | 0 | 13.6 | 0 | 15.8 | 0 | 5.3 | 5.3 | 73.7 | 0 |
| Ebbsfleet | 18 | | 25.0 | 68.7 | 6.3 | 61.1 | 27.8 | 11.2 | 11.1 | 61.1 | 11.1 | 16.7 | 76.5 | 0 | 23.5 | 0 | 0 | 16.7 | 16.7 | 0 | 66.7 | 0 |
| Creffield Road | 15 | | 30.8 | 46.2 | 23.1 | 73.3 | 0 | 26.7 | 40.0 | 53.3 | 0 | 6.7 | 26.7 | 26.7 | 46.6 | 6.7 | 20.0 | 0 | 20.0 | 0 | 53.3 | 0 |
| Yiewsley | 26 | 0 | 0 | 100 | 0 | 53.8 | 26.9 | 19.2 | 15.4 | 57.7 | 19.2 | 7.7 | 84.6 | 0 | 15.4 | 0 | 3.8 | 0 | 0 | 0 | 96.2 | 0 |

**Table 3** Further technological data for all SPC and Levallois cores from MIS 9 and MIS 7 assemblages (Rawlinson, 2021; Scott, 2011)

| Site | n | No. removals on flaking surface | | | | No. removals on striking platforms | | | | % cortex on striking surface | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1–5 | 6–10 | 11–15 | > 16 | 1–5 | 6–10 | 11–15 | > 16 | 0 | 0–25% | 26–50% | 51–75% | > 75% |
| MIS 9 | | | | | | | | | | | | | | |
| Purfleet | 134 | 77.6 | 22.4 | 0 | 0 | 81.4 | 17.9 | 0.7 | 0 | 0.7 | 8.9 | 26.1 | 24.6 | 39.6 |
| Baker's Farm | 3 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 66.7 | 33.3 | 0 | 0 |
| Cuxton (Tester) | 4 | 75 | 25 | 0 | 0 | 75 | 25 | 0 | 0 | 0 | 0 | 25 | 25 | 50 |
| Sonning | 2 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 50 | 0 | 50 | 0 | 0 |
| Barnham Heath | 17 | 47.1 | 52.9 | 0 | 0 | 47.1 | 41.2 | 11.8 | 0 | 5.9 | 35.3 | 47.1 | 0 | 11.8 |
| Biddenham | 13 | 53.9 | 30.8 | 15.4 | 0 | 38.5 | 53.9 | 7.7 | 0 | 23.1 | 7.7 | 15.4 | 7.7 | 46.2 |
| Kempston | 3 | 66.7 | 33.3 | 0 | 0 | 0 | 100 | 0 | 0 | 33.3 | 66.7 | 0 | 0 | 0 |
| Dunbridge | 4 | 25 | 75 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 | 25 | 0 | 75 |
| MIS 7 | | | | | | | | | | | | | | |
| Bakers Hole | 19 | 10.5 | 31.6 | 36.8 | 21.1 | 0 | 42.1 | 42.1 | 15.8 | 26.3 | 10.5 | 15.8 | 31.6 | 15.8 |
| Ebbsfleet | 18 | 44.4 | 44.4 | 11.1 | 0 | 27.8 | 33.3 | 27.8 | 11.1 | 5.6 | 44.4 | 27.8 | 16.7 | 5.6 |
| Creffield Road | 15 | 53.3 | 46.7 | 0 | 0 | 26.7 | 46.7 | 26.7 | 0 | 60.0 | 13.3 | 20.0 | 6.7 | 0 |
| Yiewsley | 26 | 3.8 | 57.7 | 26.9 | 11.5 | 7.7 | 19.2 | 46.2 | 26.9 | 23.1 | 34.6 | 30.8 | 11.5 | 0 |

**Table 4** Cores from MIS 9 assemblages with means and standard deviations for basic metrical data (Rawlinson, 2021; Scott, 2011)

| Site | Core Type | n | Cores | | | | | Flaking Surface Removals | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Length | Width | Thickness | Elongation (W/L) | Flatness (Th/W) | Length | Width |
| Purfleet | SPC | 134 | 93.8 ± 17.8 | 89.76 ± 20.8 | 44.8 ± 14.2 | 0.98 ± 0.26 | 0.53 ± 0.37 | 67.9 ± 19.1 | 55.6 ± 16.2 |
| | SMPC + Discoids | 163 | 96.0 ± 24.5 | 88.0 ± 20.8 | 50.7 ± 15.6 | 0.96 ± 0.28 | 0.59 ± 0.17 | - | - |
| Bakers Farm | SPC | 3 | 171.8 ± 15.2 | 123.1 ± 40 | 44.9 ± 11.8 | 0.71 ± 0.2 | 0.37 ± 0.06 | 77.3 ± 8.6 | 59.9 ± 17.6 |
| | SMPC | 0 | - | - | - | - | - | - | - |
| Cuxton | SPC | 4 | 128.2 ± 17.7 | 107.3 ± 10.1 | 49.1 ± 6.9 | 0.85 ± 0.12 | 0.46 ± 0.07 | 70.4 ± 16.4 | 67.7 ± 7.5 |
| | SMPC | 23 | 100.7 ± 27.6 | 73.5 ± 22.0 | 48.0 ± 12.5 | 0.75 ± 0.20 | 0.68 ± 0.18 | - | - |
| Sonning | SPC | 2 | 100.7 ± 29.3 | 92.0 ± 23.0 | 36.9 ± 7.4 | 0.92 ± 0.04 | 0.40 ± 0.02 | 65.3 ± 3.9 | 55 ± 10.4 |
| | SMPC | 1 | 155.3 | 90.1 | 47.2 | 0.58 | 0.52 | | |
| Barnham Heath | SPC | 17 | 98.0 ± 23.9 | 98.4 ± 21.5 | 44.0 ± 14.8 | 1.02 ± 0.18 | 0.45 ± 0.18 | 66.1 ± 18.4 | 57.6 ± 16.4 |
| | SMPC | 32 | 121.5 ± 35.7 | 108 ± 38.5 | 57.7 ± 17.7 | 0.95 ± 0.41 | 0.58 ± 0.22 | - | - |
| Biddenham | SPC | 13 | 83.1 ± 20.5 | 81.0 ± 23.5 | 31.4 ± 12.7 | 0.98 ± 0.20 | 0.39 ± 0.12 | 54.5 ± 13.3 | 43.2 ± 16.4 |
| | SMPC + Discoids | 13 | 94.3 ± 41.78 | 78.6 ± 28.4 | 31.7 ± 12.4 | 0.87 ± 0.22 | 0.41 ± 0.12 | | |
| Kempston | SPC | 3 | 94.2 ± 18.1 | 96.4 ± 17.6 | 38.3 ± 11.0 | 1.03 ± 0.06 | 0.39 ± 0.06 | 73.4 ± 2.8 | 60.6 ± 10.68 |
| | SMPC | 5 | 86.1 ± 25.0 | 84.4 ± 29.03 | 51.0 ± 27.6 | 0.99 ± 0.19 | 0.59 ± 0.15 | - | - |
| Dunbridge | SPC | 4 | 106.9 ± 15.7 | 74.3 ± 10.7 | 30.9 ± 8.7 | 0.69 ± 0.01 | 0.42 ± 0.13 | 61.3 ± 6.4 | 49.5 ± 2.4 |
| | SMPC | 14 | 105.7 ± 32.5 | 96.7 ± 27.8 | 52.9 ± 15.5 | 0.94 ± 0.28 | 0.57 ± 0.18 | | |

elongation ($t(240) = 0.55$, $p = 0.58$ and $t(240) = 1.21$, $p = 0.23$, respectively) and a weak difference in flatness ($t(240) = 1.80$, $p = 0.07$). However, statistically significant differences were noted in both length and, especially, thickness ($t(240) = 2.00$, $p = 0.05$ and $t(240) = 3.68$, $p = 0.00$ respectively).

In addition, Levallois cores generally display greater levels of recurrent working, a higher number of 'preferential' removals and more all-round working of the striking surface. This suggests more complex knapping, which is supported by an increased number of removals from both

**Table 5** Cores from main MIS 9 and 7 assemblages with means and standard deviations for basic metrical data ( Scott, 2011; Rawlinson, 2021)

| Site | Core Type | n | Cores | | | | | Flaking Surface Removals | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Length | Width | Thickness | Elongation (W/L) | Flatness (Th/W) | Length | Width |
| MIS 9 | | | | | | | | | |
| Purfleet | SPC | 134 | 93.8 ± 17.8 | 89.8 ± 20.8 | 44.8 ± 14.2 | 0.98 ± 0.26 | 0.53 ± 0.37 | 67.9 ± 19.1 | 55.6 ± 16.2 |
| Barnham Heath | SPC | 17 | 98.0 ± 23.9 | 98.4 ± 21.5 | 44 ± 14.8 | 1.02 ± 0.18 | 0.45 ± 0.18 | 66.1 ± 18.4 | 57.6 ± 16.4 |
| Biddenham | SPC | 13 | 83.1 ± 20.5 | 81.0 ± 23.5 | 31.4 ± 12.7 | 0.98 ± 0.20 | 0.39 ± 0.12 | 54.5 ± 13.3 | 43.2 ± 16.4 |
| MIS 7 | | | | | | | | | |
| Bakers Hole | Levallois | 19 | 132.4 ± 32.4 | 119.3 ± 27.8 | 46.2 ± 15.4 | 0.91 ± 0.12 | 0.39 ± 0.09 | | |
| Ebbsfleet | Levallois | 18 | 96.6 ± 21.1 | 84.1 ± 19.1 | 42.1 ± 14.2 | 0.91 ± 0.34 | 0.50 ± 0.12 | | |
| Creffield Road | Levallois | 15 | 66.9 ± 10.8 | 60.7 ± 7.3 | 20.9 ± 4.2 | 0.93 ± 0.20 | 0.35 ± 0.08 | | |
| Yiewsley | Levallois | 26 | 94.4 ± 18.6 | 94.1 ± 19.3 | 34.8 ± 12.3 | 1.01 ± 0.14 | 0.36 ± 0.06 | | |

**Table 6** Flakes from MIS 9 and Levallois flakes from MIS 7 assemblages with means and standard deviations for basic metrical data (Rawlinson, 2021; Scott, 2011)

| Site | *n* | Length | Width | Thickness | Elongation (W/L) |
|---|---|---|---|---|---|
| MIS 9 | | | | | |
| Purfleet | 433 | 70.2 ± 21.0 | 63.0 ± 20.0 | 21.3 ± 9.4 | 0.94 ± 0.30 |
| Cuxton (Tester) | 362 | 56.1 ± 21.8 | 54.6 ± 23.2 | 16.9 ± 9.2 | 1.01 ± 0.33 |
| Sonning | 24 | 87.95 ± 29.2 | 66.6 ± 17.6 | 15.9 ± 5.2 | 0.83 ± 0.32 |
| Barnham Heath | 271 | 95.6 ± 24.1 | 84.2 ± 26.2 | 26.1 ± 11.2 | 0.91 ± 0.30 |
| Biddenham | 483 | 70.3 ± 20.1 | 58.2 ± 19.4 | 16.3 ± 7.5 | 0.87 ± 0.30 |
| Kempston | 118 | 76.2 ± 20.2 | 58.4 ± 18.3 | 18.3 ± 8.2 | 0.82 ± 0.30 |
| Dunbridge | 104 | 76.5 ± 18.6 | 66.9 ± 17.2 | 22.7 ± 8.5 | 0.91 ± 0.25 |
| MIS 7 | | | | | |
| Bakers Hole | 100 | 127.4 ± 25.2 | 77.5 ± 18.3 | 20.5 ± 8.3 | 0.62 ± 0.16 |
| Ebbsfleet | 34 | 99.4 ± 25.8 | 64.65 ± 23.1 | 16.9 ± 6.0 | 0.68 ± 0.25 |
| Creffield Road | 63 | 82.7 ± 19.7 | 50.5 ± 8.8 | 12.2 ± 2.4 | 0.64 ± 0.15 |
| Yiewsley | 242 | 90.1 ± 17.1 | 59.6 ± 12.2 | 14.4 ± 7.2 | 0.68 ± 0.16 |

the striking platforms and striking surface, together with general less cortex retention.

For the mean flake data from MIS 9 and MIS 7, no statistically significant differences were noted in terms of flake width ($t(2232) = 0.37$, $p = 0.71$), but differences were observed in length, thickness and elongation ($t(2232) = 20.63$, $p = 0.00$, $t(2232) = 8.02$, $p = 0.00$, and $t(2232) = 17.33$, $p = 0.00$, respectively), with MIS 7 flakes being on average longer and with greater elongation, while MIS 9 flakes are on average thicker. It therefore appears that, although cores show a degree of similarity, desired flake end products were different.

## The 'Purfleet' chaîne opératoire

The 'simple prepared core' technology at Purfleet has previously been described as proto-Levallois or Mode 3 and as conforming to the Levallois concept in all but one criterion, the management of distal and lateral convexities on the flaking surfaces, the knapper instead using the natural convexities of the nodule (White & Ashton, 2003; Bolton, 2015; Scott, 2011; White et al., 2011; Rawlinson, 2021). In such a technological reading, the actions of the knapper are seen as sequentially-linked parts of an overarching scheme, one planned from the outset to produce flakes of a desired form. In the case of Levallois, this end-product assumes a small number of readily identifiable forms, which are oval, rectangular, elongated, or pointed, but SPC do not produce any characteristic product and it has not been possible to metrically or technologically distinguish them from among the thousands of flakes recovered from these sites (Rawlinson, 2021; see Table 6 and Fig. 2). SPC flakes blend into the products of the SMPC working. The Purfleet SPC thus differ from Levallois cores not only in showing little control over the convexity of the flaking surface but also in showing minimal control over the form of the target flakes, beyond perhaps a desire to maximise the length of the flake relative to the dimensions of the core. In other

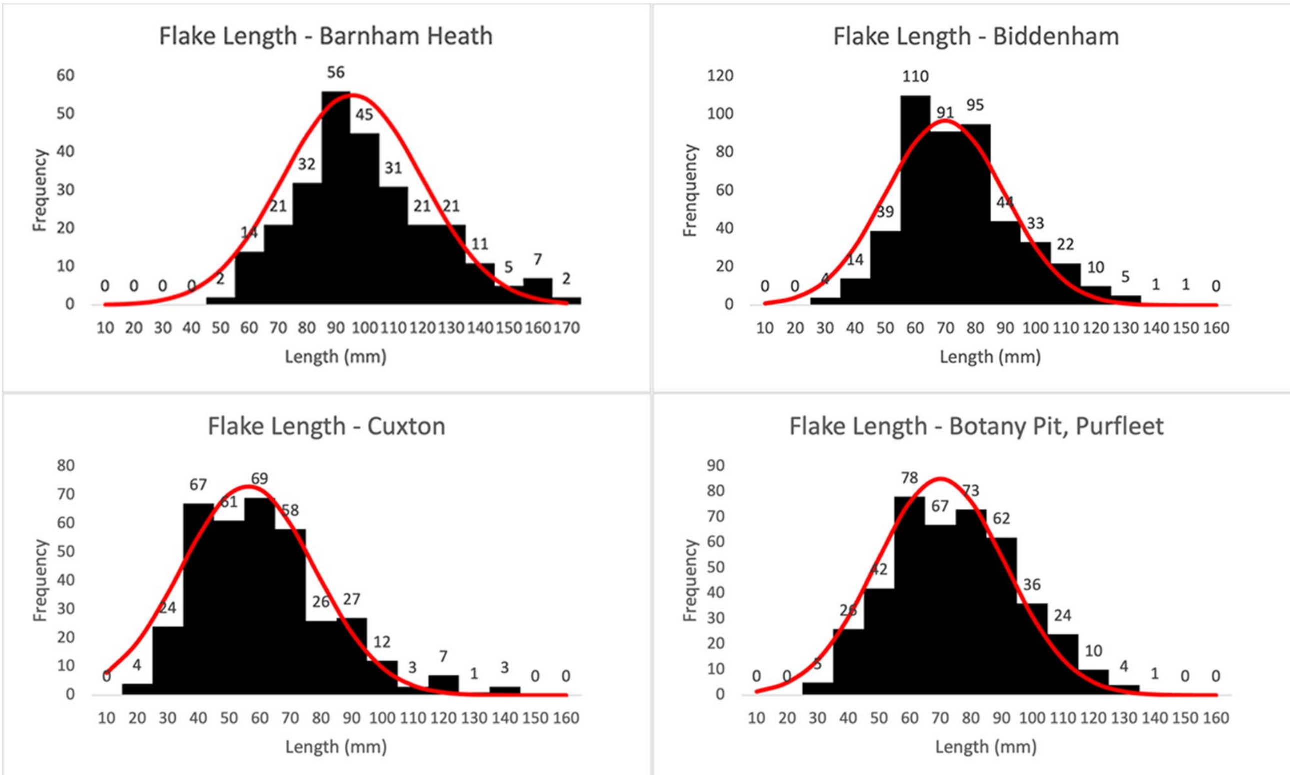


**Fig. 2** Flake size distribution for selected sites

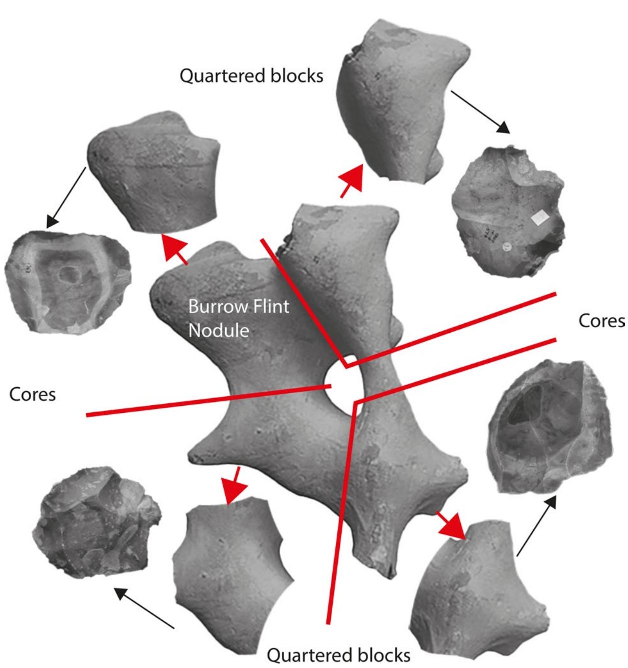


**Fig. 3** Diagram showing how SPC from Purfleet result from quartering the irregular burrow flint nodules seen eroding from the Chalk at the site

words, there is no predetermination and no preferential or 'target' flake/s.

An alternative chaîne opératoire can be constructed for these 'simple prepared cores'. Rather than forming an embryonic stage in the development of the Levallois concept, a linked sequence of actions aimed at producing flakes of a target form, the technology at Purfleet can instead be seen as geared around individual episodes of parallel and alternate flaking, the main aim of which was to remove one or more flakes from the largest surface of angular, ellipsoid-shaped flint blocks produced by quartering the local flint nodules (Fig. 3). Quartering is the process of splitting a flint nodule, leaving large breakage surfaces to serve as a platform and main flaking surface. This would explain the direct correspondence between flaking surface configuration and position, and the number of removals on the striking platform surface (Table 4). In this regard, they differ from SMPC working in one key characteristic: while in SMPC the striking platforms 'migrate' around the surface of a core to exploit another secant plane, in SPC the striking platforms migrate around a single plane that encircles the largest surface area of the core. Some may have seen intensive flaking, with a well-worked circumference and apparently privileged flakes, but they depart from Boëda's Levallois

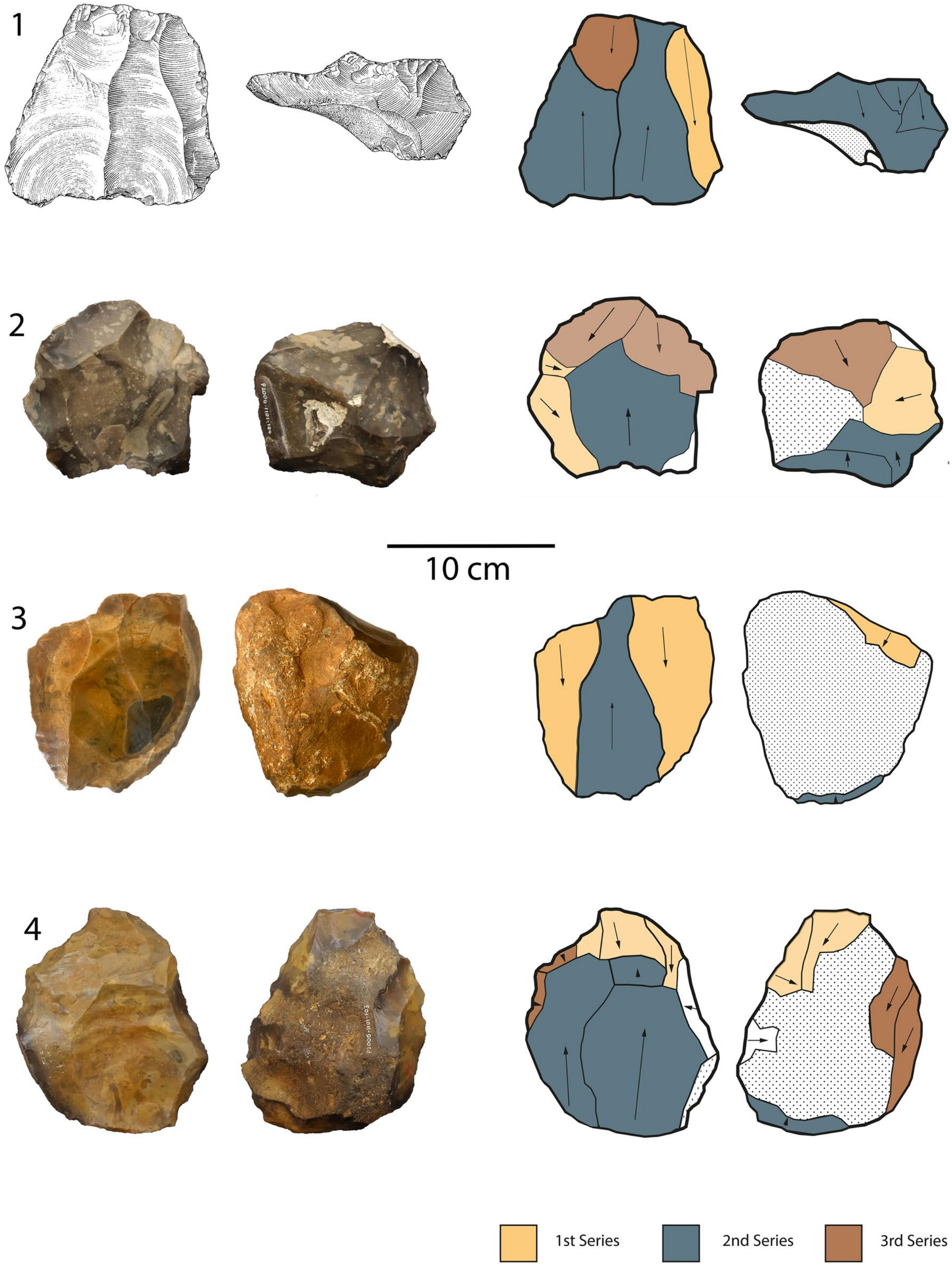


**Fig. 4** Left: Photographs or line drawings of four cores from Purfleet. Right: Diacritical diagrams of the same cores illustrating the independent series of parallel and alternate removals from a single plane, fortuitously resembling Levallois cores but not produced using the Levallois method. See text for details

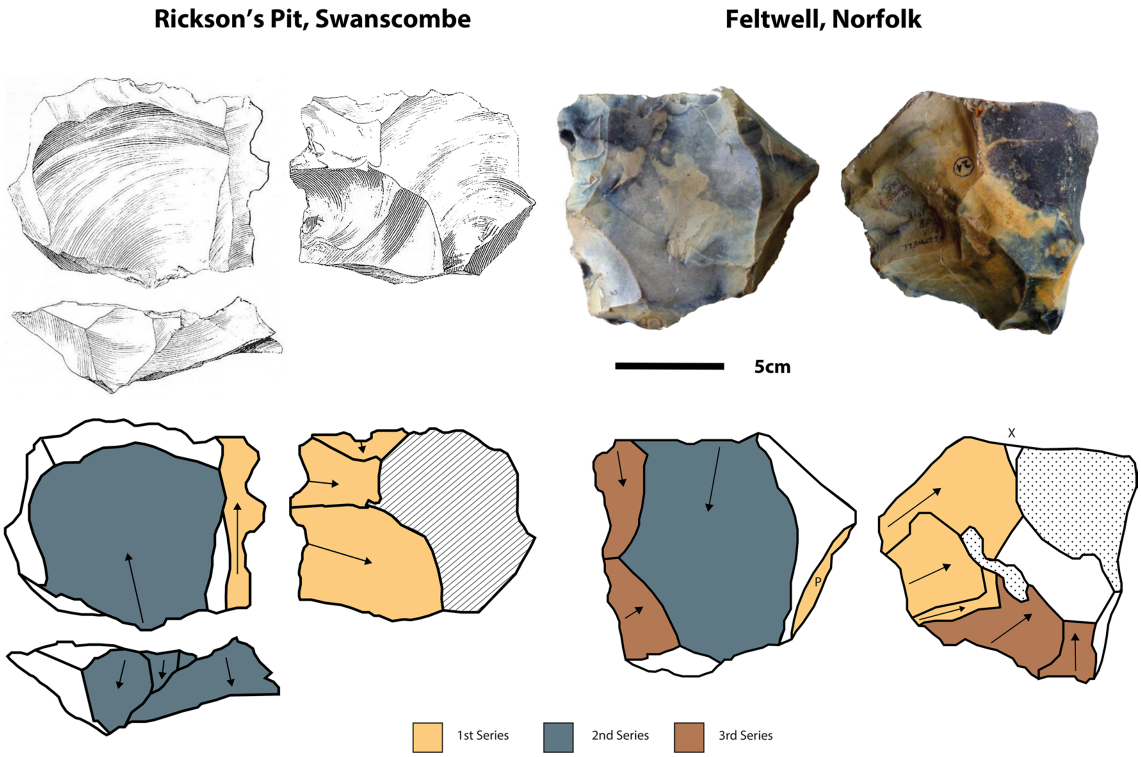


**Fig. 5** Supposed Levallois cores from the MIS 11 site at Rickson's Pit, Swanscombe, and a pre-Anglian (MIS 12) core from Feltwell, with diacritical diagrams showing the relationship and sequence of removals

concept in showing no predetermination (foundational), no control of convexities on the flaking surface (Crit. 3) and having a hinge that is not necessarily perpendicular to the long-axis of percussion (Crit. 5). They conform in three criteria: flaking exploits a single plane of intersection (Crit. 1), they are often but not invariably flaked hierarchically (Crit. 2), and flakes from the flaking surface usually run parallel to this plane (Crit. 4), but this is likewise not invariantly true. In this reading SPC are not a proto-form of Levallois that merges known technologies in different ways, but the application of well-known flaking routines to a particular problem — useable-flake production on nodules with only one large flaking surface. The lack of control over the convexity of the flaking surface resulted in variation in the 'preparation' and exploitation of the flaking surface of SPCs. They can therefore be interpreted in terms of how many times the knapper was successful in moving the platform. A single large flake from a single platform will resemble preferential Levallois; multiple removals from the same surface would assume a unidirectional recurrent Levallois form. A move to a new platform opposite the first, and two unconnected episodes of alternate flaking overlap to appear like a bidirectional Levallois technique. Another platform switch to one or more of the margins and the overlapping episodes begin to resemble centripetal working. How far each core was worked was ultimately determined by the knapper and what they hoped to achieve from the nodule they had selected, in terms of number and size of flakes.

Some illustrated examples will help to explain this reading of the chaîne opératoire of the 'simple prepared cores' from Purfleet (Fig. 4). Numbers 1 and 3 in Fig. 4 have both been worked by several brief but overlapping sequences of alternate flaking, from opposing ends of flat squarish blocks. Each sequence represents one or two removals from the shorter peripheral edge, creating a platform for single or parallel removals from the larger and flatter face, each of which show clear negative bulbs on the flaking surface (see left had images in Fig. 1). They are completely unprepared and resemble recurrent Levallois simply because the platforms fall along the same plane and the flakes run parallel to the surface of the nodule. In form, number 2 resembles a centripetally-prepared, lineally exploited Levallois core, and has certainly been interpreted as such in the past, but is actually a flat discoid-like or SMPC core (having one parallel plane); the largest removal from the apparent hierarchical flaking surface is part of the second series of removals and was followed by another series that delivered an equally large flake from the 'striking platform surface'. Number 4 is an example of a SPC from Purfleet most frequently attributed to Levallois (White & Ashton, 2003), and it is easy on first sight to understand why. A diacritical reading, however, shows that the apparent preferential

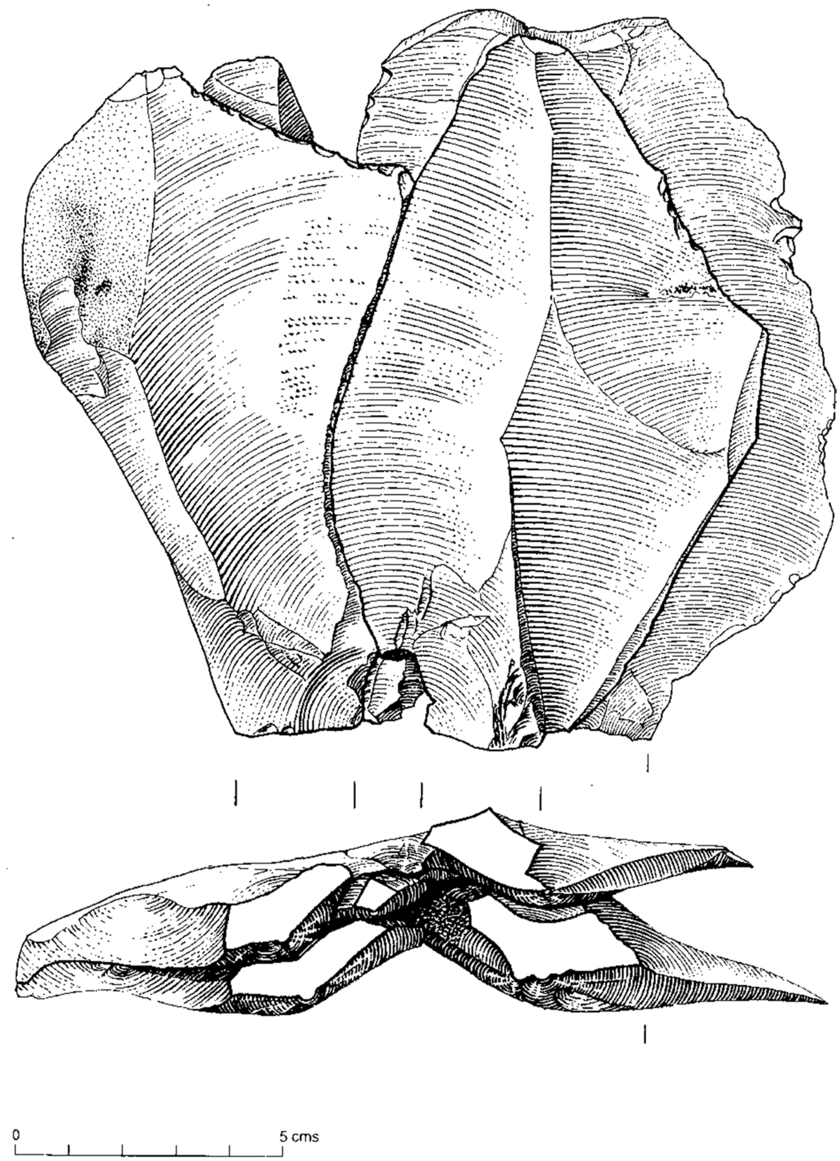


**Fig. 6** A refitting parallel knapping episode from Frindsbury, Kent, showing five very accomplished flakes from a single platform, but with little predetermination

flake forms part of a parallel series from a single platform, probably the first episode on the core, while the apparent centripetal preparation at the distal and lateral margins relates to a later alternate sequences that produced the final shape of the flaking surface but did not affect the previous flake removals. It could represent re-preparation of the flaking surface but could alternatively be an attempt to begin exploiting the domed underside. This convergence on Levallois is undeniable, but we think that this is a Cinderella technology, one that is not what it seems, but a coincidental outcome of much simpler flaking strategies along a plane of intersection. In many of these cases, had flaking gone on to exploit a new plane, the Levallois illusion could well have been shattered, and the core transformed into another multiple platform piece.

## Discussion

### Purfleet in a British Context

SPC resembling those from Purfleet are found in small numbers at many Lower Palaeolithic sites (Table 1), where they can be seen as an infrequently used method of exploiting the largest surface area of an unequally proportioned (flattish) block by keeping the striking platforms in one plane. Conceptually and geometrically, they share the same methods seen in roughing out a handaxe and have more in common with the discoidal and chopper cores of the Clactonian than with Levallois. Precocious instances of 'proto-Levallois' from sites such as Rickson's Pit and Feltwell (Roe, 1981; MacRae, 1999) can be explained in a similar fashion (Fig. 5).

Although both clearly resemble Levallois cores neither have been made using the Levallois concept. In the Rickson's Pit specimen, the core has been formed from a large flake (diagonal lines indicate the ventral), from which two series of removals have been detached from two separate platforms. Two further flakes (uncoloured) are cut by the second series but have no point of origin and are interpreted as relicts of the original distal surface. The second series is marked by parallel platform preparation followed by one large flake from the original dorsal surface, but despite appearances, the first series is not a preparatory phase to the platform/flaking surfaces but an unrelated parallel sequence that exploits the original ventral. It could be described as a flat discoidal, SMPC, a flake-cum-core, a flaked-flake or a trifacial core, depending on the analyst, but it is not Levallois. The Feltwell example also shows apparent preparation to surfaces and a large dominant flake from the flatter face. The 'first' series is a parallel sequence that cannot be related to the other two series, while the 'second' series is a single removal from a clear and independent platform unrelated to any preparation of the flake surface. The 'third' sequence represents two removals from a platform on the opposite edge, which although seemingly related to preparation of the upper flaking surface, can be seen to cut the dominant flake in the second series, which must therefore precede them. Both superficially resemble Levallois in shape but have not been worked using the Levallois concept: they are better described as pseudo-Levallois discoids.

Our revised reading of the technology at Purfleet points to a very different conclusion to that presented 20 years ago (White & Ashton, 2003). The SPCs are not proto-Levallois, have little meaningful technological relationship with Levallois beyond a common root in the Acheulean, and are not prepared in any meaningful sense, with some previously identified examples lacking even hierarchical surface exploitation. All of this makes us question whether they can be considered 'prepared' or 'Mode 3' type cores at all (but for an alternative view see Gill et al. forthcoming). They are instead a particular application of basic parallel and alternate (i.e. Mode 1) reduction methods. They are also found in Clactonian contexts alongside discoidal cores, and it is for this reason that early workers such as Warren (1924, 1932) and Breuil (1926, 1932) saw direct evolutionary links between their Clactonian and Levalloisian cultures. We wonder whether, if Purfleet had been discovered in the 1920s or 1930s, it would have been interpreted as an evolved form of the Mesvinian–Clactonian (see White, 2023 for full discussion of the history of these terms). Our failure to identify characteristic target flakes might then be explained very simply; they do not exist; they are all just part of the general project to produce the largest flakes possible depending on the surface configuration of the original block, and blend into other hard-hammer flakes (see also Bustos-Pérez et al., 2023). The previously published refitting cluster from the MIS 9 site at Frindsbury, Kent (Cook & Killick, 1924; White & Ashton, 2003), reproduced in Fig. 6, shows a successful parallel sequence of five large ovoid flakes from a single platform without any hint of actual flaking-surface preparation, likewise conforms to this new reading of the technology: controlled and purposeful, but little predetermination. A second refitting group of three large, parallel flakes from Frindsbury are housed with these in the British Museum and shows the same lack of preparation. As none of the flakes were evidently selected for use, and in the absence of any refitting cores, we cannot eliminate the possibility that they are derived from the roughing out of handaxes from large nodules; a similar set of removals from Caddington refits to form the cast of just such a roughout (Smith, 1894, 150–152).

The relatively large numbers of SPCs from Purfleet, Biddenham, and Barnham Heath still demand some explanation.

The assemblage from Purfleet is noteworthy not only for the large number of SPC but also for the small number of poorly-made handaxes and the sheer number of cores present (~300), more even than the classic core-and-flake assemblages from Clacton-on-Sea and Swanscombe. The Purfleet sites are situated on the left bank of an erstwhile sinuous loop in the Thames (the Ockenden Loop), which at the time of occupation presented a wide river-beach flanked by Chalk river-cliffs from which large flint nodules were actively eroding. Remnants of these river cliffs are today visible in the relict edges of the old Botany Pit and in the Greenlands Pit SSSI, where they contain bands of flint occurring in irregular burrow-like formations, in a variety of rounded and flatter volumes. This situation seems to have encouraged repeated visits to Purfleet, primarily for the purposes of extracting the local flint resources and producing large numbers of flakes from nominally reduced cores. Many cores were worked in the typical SMPC fashion but, in almost 40% of cases, knapping focussed on exploiting a single plane. This could be interpreted as a local tradition, a unique glimpse at a wider European trend towards more optimal use of stone resources, or just a situational response to plentiful good-quality resources drawn from a general set of principles. The use of the same source of nodules for the associated handaxes at Purfleet may also help explain their irregular nature.

Barnham Heath was included in this study because it was known to contain SPC and Levallois alongside handaxes (Wymer, 1985). The site is situated to the north of the MIS 11 site at East Farm, Barnham (Ashton et al., 1998, 2016), in the valley of the Little Ouse. Gravel workings during the 1940s and 1950s, monitored by Basil Brown on behalf of Ipswich Museum, spanned two terraces dated to MIS 9/8 and MIS 7/6 respectively (Davis et al., in prep.). It is clear from Brown's notes (curated at the Suffolk Records Office and Suffolk Archaeological Service) that the majority of the Palaeolithic material came from the higher, older terrace. He describes handaxes and flakes from the higher terrace, but the only mention of Levallois is in relation to a pit situated on the lower, younger terrace. The majority of the assemblage is in abraded or heavily abraded condition, although it is notable that half of the 'prepared cores' from the site show the lowest levels of abrasion. On this basis, it seems likely that there are at least two assemblages present in the Barnham Heath collections, with handaxes, hard hammer flakes and SMPC belonging to MIS 9, and Levallois cores and flakes to MIS 7. The provenance of the 'proto-Levallois' cores is more uncertain, although one can be linked to the higher terrace, suggesting they may be part of the MIS 9 material. They are in mixed condition and while several show the technological method seen in the cores at Purfleet, it remains a possibility that they derive from multiple assemblages of different ages.

Despite being discovered in 1861, Biddenham was included because of known SPC, a confirmed geological context (Harding et al., 1991), and the known behaviour of key collectors such as Knowles, who saved everything from the site, not just selected objects. The dating of the core assemblage is far less secure, however. The Biddenham deposits lie on Terrace 3 of the Great Ouse, the highest terrace in this part of the valley but younger than the MIS 12 boulder clay (Wymer, 1999:121). The correlation of the Terrace 2 non-archaeological site at Stoke Goldington with late MIS 7 or MIS 6 (Boreham et al., 2010; Wymer, 1999) brackets the Biddenham deposits to MIS 10–early MIS 7, although the mixed but predominantly abraded condition of the artefacts suggests it is a mixture of industries that potentially span MIS 11 onwards. The Levallois element of the site has been used to argue that the site could be MIS 7 or later (Wymer, 1968: 124), but analysis of the handaxes (Dale, 2022) has demonstrated a strong affinity with MIS 9 sites, confirming the suggestion of Harding et al., (1991). The most rolled elements may date to MIS 10 or MIS 11. It certainly provides no evidence for a regional increase in the importance of SPC in MIS 9 or that these represent a gradual transition to the Middle Palaeolithic.

## Britain in a European Context

Pleistocene Britain formed part of Gamble's biotidal zone, where human and animal populations ebbed and flowed with the climatic rhythms of the Pleistocene (Gamble, 2009). It was a sink, a cul-de-sac at the end of the world, in which demographic crashes (climatically driven or otherwise) would require re-population from neighbouring areas of Europe, via the Weald-Artois Chalk ridge prior to its MIS 12 breaching and thereafter during cooler periods when sea levels were sufficiently low to allow a terrestrial crossing via the Channel or Doggerland basins (Hijma et al., 2012).

As the MIS 8 ice sheet pushed its way towards Lincolnshire and the British Midlands (White et al., 2010), the likely fate of the MIS 9 human occupants of Britain was local extinction rather than long-distance relocation (cf. Hublin & Roebroeks, 2009; Hublin, 2009). The same fate probably befell the neighbouring populations in Belgium and the loëss belt of northern France, who during the MIS 10–9–8 interval used locally varying blends of handaxes and nodule reduction strategies, which sometimes resulted in Levallois-like and Purfleet-like cores (e.g. Kesselt, Op de Schans, Mesvin, Petit Spiennes in Belgium, Cagny l'Epinette, Etricourt-Manacourt; see Hérisson et al., 2016a, 2016b and references therein; Di Modica & Pirson, 2016); Hérisson and Soriano (2020). This included what seems to be a precocious local development at the Cagny sites in the Somme of the removal of large flakes from handaxes, a technique that resembles Levallois, but which does not fulfil all of Boëda's criteria (Breuil & Kelley, 1956; Lamotte & Tuffreau, 2001).

In these cases, Purfleet and other MIS 9 assemblages from north-west Europe have very little to tell us about the Middle Palaeolithic transition. They may reflect wider European technological trends during the late Lower Palaeolithic (see below), or may have developed from localised idiosyncrasies, but they were arrested in development and can claim no direct line of descent to the Middle Palaeolithic occupants of MIS 7. The site at Harnham (Wiltshire), argued to date to an intra MIS 8 warm episode (Bates et al., 2014), contains a ficron handaxe and cleaver assemblage typical of the MIS 9 interglacial and might, in this case, represent relict populations who returned from closer cryptic refugia during brief warm substages. Levallois arrived in Britain from the south during the climatic warming limb of MIS 8–7, as populations began to expand from their glacial refugia in Iberia, southern France, Italy, the Balkans, and the Levant. It is thus to the Mediterranean belt that we must look for evidence of in situ evolution versus the sudden appearance of Levallois.

The final Lower Palaeolithic in the Levant, between 400 and 250 ka, is characterised by the unique regional variant, the Acheulo-Yabrudian (Gopher et al., 2010; Mercier et al., 2013; Valladas et al., 2013; Zaidner and Weinstein-Evron, 2016, Zaidner and Weinstein-Evron, 2020). The three members of this complex share common technological features with the Acheulean and with each other (Barkai & Gopher, 2011; Malinsky-Buller, 2016a; Shimelmitz et al., 2016), including 'hierarchically-organised surface cores' that may be comparable to the SPC from Purfleet (Malinsky-Buller, 2016a; Shimelmitz et al., 2016; Zaidner & Weinstein-Evron, 2016, 2020). Misliya Cave in Israel preserves a rare recently excavated sequence spanning the transition from the final

Lower Palaeolithic Acheulo-Yabrudian (~ 350–250 ka) to the Early Middle Palaeolithic (~ 240 ka) (Zaidner & Weinstein-Evron, 2016, 2020). The Acheulo-Yabrudian here was characterised by rough bifaces, Quina scrapers, and hierarchically organised surface cores, but these technologies are all absent from the succeeding early Middle Palaeolithic (EMP), which was based on Levallois points, flakes and blades, cores-on-flakes, and characteristic 'Abu Sif' points. Almost all Levantine EMP sites dated to 250–240 ka show the same technological turnover (Malinsky-Buller, 2016a; Shimelmitz & Kuhn, 2013; Zaidner & Weinstein-Evron, 2020), which in a regional context has been interpreted as a major conceptual shift marking rupture not continuity. The association of the maxilla of an early *Homo sapiens* with the EMP industry at Misliya (Hershkovitz et al., 2018) supports the contention that modern humans introduced Levallois technology into this region from Africa.

Palaeolithic sites of MIS 9 age in Mediterranean Europe show a range of handaxes, cores-on-flakes, laminar technologies, as well as a range of hierarchically-organised cores (Hérisson et al., 2016a; Malinsky-Buller, 2016b). The most important site is Orgnac 3 in south-east France, which has yielded evidence of human occupation over 10 levels dated to between 350 and 298 ka (Moncel et al., 2005, 2011, 2012; Bahain et al., 2022). The oldest levels (8–6, MIS 9) show a variety of non-Levallois methods, including a hierarchically organised centripetal technique, with prepared-core technology first appearing as a numerically low 'complementary method' in Level 5b. In its earliest manifestation, it is generally unidirectional or bidirectional, its overall configuration suggesting a method that was controlled but with rules that were 'not fully standardised'. By levels 4a and 4b (MIS 8), fully fledged and formalised Levallois technology is seen; 40% of all cores for these levels are Levallois and include most of the variants identified by Boëda. Orgnac 3 then appears to show little evidence of sudden rupture, instead showing a gradual in situ development.

In Italy, the earliest Levallois has been claimed from MIS 11–10 contexts at Guado San Nicola, Central Italy. Peretto et al. (2016) described the lithic industry as Acheulean, containing a range of handaxes, SMPCs, hierarchically organised surface cores and Levallois, the last increasing in both frequency and level of predetermination through time. Soriano and Villa (2017), on the other hand, regarded all the cores from Guado San Nicola as non-Levallois hierarchically-worked forms, placing the first occurrence of Levallois at 295–290 ka, as seen at Sedia del Diavolo and Monte delle Gioie near Rome, the first of which had also produced Neanderthal skeletal material.

In Iberia, hierarchically worked cores with no predetermination, but like Purfleet aimed at realising the maximum potential of raw materials, have been reported from Level TD10.1 in the Gran Dolina at Atapuerca, northern Spain (de Lombera-Hermida et al., 2020, 11), dated to between 379 ± 57 and 337 ± 29 ka. Similar technologies occur in other MIS 10–9 contexts at Bolomor Cave, Cuesta de la Bajada, Ambrona, and Aridos 1 (*ibid.*). The classic Middle Palaeolithic, in terms of the loss of handaxes and appearance of Levallois, is seen from at least terminal MIS 9, but a Large Flake Acheulean does not disappear until MIS 6, with unequivocal Acheulean assemblages of this age found in the Basins of the Taho, Duero and Miño, and possibly also southern France (Santonja & Villa, 2006; Santonja et al., 2014, 2016; Ollé et al., 2016; Méndez-Quintas et al., 2019, Méndez-Quintas et al., 2020).

There is thus little from the literature to suggest a complete rupture at the Lower–Middle Palaeolithic transition in Mediterranean Europe. Instead it is characterised by more gradual developments in the number and type of core reduction methods, geared towards maximising the potential of the raw materials (de Lombera-Hermida et al., 2020), with discoidal and hierarchical forms used alongside handaxes from MIS 11–8, and full Levallois appearing by ~ 295 ka. That said, there is an urgent need for clarifying the nature and standardising the definition of hierarchical working methods in these regions, determining whether it is a local response influenced by abundance and form of local raw materials (i.e., like Purfleet) or a more widespread practice, and if/when hierarchical cores become persistent in the record.

The presence of *Homo sapiens* at Misliya Cave in Israel and at Apidima in Greece by at least MIS 7 (Harvati et al., 2019) suggests that an African originating population with a full Levallois technology was present in the east. This would make the Aegean/Balkan refugium and the Levant an unlikely source for the MIS 8–7 northern Neanderthals, although there are no technological or typological traits that would allow a source population from the more continuously-occupied Neanderthal refugia in France, Spain, or Italy to be firmly identified (cf. Malinsky-Buller, 2016b). The replacement of the archaic Neanderthal Y-chromosome with a *Homo sapiens* Y-chromosome sometime between 370 and 100 ka (Petr et al., 2020), and introgression of *Homo sapiens* mtDNA ~ 468–219 ka (Posth et al., 2017), shows that these regional populations interacted and interbred, even if this left little expression in the Neanderthal phenotype in Europe. Thus, the simultaneous appearance of Levallois across much of the western Old World (the earliest traces of Levallois in the Caucasus (Adler et al., 2014) also fall within this time frame) need not strictly represent a major dispersal event nor a local invention, but genetic and cultural ripples that circumnavigated the Mediterranean, a horseshoe of interaction from north-west Africa, through the Levant into southern Europe and from there, when conditions were suitable, into the north via direct population movements. Movements across the Strait of Gibraltar may have occasionally closed the circuit (Sharon, 2011).

One of the selective forces that possibly drove this adoption was the miniaturisation of technology that took place in Africa after 400 ka, probably linked to an increase in hafted tools and weapons at the expense of larger hand-held tools (Barham, 2013; Coe et al., 2022; Shipton, 2022), as well as more task-specific tools (Tryon et al., 2006; Shimelmitz & Kuhn, 2018; Groman-Yaroslavski et al., 2021).

## Conclusions

Our revised interpretation of the SPC of MIS 9 Britain calls into question their status as markers of the early Middle Palaeolithic, rather than just a particular application of alternate and parallel flaking in which the 'migrating' platforms fall along a single plane. This suggests:

1) That the Purfleet cores were not prepared and cannot be considered Mode 3.
2) That the Middle Palaeolithic did not emerge gradually in Britain from pre-existing technologies but appeared suddenly and fully formed in MIS 7 as part of the post-glacial re-colonisation.
3) The question of independent European invention depends on a close reading of the evidence from Mediterranean Europe.
4) That, given the presence of *Homo sapiens* in the eastern Mediterranean during MIS 7, with genetic admixture replacing the Neanderthal Y-chromosome with that of *Homo sapiens* between 370 and 100 ka, it now seems to us likely that the Levallois concept and associated hafting technologies were of African origin and were introduced into European Neanderthal populations along a genetic and cultural corridor running southeast to northwest.

To test these ideas further, the international Palaeolithic community needs to come together to agree on a definition and a standard term for the method of reduction seen at Purfleet and other sites, as well as its distribution and frequency in time and space; if for nothing else than to ensure that we are all describing the same Europe-wide phenomenon and not several different technological schemes that emerge from local circumstance. Doing so would allow us to fundamentally differentiate between those late Lower Palaeolithic core reduction techniques that aim at maximising materials and the occurrence of formative Levallois techniques with predetermined products, allowing the distribution and spread of the latter to be reconstructed in greater detail. The results could revolutionise our understanding of the Palaeolithic world and the divisions we create within it.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s41982-024-00177-z.

**Acknowledgements** We would like to thank the staff members 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 Department of Geography, Royal Holloway, for access to collections. This project was partly funded by the RCUK AHRC doctoral scholarships awarded to AAR and LD, and through the AHRC-funded major research project "Digital Technologies, Acheulean handaxes and the Social Landscapes of the Lower Palaeolithic" (AH/W009951/1). Work at Barnham Heath was undertaken as part of the "Breckland Palaeolithic Project," funded by a Research Project Grant from the Leverhulme Trust (RPG-2016-039).

**Author Contributions** MW, AR, FF, LD, RD, DB, CS and NA were all involved in the analysis of the lithic collections. MW and NA wrote and revised the main manuscript text. MW prepared the figures. FF conducted the statistical analysis. All authors reviewed the manuscript.

**Funding** This project was partly funded by the RCUK AHRC doctoral scholarships awarded to AAR (AH/R002444/1) and LD (AH/L503927/1) and through the AHRC-funded major research project "Digital Technologies, Acheulean handaxes and the Social Landscapes of the Lower Palaeolithic" (AH/W009951/1). Work at Barnham Heath was undertaken as part of the "Breckland Palaeolithic Project," funded by a Research Project Grant from the Leverhulme Trust (RPG-2016–039). NA and RD received funding for the Pathways to Ancient Britain Project from the the Calleva Foundation.

**Data Availability** The materials can be accessed at the following institutions (all in the UK): 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 Royal Holloway, University of London.

## Declarations

**Ethics Approval** Not applicable.

**Competing Interests** The authors declare no competing interests.



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