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► To cite this version:

Marie-Hélène Moncel, Nick Ashton, Marta Arzarello, Federica Fontana, Agnès Lamotte, et al.. Early Levallois core technology between Marine Isotope Stage 12 and 9 in Western Europe. *Journal of Human Evolution*, 2020, 139, pp.102735. 10.1016/j.jhevol.2019.102735 . hal-02489414

HAL Id: hal-02489414

<https://hal.science/hal-02489414>

Submitted on 12 Nov 2020

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1 Early Levallois core technology between MIS 12 and 9 in Western Europe?

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3 **Marie-Hélène Moncel^{a,*}, Nick Ashton^b, Marta Arzarello^c, Federica Fontana^c, Agnès Lamotte^d, Beccy**
4 **Scott^c, Brunella Muttillio^b, Gabriele Berruti^{b,e}, Gabriele Nenzioni^f, Alain Tuffreau^d, Carlo Peretto^b**

5

6 ^a *UMR 7194 CNRS – Département Hommes et environnement, Muséum National d’Histoire Naturelle,*
7 *Institut de Paléontologie Humaine, Paris, France*

8 ^b *Department Britain, Europe & Prehistory, British Museum, Franks House, 56 Orsman Road, London*
9 *N1 5QJ, UK*

10 ^c *Sezione di Scienze preistoriche e antropologiche, Dipartimento di Studi Umanistici, Università degli*
11 *Studi di Ferrara, Corso Ercole I d’Este, 32 – I-44121, Italy*

12 ^d *University of Lille, UMR 8164, Bâtiment de géographie, avenue Paul Langevin, Villeneuve d’Ascq,*
13 *France*

14 ^e *Museo di Archeologia e Paleontologia C. Conti, Borgosesia, Italy*

15 ^f *Museo della Preistoria “L. Donini”, Via Fratelli Canova, Italy*

16

17 *Corresponding author.

18 *E-mail address: marie-helene.moncel@mnhn.fr (M.H. Moncel).*

19

20 **Acknowledgements**

21 This study belongs to a research project between the CNRS-National Museum of Natural History,
22 the British Museum (UK), the University of Ferrara (Italy), the University of Lille (France), the Museo di
23 Archeologia e Paleontologia C. Conti (Italy) and the Museo della Preistoria L. Donini (Italy). Results
24 were presented at the University of Haifa (Israel), November 2017 “The Lower to Middle Paleolithic
25 boundary: A view from the Near east” (Isreal Science Fondation and Wenner-Gren Foundation
26 workshop). We would like to thank Mina Weinstein-Evron and Yossi Zaidner for the organization.

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28

29 **Abstract**

30 Early Levallois core technology is usually dated in Europe to the end of Marine Isotope Stage (MIS) 9,
31 and particularly from the beginning of MIS 8 to MIS 6. This technology is considered as one of the
32 markers of the transition from Lower to Middle Paleolithic or from Mode 2 to Mode 3. Recent
33 discoveries show that some lithic innovations actually appeared earlier in western Europe, from MIS
34 12 to MIS 9, contemporaneous with changes in subsistence strategies and the first appearance of
35 early Neanderthal anatomical features. Among these discoveries, there is the iconic Levallois core
36 technology. A selection of well-dated assemblages in the United Kingdom, France, and Italy dated
37 from MIS 12 to 9, which include both cores and flakes with Levallois features, has been described
38 and compared with the aim of characterizing this technology. The conclusion supports the
39 interpretation that several technical features may be attributed to a Levallois technology similar to
40 those observed in younger Middle Paleolithic sites, distinct from the main associated core
41 technologies in each level. Some features in the sample of sites suggest a gradual transformation of
42 existing core technologies. The small evidence of Levallois could indicate occasional local innovations
43 from different technological backgrounds and would explain the diversity of Levallois methods that is
44 observed from MIS 12. The technological roots of Levallois technology in the Middle Pleistocene
45 would suggest a multiregional origin and diffusion in Europe, and early evidence of regionalization of
46 local traditions through Europe from MIS 12 to 9. The relationships of Levallois technology with new
47 needs and behaviors are discussed, such as flake preference, functional reasons related to hunting
48 and hafting, an increase in the use of mental templates in European populations and changes in the
49 structure of hominin groups adapting to climatic and environmental changes.

50 **Keywords:** Neanderthals; Early Levallois; Western Europe; Technology

51

52 **1. Introduction**

53 Early Levallois core technology is usually dated in Europe to the end of MIS 9, and particularly from
54 the beginning of MIS 8 to MIS 6. This technology is considered as one marker of the transition from
55 the Lower to Middle Paleolithic or from Mode 2 to Mode 3 (Clark, 1969), resulting in the general
56 adoption of more complex flaking strategies and a higher standardization of products (White and
57 Ashton, 2003; Monnier, 2006; Moncel et al., 2011, 2012; Scott, 2011; White et al., 2011; Fontana et
58 al., 2013; Adler et al., 2014; Wiśniewski, 2014; Villa et al., 2016; Picin, 2017). Recent discoveries show
59 that some lithic innovations actually appeared earlier in Western Europe, from MIS 12 to MIS 9,
60 contemporaneous with changes in subsistence strategies and the first appearance of early
61 Neanderthal anatomical features. Evidence of progressive or gradual developments in behaviour is
62 recorded from c. 400 ka with fire use (Roebroeks and Villa, 2011; Gowlett, 2016) and c. 300 ka through
63 organized hunting strategies (e.g., at Schöningen in Germany; Thieme, 1997; Blasco et al., 2013;
64 Conard et al., 2015; Rodriguez-Hidalgo et al., 2017) and. Likewise, paleontological studies and recent
65 DNA analyses suggest the appearance of the earliest Neanderthal features across Western Europe in
66 *Homo heidelbergensis* populations between 600 and 450 ka (Krings et al., 1997; Hublin, 1998, 2009;
67 Hublin and Pääbo, 2005; Orlando et al., 2006; Bischoff et al., 2007; Rightmire, 2008, Endicott et al.,
68 2010; Green et al., 2010; Stringer, 2012; Meyer et al., 2014, 2016).

69 Among the lithic innovations, the first evidence of Levallois technology can be reinvestigated, as
70 recent findings seem to attest to an earlier practice. A fresh look at old collections named proto-
71 Levallois, pre-Levallois or Prepared core Technology (PCT) prior to MIS 9/8 has to be undertaken in the
72 context of these new discoveries. Levallois technology was first identified by Boucher de Perthes
73 (1857) with the recognition of three main criteria (preparation of the core surface, role of the
74 convexities and subsequent detachment of one flake). The definition varied over time, changing from
75 the production of one main end-product to various predetermined end-products (De Mortillet G.,
76 1883; Commont, 1909; Bordes, 1950; Boëda, 1986). Experiments clarified the definition and
77 technological requirements, often (but not always) faceted platforms, angles of percussion and
78 management of the volume of the core (Breuil and Kelley, 1954; Boëda, 1995; Lenoir and Turq, 1995).

79 All the definitions recognized that this technology enabled control of the shape and standardization of
80 the end-products, and required general preparation of the core volume and management of core
81 convexities. Recognition of these technological features on cores and flakes allows identification of
82 Levallois core technology.

83 We have selected well-dated assemblages from MIS 12 to 9 where in the past both cores and flakes
84 were described as Levallois, proto-Levallois or ‘prepared cores’, or have recently been found by new
85 fieldwork. They are located from the northwest to the south of Europe in the UK (Purfleet and
86 consideration of other occurrences), France (Cagny-la-Garenne I-II, Orgnac 3), and Italy (Guado San
87 Nicola, Cave dall’Ollio; Fig. 1) and described as the earliest evidence for each country of Levallois core
88 technology. These assemblages are frequently discussed with the consideration that not all the
89 classical Levallois characteristics are found together (i.e., Malinsky-Buller, 2016b; Soriano and Villa,
90 2017). We aim to review the attribution of these cores and flakes in the light of the new data, to
91 characterize this technology (accidental or evidence of technical innovation), which coexisted for an
92 extended period with earlier technologies. These technologies will be discussed by region with ideas
93 on its origin, such as technological roots in the Middle Pleistocene, arrival of populations or diffusion
94 from multiple areas, the relationship with new needs and behaviours, and the evolution of European
95 populations. In the light of the recent findings, the period of MIS 12 to 9 can be considered as a
96 threshold in cultural human evolution and testing of new technological behaviours, raising questions
97 on how we term this important period. Are we dealing with a phase of invention, deliberate or by
98 chance (Renfrew 1978), or innovation, namely the adoption of an invention by a large number of
99 individuals? Determining the timing and mode of the onset of Levallois core technology in Europe is
100 crucial to understanding how these behavioural changes developed at the inception of the
101 Neanderthal (or *Homo heidelbergensis*) way of life.

102

103 **2. Materials and methods**

104 *2.1. The corpus of sites*

105 From the north to south of western Europe, there are well-dated archaeological sites that show
106 isolated examples of core technologies that have been identified in the past by the originality of the
107 preparation of the flaking surface and the control of the form of the end-products. A selection of these
108 sites, dating from MIS 12 to the end of MIS 9 and from a range of environmental and geological
109 contexts, are reviewed to describe the variation in this technology and to discuss the attribution (or
110 not) to an early form of Levallois core technology. These assemblages are often, but not always,
111 associated with bifaces.

112 While from MIS 8 the recognition of Levallois is not questioned and the definition of Levallois core
113 technology is largely agreed, the multitude of terms for earlier Levallois indicates that the recognition
114 of this core technology older than MIS 8 is more problematic. The terms used include proto-Levallois,
115 pre-Levallois, prepared cores, or simple prepared cores (Wymer, 1968; Roe, 1981; White and Ashton,
116 2003). Discovery of some sites in the earlier years of the subject, led to the use of the terms proto- or
117 pre-Levallois due to the unusual nature of the cores, which did not resemble the 'classic' Levallois cores
118 from sites such as Baker's Hole in Britain. In the UK, this led to the adoption of the term 'simple
119 prepared cores' in part to try and avoid the implication of an evolutionary progression that was
120 promoted by the terms proto- or pre-Levallois (White and Ashton, 2003). Despite the adoption of the
121 new term, it was still sometimes used to imply an early date (e.g., Bolton, 2015), even though such
122 cores are found in both pre-MIS 8 and post-MIS 8 contexts (see below).

123 The background of the selected sites for this review are briefly described below in chronological
124 order. The site of Cagny-la-Garenne is located in fluvial deposits of the Middle Terrace of the Somme
125 Valley (North France). Human occupations took place between the alluvial plain and the limestone
126 slope. The gravels have been attributed to MIS 12 based on the strong regional geological framework
127 of the Somme (i.e. Antoine et al., 2007, 2016). The terrace system of the Somme is particularly well
128 represented in the middle part of the valley, between Amiens and Abbeville, where a set of stepped
129 alluvial formations is preserved by a covering of well developed loess-and palaeosols. In this area, 10
130 stepped alluvial formations have been recognized between + 5/6 m and + 55 m relative height above

131 the maximum incision of the present day valley. The summary of the data (sedimentology, bio-
132 indicators and geochronology) shows that each alluvial formation corresponds to the
133 morphosedimentary budget of a single glacial-interglacial cycle. The glacial stages are characterized by
134 a braided river system and mainly sand and gravel deposition while interglacial stages correspond to a
135 meandering river system, with overbank silt deposition and marshy soil formation at the top.
136 Interglacial.

137 The Electro Spin Resonance (ESR) date of the formation at the site of Cagny-la-Garenne I is of 400
138 ± 101 ka, while other dates on the same alluvial formation (n°V Garenne Formation + 27-29 m) have
139 given ages of 448 ± 68 ka, 443 ± 53 ka and 403 ± 73 ka (Antoine et al., 2003, 2007, 2016). The dates in
140 combination with the evidence of deposition in a cold environment suggest an MIS 12 age for the
141 formation.

142 At Cagny-la-Garenne I, the six artifact assemblages (Level CA to CXB) were made from the locally
143 available flint and consist of bifaces, core and flake manufacture with notches and denticulates
144 (Tuffreau, 1987; Lamotte, 1994, 2012). Assemblages CXCA and CA are in primary context close to the
145 Chalk slope, LJ and LG come from fluvial silts, CXB from limestone gravels and at the top CXV comes
146 from coarse, periglacial gravels (Tuffreau and Lamotte 2010). At Cagny-la-Garenne II, 100 m from
147 Cagny-la-Garenne I, four archaeological levels (I, J, K and L) were recovered, while at the top, five
148 archaeological levels (I0–I4 and J) came from gravels (Tuffreau and Lamotte, 2001). Once again, the
149 fluvial sequence is banked up against the Chalk slope. Raw material was available on site in the form
150 of large flint nodules. All stages of core working and biface manufacture are present.

151 The site of Guado San Nicola is located in south central Italy (Molise Region). It is an open-air site
152 systematically excavated from 2008 to 2015 over an area of 98 m^2 (Peretto et al., 2016). A 20 m
153 stratigraphic core in the immediate vicinity of the excavation, and a series of stratigraphic sections
154 investigated in the area, have confirmed the sequence of the excavation. From bottom to top, the
155 sequence is composed of eight stratigraphic units (S.U.) The 2 m thick-sequence is of polygenic gravelly
156 silty and clayey deposits and contains interstratified tephra layers. It has been dated on the basis of

157 morphostratigraphic considerations and radio-isotopic dating of volcanic deposits. The $^{40}\text{Ar}/^{39}\text{Ar}$ and
158 ESR/U-series dates clearly place the archaeological occupation at the transition between MIS 11 and
159 10 (400 and 345 ka). Unit S.U.C., rich in lithic and faunal remains, is dated to 400 \pm 9 ka by $^{40}\text{Ar}/^{39}\text{Ar}$
160 (Pereira et al., 2016). The faunal assemblage can be attributed to the typical Galerian and to the
161 Fontana Ranuccio Faunal Unit. The faunal assemblage is mainly composed of the remains of *Cervus*
162 *elaphus acoronatus*, *Cervidae*, *Equus ferus* ssp., followed by *Palaeoloxodon* sp., *Bos primigenius* and
163 *Stephanorhinus kirchbergensis*, *Ursus* sp. and *Dama* sp. The sedimentary succession consists of four
164 archaeological levels (C, B*C, B, A*B) with lithic assemblages composed of reduction sequences of both
165 debitage and shaping. The raw material, (mainly flint of good quality with a high degree of silicification
166 and, more rarely, limestone) was collected from a secondary context in the form of cobbles or slabs.
167 The main flaking methods are an opportunistic exploitation (c.f. alternate platform), followed by
168 discoidal and centripetal debitage. The reduction sequences for bifaces are not complete and lack
169 preparation phases (Muttillio et al., 2014). They were made by direct percussion with a hard hammer
170 and final retouch by soft hammer.

171 The site of Orgnac 3 in southeast France, first developed as a cave and then became an open doline.
172 The archaeological sequence of 10 levels is dated through biostratigraphy and ESR, U/Th dating from
173 MIS 9, while for levels 2 and 1 at the top of the sequence, dated by volcanic mineralogy to the beginning
174 of MIS 8 (Combiér, 1967; Debard and Pastre, 1988; Falguères et al., 1988; Masaoudi, 1995; Moncel et
175 al., 2011, 2012). ESR and Uranium/Thorium (U/Th) give ages of 288 \pm 45/+ 82 ka, 309 \pm 34 ka and 374
176 \pm 94/+ 165 ka for the bottom of the archaeological sequence (levels 5b and 6) (Falguères et al., 1988;
177 Laurent, 1989; Masaoudi, 1995), attributed to the MIS 9. Four pure calcite samples of the levels 5b–6–
178 7 (bottom of the sequence) have been dated by U/Th by MC-ICPMS (High-precision Mass Spectrometry
179 and Environment Change Laboratory, HISPEC, Taiwan). Dates vary between 255 and 319 ka (Michel et
180 al., 2011). Level 2 contains volcanic minerals from an eruption of the Mont-Dore volcano, eruption
181 dated to the beginning of the MIS 8 (298 \pm 55 ka) (Debard and Pastre, 1988). Direct dating by $^{40}\text{Ar}/^{39}\text{Ar}$
182 on sanidine grains (cineritic material) has been applied to level 2 (Org-C1). The 12 dates are between

183 276 and 326 ka with an average age of 308.2 ± 6.8 ka. The result is in agreement with the age of 298 ± 55
184 ka by Fission track dating (FT) on zircons (Khatib, 1994). The biostratigraphy associating large
185 mammals, micromammals and pollen date the bottom of the sequence (levels 7 to 3) to an interglacial
186 of the Middle Pleistocene (Mourer-Chauviré, 1975; Tillier, 1991; Jeannet, 1981 ; Guerin, 1980;
187 Gauthier, 1992 ; El Hazzazi, 1998 ; Aouraghe, 1999 ; Sam, 2009). Level 1 is indirectly attributed to the
188 MIS 8 by *Hemitragus bonali* and *Ursus deningeri*. Levels 2 and 1 attest of open landscape with the
189 replacement *Equus mosbachensis* by *Equus steinheimensis* (Forsten and Moigne, 1988).

190 Pre-Neanderthal human remains were discovered in the lowest layers (Lumley de, 1981). The lithic
191 assemblages record a mosaic of changes over time, towards Early Middle Paleolithic strategies (Moncel
192 et al., 2012; Moigne et al., 2016). Debitage activity is dominant and bifaces have variable ratios through
193 the sequence with less than 1% in the top levels. Thin slabs of flint were the main blanks collected
194 locally.

195 The open air site of Cave dall'Olio is located in an alluvial context along the Northern Apennine edge
196 near Bologna, northern Italy. The lithic assemblage was recovered in the 1970s along a stratigraphic
197 profile brought to light by quarry activities at the top of a fersiallitic palaeosol within the gravels of the
198 River Idice at a depth of about 20 m below the present surface. The fersiallitic palaeosol has been
199 referred to the Molino Unit of the Apennine-Po Plain Quaternary stratigraphic framework dated to MIS
200 9, indicating a terminus ante quem for the chronology of this assemblage (Farabegoli and Onorevoli,
201 1996, 2000; Fontana et al., 2010). The dating of the gravels and the soil containing the lithic industry
202 of Cave dall'Olio, as well as their paleoenvironmental interpretation, are based on the integration of
203 data derived from the study of the profile of S. Mamante (Faenza); 22 shallow marine to terrestrial
204 Quaternary units were produced by the long-term activity of a right transcurrent fault with various
205 outcrop segments distributed across a sector of the Emilia-Romagna Apennines edge for a total length
206 of more than 150 km (Farabegoli and Onorevoli, 1992, 1996). Within the reconstructed scheme, the
207 first continental units are dated to the Upper Matuyama chron reverse period and to the Bruhnes
208 direct palaeomagnetic chron. The latter contains the earliest evidence of human occupation in this

209 area (on a stratigraphic basis Bel Poggio and Romanina Bianca are considered to be of the same age as
210 Ca' Belvedere di Montepoggiolo with mode 1 assemblages). The sediments of the continental units
211 correspond in most cases to the glacial-interglacial transition periods and are intercalated with 8
212 fersiallitic soils typical of warm interglacial phases. Correlations have been established between the
213 different portions of the outcropping terraced deposits, which are recognizable upstream along the
214 valley flanks. These have allowed the fersiallitic paleosoil identified at Cave dall'Olio to be referred to
215 as the Molino Unit of the Apennine-Po plain Quaternary stratigraphic framework, dated to MIS 9. Initial
216 studies led to classification of this lithic industry, which is dominated by debitage with evidence of
217 manufacturing of bifaces as ancient Clactonian and proto-Levallois (Bisi et alii 1982; Lenzi and Biagioli,
218 1996) after the original definition by Palma di Cesnola (1967).

219 In the UK, at Purfleet, Essex, Paleolithic artifacts have been recovered from sediments exposed in
220 four chalk quarries, in the Lower Thames Valley. From east to west, these are the Bluelands,
221 Greenlands, Esso and Botany Pits. The pits reveal terrace deposits occupying an abandoned meander
222 loop of the Thames as part of the Lynch Hill/Corbets Tey terrace (Bridgland, 1994), banked up against
223 the north facing chalk slope of the Purfleet anticline. The sequence comprises gravel (Little Thurrock
224 Member) overlain by interglacial deposits rich in faunal material (Purfleet Member) fining upwards to
225 a silty clay and surmounted by gravel (Botany Member). An assemblage of artifacts excavated and
226 collected by Andrew Snelling from the Botany Gravel at Botany Pit was initially described as 'Proto-
227 Levallois' (Wymer 1968), and 'reduced' Levallois with simplified preparatory stages (Roe, 1981). This
228 gravel reflects a return to cold climate gravel deposition following a fully temperate episode,
229 suggesting an MIS 9/8 date, an attribution which is supported by an OSL date of 324 ka (MIS 9) from
230 an equivalent position at Greenlands Pit (E. Rhodes, quoted in White and Ashton 2003).

231

232 *2.2. Methods*

233 For this paper we use the terminology of Boëda (1986, 1993, 1995) for the overall concepts of
234 Levallois: a volumetric concept with six technological criteria: (1) core maintenance (lateral and distal

235 convexities), (2) predetermination of end-products, (3) normalization of end-products, (4) potential for
236 resharpening, (5) ramification, and (6) productivity. The lower surface of the core is devoted to the
237 striking platform and the upper surface to Levallois flake production. To distinguish between cores,
238 such as those from Purfleet, we use the term 'simple prepared core', without implication for an early
239 date. As defined by White and Ashton (2003) they are cores where the striking platform has been
240 selected, minimally prepared and orientated in relation to the pre-existing lateral and distal convexities
241 of one flaking surface. The flakes removed from this surface tend to be larger than any of the
242 preparatory flakes (by which the platform was created), and to flake along the surface at an angle close
243 to 90° to the platform, rather than biting excessively into the core volume. For cores, such as those
244 from Baker's Hole where there is a preferential, single removal, we use the term 'classic Levallois', as
245 for the other sites of our corpus, Cagny-la-Garenne I-II, Orgnac 3, Cave dall'Olio and Guado San Nicola.

246

247 **3. The technological review of lithic material described as Levallois**

248 *3.1. Cagny-la-Garenne I and II (North France)*

249 At Cagny-la-Garenne I, from the base of the sequence (level CA) toward the top (level CXV), the
250 appearance of flakes and cores, described in the past as proto-Levallois, increases, but always in low
251 quantity. In the sandy levels of the middle of the sequence (levels Lj, Lg), this kind of production is
252 rare or absent. At Cagny-la-Garenne II, three levels yielded one or two cores (levels I3, I4, J; Table 1).

253 For each layer, the main core technology is unipolar and unifacial with few scars and a
254 prepared/cortical platform. On a small quantity of cores, various methods (lineal, unipolar, bipolar and
255 centripetal) are employed for the extraction of the end-products with evidence on the cores of
256 management of the distal and lateral convexities and plain or faceted platforms (Figs. 2–4). The
257 removals extend over at least half of the main length of the core surface and their morphology is due
258 to the organization of the convexities. The preparation of the convexities tends to change from
259 unipolar towards centripetal at the top of the sequence for Cagny-la-Garenne I. Most core sizes vary
260 between 50 and 110 mm in maximum dimension. Among the flakes, we can identify some core edge

261 flakes (débordant flakes) with many scars, which are probably from the preparation of the core
262 convexities. In assemblage CXB at Cagny-la-Garenne I, there are several biface-cores with invasive
263 removals interpreted as attempts at Levallois.

264

265 3.2. *Guado San Nicola (south central Italy)*

266 The Levallois assemblage is fresh and the main raw material is aphanitic and microbrecciated flint,
267 or occasionally macrobrecciated flint and silicified limestone. It is of better quality than that used for
268 the bifaces. The supports were ovoid cobbles and quadrangular slabs, or occasionally large flakes.
269 Different stages of the reduction process can be identified and reveal careful preparation,
270 management and maintenance of flaking platforms (angles ranging from 55 to 85°) and convexities
271 (mainly centripetal), indicating the ability to prepare and reprepare cores for predetermined flakes
272 (Fig. 5). Various methods were used in equal quantity (single preferential flake, recurrent centripetal,
273 unipolar and bipolar) and there is evidence of faceted platforms for lineal and recurrent unipolar
274 debitage (Table 4; Fig. 5, 6). The Levallois cores are exhausted and some were made on flakes.

275 Overshot flakes managed the lateral and distal convexities, except for the lineal debitage with
276 centripetal removals. Levallois flakes ($n = 55$) mostly result from 'plein debitage' or reparation of
277 the convexities, produced by unipolar and centripetal recurrent method (Fig. 6). The striking platforms
278 are dihedral or flat, rarely faceted. Levallois points and blades, as well as retouched Levallois flakes,
279 are extremely rare.

280

281 3.3. *Orgnac 3 (south east France)*

282 In the lowest levels (5b and 5a), less than 10% of the cores and less than 3% of the flakes can be
283 classified as Levallois (Table 2; Figs. 7 and 8). The cores are unipolar/bipolar or centripetal recurrent.
284 The knapping surface indicates the utilization of the core edges, one or two partially prepared striking
285 platforms, and maintenance of lateral and distal convexities. The 'Levallois' cores are very different to
286 the frequent unexhausted unifacial and bifacial centripetal cores on slabs or thick flakes, where there

287 is no sign of management of the convexities. Centripetal and Levallois cores are associated with some
288 prismatic, polyhedral and orthogonal cores. Some 20% of the rare Levallois flakes are débordant flakes,
289 while 30% of platforms are faceted and 10% dihedral.

290 In levels 4b and 4a, around 40% of the cores and 2–8 % of flakes can be defined as Levallois (Figs.
291 8–10). The Levallois cores are associated again with centripetal cores. The cores on flakes again
292 indicate evidence of predetermined flaking, preparation of distal and lateral convexities, use of hard
293 hammer and distinctions between striking platform and flaking surface. The methods applied are again
294 unipolar and bipolar recurrent, but the preferential flake method, not used in the lower levels,
295 becomes the most common. In contrast to the underlying levels, the predetermined removals never
296 cover the flaking surface. As for levels 5b-5a, the quantity of Levallois flakes is very low suggesting
297 export of flakes. Débordant flakes total between 20 and 50% of the assemblage. The removals are
298 mainly centripetal and the ratio of flakes with an invasive scar on the upper face increases. The size of
299 flakes is more variable than the cores.

300

301 *3.4. Cave dall'Olio and other assemblages of the Northern Apennine margin (northern Italy)*

302 The assemblage totals 494 lithic artifacts, with 71 cores, 403 retouched and unretouched blanks, 5
303 pebble tools and 15 bifaces (Table 3; Fontana et al., 2013). Most of the assemblage was obtained from
304 a dark colored silicified siltstone that is very abundant locally and available in large-sized nodules and
305 pebbles (10–40 cm). Bifaces were mostly obtained from large flakes and were always worked with a
306 small number of deep removals.

307 Cores are dominated by unidirectional recurrent schemes with either parallel or convergent
308 removals and represent around 30% of the assemblage. Recurrent crossed methods predominate,
309 while lineal, recurrent bipolar and centripetal flaking methods are rarer (Fig. 11). The flaking surfaces
310 were prepared by either débordants or orthogonal removals and core platforms were variably
311 prepared. Levallois cores are associated with a few prismatic types resulting from the application of a
312 laminar reduction process sensu lato—also reported as 'direct non-Levallois reduction sequence'

313 (Révillon, 1995)—and with a small group of cores featuring mixed characteristics between Levallois
314 and laminar reduction. Other methods include Kombewa, opportunistic and possibly discoid reduction.

315 Levallois end-products vary in shape and elongation according to the method applied. There are
316 elongated blanks with parallel edges and frequently characterized by a backed edge from
317 unidirectional parallel and bidirectional methods (with some items possibly obtained from a laminar
318 reduction). There are also flakes with convergent and frequently déjétés lateral margins derived from
319 application of the recurrent unidirectional convergent scheme, small-middle sized oval-shaped flakes
320 from the lineal method and small oval and subtriangular flakes extracted with centripetal debitage.
321 Most products measure between 40 and 90 mm in length. Platforms are generally flat while faceted
322 types are rare (7%, including one ‘chapeau de gendarme’). Although in several cases the condition of
323 the artifact surfaces was altered by fluvial deposition, around 30 retouched blanks were identified,
324 especially scrapers and denticulates, including some on Levallois flakes.

325 Several other assemblages recovered during field surveys from the river terraces of the Northern
326 Apennine edge, which are dated to the same age as Cave dall’Olio, are characterized by similar
327 technological features. The general features of such assemblages show that this area was intensively
328 occupied by human groups that were able to apply different predetermined debitage reduction
329 sequences prior to MIS 9/8 (Lenzi and Nenzioni, 1996).

330

331 *3.5. Purfleet (UK) and other UK sites with simple prepared cores*

332 The assemblage from Purfleet consists of over 4000 artifacts, including 30 bifaces, but the vast
333 majority are flakes (White and Ashton, 2003; Scott, 2011; Bolton, 2015). Distinguishing end-products
334 is problematic and only rare examples of potential Levallois flakes can be identified. A sample of more
335 than 300 cores has been examined in more detail (Scott, 2011). They consist of 170 migrating platform
336 cores, 28 discoidal cores, 80 simple prepared cores and 25 cores that are considered as Levallois. The
337 simple prepared cores conform to the description above, while the few Levallois cores have mainly
338 lineal exploitation (84% with one invasive removal) with a few examples showing unipolar, bipolar and

339 recurrent techniques (with 2 to 3 removals on the flaking surface). The mean length of Levallois cores
340 is 87 mm. The preparation method is mainly centripetal (96%) and there are also cores with proximal,
341 lateral and/or distal preparation of the convexities (Fig. 12). The striking platform is mainly partial.
342 There are also four core débordant flakes and overshoot distal flakes. A total of 26 flakes are considered
343 as Levallois. They are large and elongated (mean length of 115 mm) and result from lineal exploitation
344 with a centripetal preparation. None has faceted platforms. As the assemblage was recovered from
345 fluvial gravel, it is not certain whether all the elements of the assemblage are contemporary. The
346 condition of the bifaces is broadly similar to most of the cores, although some of the Levallois cores
347 are fresher in condition. Purfleet remains the best dated and described British site showing application
348 of the principles of Levallois flaking prior to MIS 8.

349 One of the problems with using the term simple prepared core is that this approach to core working
350 is not rigidly defined or necessarily early, but rather reflects variation in the application of the
351 volumetric principles of Levallois flaking. Apart from Purfleet, there are several UK sites within which
352 simple prepared cores, or cores previously described as proto- or reduced Levallois, have been noted.
353 Some of these are of MIS 7 age, such as Ebbsfleet in the Lower Thames Valley, where simple prepared
354 cores are merely the application of the Levallois flaking system to small pebbles alongside full Levallois
355 applied to larger material (Scott et al., 2010).

356 There are occasional sites that are pre-MIS 8 in age with individual pieces being reported as simple
357 prepared cores. These include a piece described as coming from the 'upper brickearth' at Rickson's Pit,
358 Swanscombe (Burchell, 1931; Roe, 1981), where the Thames terrace deposits date to MIS 11, and
359 Baker's Farm in the Middle Thames from terrace deposits assigned to MIS 10–8 (Wymer, 1999).
360 Although the cores are illustrated, it is not clear in which museum they are curated and cannot be
361 physically located. They may (as with much of the Levallois material from the Middle Thames) actually
362 come from colluvial sediments overlying and sealing the terrace (Ashton et al., 2003; Scott, 2011).
363 Alternatively, the cores only make up a very small component of the whole assemblage, and may
364 reflect the fortuitous end result of exploiting a nodule which favoured the application of this strategy.

365 There are other sites which contain simple prepared cores, but which are difficult to date. These
366 include assemblages from the middle terraces of rivers, such as at Biddenham, Cuxton, Dunbridge and
367 Woodston. The age of these sites could range anywhere between MIS 11 to possibly as late as MIS 7.
368 The Cottages Site is one of several dolines at Caddington and is also undated, but contains simple
369 prepared cores alongside classic Levallois material, including refitting sequences (Sampson, 1978; Roe,
370 1981).

371 Finally, one intriguing site is Frindsbury in the Medway Valley, but again unfortunately undated.
372 The assemblage originally consisted of thousands of artifacts recovered from within a shallow hollow
373 in the chalk (Cook and Killick, 1924). Only 500 artifacts now survive, but include refitting groups of
374 flakes. White and Ashton (2003) described this material as similar to that from Purfleet, with 14 of the
375 16 cores from the site as simple prepared. They suggested that a sequence of large refitting flakes
376 might provide insight into the flake production at Purfleet (Fig. 12). More recent analysis of the
377 material suggests that five of the simple prepared cores actually result from unipolar recurrent
378 Levallois flaking, as does the refitting sequence of five Levallois flakes. There are also three classic
379 Levallois flakes in the assemblage. Further dating is required to understand this potentially important
380 site.

381

382 **4. Discussion**

383 *4.1. Characterization of these early technologies: Levallois or Levallois-type?*

384 The hypothesis of a controlled but not fully standardized technology has sometimes been suggested
385 for these early lithic assemblages (i.e., White and Ashton, 2003; Malinsky-Buller, 2016; Soriano and
386 Villa, 2017). The production of classic Levallois flakes could have been accidental because these flakes
387 did not share all the characters. Several technical features are however common to most of the
388 assemblages:

389 (a) Flaking is already organized around a plane of intersection with asymmetrical faces hierarchically
390 related.

391 (b) Flaking surfaces on cores show maintenance of peripheral convexities with short or more invasive
392 removals (distal and lateral) respecting the plane of intersection. This phase precedes the removal
393 of the predetermined product(s). One face of the core is devoted to the debitage and the opposite
394 face is for preparing the suitable striking platform, which is made by oblique removals and is often
395 a partial function of the form of the support and the type of management of the flaking surface.
396 The location of the removals for the convexities determines the shape of the predetermined
397 products. There is a hierarchy in the management of the two faces of the core.

398 (c) Flake platforms are usually plain, but occasionally dihedral and faceted.

399 (d) Selection of raw material is of good quality and with a specific morphology to reduce the shaping
400 phase.

401 (e) Unipolar and bipolar schemes, sometimes crossed, dominate over centripetal and lineal ones.

402 (f) Some cores are on flakes with evidence of a fragmentation of the reduction sequences. Some cores
403 show a final retouch or series of small removals on a short section of the periphery of the flaking
404 surface, perhaps recycling as a tool or for future debitage.

405 (g) Few flakes can be related to this technology in the lithic assemblages due perhaps to a higher
406 mobility than other flakes. Alternatively, they are just more difficult to recognize than classic
407 Levallois flakes, especially when resulting from shaping reduction sequences. *Débordant* flakes
408 and maintenance flakes exist, although in low quantity, in the assemblages.

409 These features indicate a control of the core flaking surface for some pieces and of the form of the
410 end-products with a recurrent management of the cores and a plane of intersection. If we refer to the
411 definition (Boëda, 1986, 1993, 1995; Boëda et al., 1990), these features may be attributed to a Levallois
412 technology similar to those observed in younger Middle Paleolithic sites.

413 However, two options exist: (1) these pieces are evidence of a mastery of Levallois technology, with
414 occasional evidence prior to MIS 9 and certainly MIS 8, (2) they are the result of accidental technological
415 events within the main core technology; due to the low number of pieces we have to consider whether
416 these cores and flakes result by chance without application of a predetermined concept. Our corpus

417 of sites can be divided in two groups: one dated confidently before MIS 9 (Cagny-la-Garenne and
418 Guado San Nicola) and one with sites dated to MIS 9 (Orgnac 3, Cave dall'Olio and some UK sites),
419 which is usually considered as a period where the Levallois core technology is well mastered in several
420 European regions.

421 In support of the first hypothesis (Levallois core technology), these cores do not seem to be
422 subgroups of the main core technologies of the assemblages, where there is no sign of management
423 of the convexities. The associated core technologies can be summarized for each site:

424 (a) At Cagny-la-Garenne I-II, cores were on flint nodules. The surfaces of these nodules were mainly
425 flaked by a few unipolar and unipolar convergent removals using the natural, flat cortical convexity
426 of the nodules. The cores are abandoned after some removals when the flaking surface becomes
427 too flat.

428 (b) At Guado san Nicola, the numerous discoidal cores were managed on slabs with typical features
429 of a discoidal debitage (unifacial or bifacial pyramidal cores). A few cores are centripetal unifacial
430 with a plane surface and there is no evidence of a hierarchy in the debitage and the preparation
431 of the striking platform and the convexities.

432 (c) At Orgnac 3, the lower levels mainly used flat flint slabs. Cores are thus asymmetrical with
433 centripetal removals covering one or two surfaces, using the natural shape of the slab and the
434 plane cortical surfaces. There is no hierarchy of the two faces and the debitage stopped when the
435 surface became too flat, as at Cagny-la-Garenne.

436 (d) At Cave dall'Olio, cores with centripetal removals on cortical surfaces existed in the assemblages
437 taking advantages of the natural convexities with no evidence of preparation of convexities.

438

439 In support of the second hypothesis (accidental debitage), the cores attributed to Levallois share
440 common technological features with the main production of the assemblage. These cores could be the
441 result of accidents supported by the small number of pieces. So, how do we interpret the innovative
442 behaviour, which are removals and thus the management of convexities controlling the forms of the

443 end-products all over the flaking and maintaining the plane debitage surface? The presence and the
444 specific location of removals of convexities helped the flaking to become independent of the geometry
445 of the stone and of the natural convexities. The flaking could continue even if the natural convexities
446 did not exist anymore and increased the productivity. In most of the Lower Palaeolithic core
447 technologies, the debitage is mainly related to the stone geometry and when it was overcome, the
448 debitage is above all discoid-type (pyramidal flaking surfaces) or polyhedral (Moncel et al., 2013, 2015).
449 When the surface remains flat (centripetal debitage on flakes for instance), the number of removals is
450 in general low and the debitage is uncontrolled. That raises two questions: (1) why do we observe
451 these removals and the possible management of convexities only on some cores?, (2) are these
452 removals accidental, used by convenience to continue the flaking for longer?

453 A second feature that characterizes these cores is the location of the striking platform in close
454 relationship to the location of the assumed controlled predetermined or “Levallois” removals on the
455 flaking surface. The peripheral striking platform (sometimes partial) was made before the
456 management of the flaking surface, a feature often considered as a Levallois criterion by the angle and
457 the location of the striking platform required to maintain the flaking surface.

458 If we analyse these two hypothesis in regard to our two groups of sites and the general
459 technological features of all the cores, the small number of pieces suggest some innovations among
460 the core technology without doubt for the MIS 11-9 assemblages, but could be accidental in the MIS
461 12 sites.

462

463 *4.2. Local innovations from existing technologies?*

464 To explain the early occasional presence of Levallois technology in some assemblages, if non
465 accidental, two hypotheses can be investigated: introduction of external inventions (coming from one
466 place), or local innovations (punctual experimentation of new ideas due to internal or external
467 pressures) possibly with earlier roots, in this case mainly Acheulean-type or at least Lower Paleolithic-
468 type technologies.

469 Some features in the sample of sites suggest a gradual transformation of existing core technologies
470 with the elaboration of reduction processes, such as the use of flakes for the debitage, and, as already
471 suggested, a fusion of elements of both façonnage (bifaces) or/and debitage (discoïdal and centripetal
472 cores; ‘hierarchical cores’; Dibble and Bar-Yosef, 1995; White and Ashton, 2003; Malinsky-Buller,
473 2016). The main core technologies at each site share some common technological features. These
474 common characteristics between the main core technologies and the limited evidence of Levallois or
475 Levallois-like core technology could indicate occasional local innovation from different technological
476 backgrounds, with possible connections between groups, and would explain the diversity of Levallois
477 methods that is observed starting with MIS 12 (Fig. 13). Evidence of removals to manage convexities
478 with a plane of intersection on cores, and Levallois and débordant flakes tend to distinguish the few
479 cores and flakes from the rest of the assemblages. This may be evidence of technological innovation
480 from a wider pool of knowledge. Levallois technology in Europe is sometimes suggested to be a
481 progressive phenomenon preceded by a preparation phase, i.e., a proto-stage. This proto-stage could
482 be observed with use of the hierarchical method, which could be described as intermediate, with a
483 limited preparation of the striking platform and lateral-distal convexities (Picin, 2017). This comes
484 under the umbrella of ‘prepared core technology’ in the UK. Technological data from the selected sites
485 suggests that this interpretation cannot be applied to all sites (from MIS 12–10) as in some cases, such
486 as Guado San Nicola, Levallois technology seems to have been mastered from an early stage.

487 The emergence of this technology could also have been associated with bifacial artifacts. An *in situ*
488 evolution from handaxe technology has been suggested for Cagny-la-Garenne, where biface
489 convexities were used as core faces (Tuffreau, 1987; Mellars, 1996; DeBono and Goren-Inbar, 2001;
490 Villa, 2009; Adler et al., 2014; White and Pettitt, 2016; Tuffreau et al., 2017). In fact, the recycling of
491 bifaces as Levallois cores is a common feature of Somme Valley sites from MIS 12 to 7 (Tuffreau et al.,
492 2007; Lamotte and Tuffreau, 2016). However, other sites in our sample do not provide any evidence
493 of a technical relationship of bifaces and the emergence of Levallois flaking (Fig. 14). It could be
494 considered as a local innovative circumstance to either reduce the thickness of a biface, or produce an

495 expedient flake. Similar behaviour is observed in Spanish and Levantine Lower Paleolithic sites with
496 evidence of recycling (Baena et al., 2018).

497

498 *4.3. Early evidence of regionalization of local traditions across Europe?*

499 While Adler et al. (2014) and Akhilesh et al. (2018) suggested an arrival of the technology from the
500 Levant and Africa, the Levallois features of the sample of sites used in the current paper look similar
501 to other early European assemblages with a Levallois component, suggesting a multiregional origin
502 and diffusion of this technology. In addition there are other early occurrences, such as the sites of
503 Atapuerca TD10 (MIS 11–10) and Ambrona (Middle complex, MIS 10?, various Levallois methods) in
504 Spain, or Kesselt-Op-de Schans (MIS 11–8?, Levallois recurrent centripetal) and Petit-Spiennes (MIS 10)
505 in Belgium, the French sites of Aldene (TU IV, MIS 9, Levallois recurrent centripetal), Petit Bost (MIS 9,
506 level 2, various Levallois methods), and Etricourt (layer HUD, MIS 9, some Levallois flakes), and in the
507 Netherlands Maastrich-Belvedere (possibly MIS 9, Site C, subunit IV–B (Roebroeks, 1988); Bourguignon
508 et al., 2008; Brenet et al., 2008; Meijer and Cleveringa, 2009; Fontana et al., 2013; Lamotte and
509 Tuffreau, 2015; Peretto et al., 2015; Di Modica et al., 2016; Di Modica and Pirson, 2016; Hérissou et
510 al., 2016a, b; Ollé et al., 2016; Pereira et al., 2016; Rossoni-Notter et al., 2016; Baena et al., 2017; Van
511 Baelen, 2017; Santonja et al., 2018). Moreover, in Italy the assemblage from Torre in Pietra, layer m,
512 dated between 400 and 200 ka, indicates the application of discoid schemes associated with Levallois
513 reduction (Villa et al., 2016). Therefore from the end of the MIS 9 there is a large diffusion of
514 technological choices sharing common rules, but with diverse methods, rather than isolated attempts
515 to produce standardized end-products (Hérissou et al., 2016b; Malinsky-Buller, 2016; Soriano and Villa,
516 2017).

517 Levallois technology clearly becomes persistent in Europe between MIS 8 and 6 over a vast territory
518 extending from north-western Europe to the Near East, including central Europe (Tuffreau, 1987;
519 Rigaud, 1988; Lamotte and Tuffreau, 2001; White and Ashton, 2003; Brenet et al., 2008; Wiśniewski,
520 2014; Sánchez-Romero et al., 2016; Soriano and Villa, 2017). Some sites show Levallois schemes, often

521 accompanied by a trend towards the production of elongated blanks (Révillon, 1995; Moncel, 2003;
522 Kozłowski, 2014). Levallois was not the only means of standardizing debitage, with for example
523 unipolar and centripetal débitage at Cueva del Bolomor in MIS 10–9 (Blasco and Peris, 2012), the
524 centripetal exploitation strategies seen in layer TD11 at Gran Dolina (Atapuerca) in MIS 10 (García-
525 Medrano et al., 2015), or the laminar method at Cave dall’Olio (Fontana et al., 2013).

526 Among these sites, technological features show early trends towards regionalization of traditions
527 as early as MIS 8 (Picin et al., 2013; Wiśniewski, 2014; Picin, 2017), supporting the hypothesis of
528 multiregional development and local roots. For instance, in south-east France, Orgnac 3 shows from
529 MIS 9 and 8 an emphasis on centripetal Levallois debitage, while in south-west France uni-bipolar is
530 dominant (Moncel et al., 2011). However, in central-eastern Europe several complexes with Levallois
531 debitage are known from MIS 10 without any evidence of an Acheulean origin, such as Korolevo VI
532 (Koulakovska et al., 2010) and Bechov I (Wisniewski, 2014). Other central European sites are younger,
533 and considered to be evidence of arrivals of new populations during favourable climate with
534 availability of good quality raw materials, such as Rheindahlen, Markkleeberg and Becoc I and IV
535 (Wiśniewski, 2014; Picin, 2017). Similar hypotheses on the arrivals of new populations have been put
536 forward for the Levant (Malinsky-Buller, 2016a; Shimelmitz et al., 2016; Shimelmitz and Khün, 2017).
537 The onset of Levallois technology and all the standardized technologies can probably be explained
538 through multiple modes of origin, dependent on area and latitude.

539

540 *4.4. Explaining Levallois core technology from MIS 12-9 in Western Europe?*

541 Flake selection and preference: Levallois end-products vs. other end-products. If of local origins, the
542 reasons for the onset of this new core technology remain enigmatic in terms of its selection over other
543 technologies. Levallois core technology is often a minor component of the assemblages, associated
544 with different methods of production, such as discoidal (Bolomor, Ambrona), Kombewa, laminar (Cave
545 dall’Olio), centripetal flaking and expedient (unifacial cores with some removals, orthogonal cores with
546 two flaking surfaces and multidirectional cores), which produce a large variety of flakes (Ashton, 1992;

547 Peris et al., 2008; Santonja et al., 2018; Vaquero and Romagnoli, 2018). When discoidal and centripetal
548 methods are used, the flaking surfaces are not hierarchically ordered and there is no evidence of
549 management of the convexities. The debitage uses the natural forms of the blank and the previous
550 removals for guiding the production. End-products are often thick and the form badly controlled.

551 Comparison of the size of Levallois-type cores and flakes to other end-products is not consistent.
552 At Guado San Nicola, despite differences in size between preferential and recurrent flakes,
553 Levallois products are similar in size to other end-products. In contrast, at Orgnac 3, Levallois flakes are
554 among the largest end-products of the assemblages (two groups with lengths of 30–50 mm and 65–70
555 mm for Levallois flakes; Fig. 15). At Purfleet, Levallois cores are slightly smaller (87 mm) than discoidal
556 and simple prepared cores (93–97 mm). The angles and length of cutting edges on Levallois products
557 do not seem to differ between the assemblages.

558 The morphology of Levallois end-products also varies between sites and regions with different
559 quantities of flakes, elongated flakes or points. Points dominate some sites in north-west Europe
560 compared to both flakes and points in the south.

561 Compared to less elaborate core technologies, a better control of the form of Levallois products
562 and a higher productivity of Levallois cores through maintenance of convexities, where all products
563 could be used, seems to be the main focus. This is perhaps linked to an increase in the use of mental
564 templates by populations (Lycett et al., 2016). Villa et al. (2016) suggest that Levallois technology
565 provided thinner products compared to Lower Paleolithic-type methods. These products did not
566 require retouch, the form being predetermined, or the 'one tool, one task' of Douze and Delagnes
567 (2016). The morphological regularity of flakes seems to have led to a reduction in retouched products
568 (Eren and Lycett, 2015). For instance at Orgnac 3, the ratio of flake-tools decreases with the increase
569 in frequency of Levallois core technology (ratio of flake tools of 6% in level 1), while the numerous
570 small flakes (10–15 mm long) produced at the end of the Levallois reduction process and from the
571 cores on flakes, are never retouched (Moncel et al., 2011). At Guado San Nicola, retouched Levallois
572 flakes are extremely rare, with just a few scrapers (Peretto et al., 2015). This decrease in flake

573 modification could have been a cost-benefit in energy. The selection of good quality raw materials (for
574 instance at Orgnac 3) also suggests that attention was paid to this type of debitage.

575 Functional reasons: For hunting and hafting? In parallel to the increase of hunting in subsistence
576 strategies and some changes in land use patterns (e.g. Moncel et al., 2011), the onset of Levallois is
577 sometimes explained by the appearance of hafting of stone points and the use of points as projectiles
578 (Villa et al., 2009; Hardy et al., 2013; Rots, 2013; Iovita and Katsuhiko, 2016). Stone points are often
579 considered as light penetrative tools (Knecht, 1997), and more effective than wooden spears (see
580 Schöningen, MIS 9; Böhner et al., 2015). The early evidence of hafting at Kathu Pan (South Africa),
581 dated to 500 ka, shows points with modification near the base and damage from hafting (Wilkins et
582 al., 2012). The emergence of the Middle Stone Age tradition in East Africa is related to convergent tool
583 technology (Douze and Delagnes, 2016). Modification on small flakes at Gesher Benot Yakov (GBY) is
584 also argued to be evidence of hafting as early as 900 ka (Alperson-Afil and Goren-Inbar, 2016).
585 However, the development of Levallois technology is only associated with the more dominant
586 production of points in north-west Europe, rather than southern Europe. The lithic assemblages of
587 Cagny-La-Garenne I and II and the other sites during MIS 12 clearly do not indicate an emphasis on
588 triangular flake production, but far more oval and rectangular removals. Moreover, microwear
589 analyses indicate that Levallois products were not systematically single purpose tools and also show
590 that form does not necessarily indicate function. Despite little hafting evidence clearly recorded in the
591 European Levallois (Ben-Dor et al., 2011; Rots et al., 2011; Rots, 2013; Iovita and Katsuhiko, 2016; Villa
592 et al., 2016), some patterns show however that Neanderthals were able to haft stone tools and use
593 glues (Mazza et al. 2006; Kozowik et al., 2017) indicating common capabilities to modern humans
594 characterized by abstraction and planning ability (Villa et Roebroeks, 2014; Soressi, 2016).

595 The role of Levallois products consequently remains obscure in terms of form and awaits more
596 microwear analyses to clarify the specific uses of these tools. At Guado san Nicola, among the 75% of
597 the studied artifacts, only 2-4.5% show traces ($n = 82$). Some Levallois flakes carry microtraces with
598 one or two different zones of use with the same activity. All show predominantly animal carcass

599 processing and occasionally plant use with mainly longitudinal actions from cutting (Berruti, 2017).
600 Flakes from Levallois, other core technologies and bifaces equally show occasional wood-plant use
601 (Peretto et al., 2015). At Orgnac 3, the development of the use of Levallois core technology is related
602 to changes in landscape use, with seasonal and specialized occupations focused on horse hunting, such
603 as in level 1 (Moncel et al. 2012).

604

605 *4.5. Increase in the mental templates over time?*

606 If control of the core knapping surface was a major initial feature, the innovation of Levallois could
607 have been in parallel with the long process of the acquisition of Neanderthal features (accretion model;
608 Hublin, 2009) and could be compared to similar isolated attempts that are observed in some sites older
609 than 400 ka in Africa (Pope et al., 2017). This process could explain why this technology became
610 dominant in many areas through the Middle Paleolithic and why it did not emerge earlier (e.g., Lycett
611 and Eren, 2013).

612 For instance, the Oldowan assemblage of Nyabusosi (Uganda) dated to 1.5 Ma shows the
613 hierarchical relationship of core surfaces (Texier, 1995). The Early Acheulean site of Peninj (1.6–1.2
614 Ma, Tanzania) shows some evidence of the preparation of core convexities, as at Wonderwerk (800–
615 500 ka, South Africa), GBY with giant Kombewa and ‘Levallois’ flakes (900–800 ka, Israel), or la Noira
616 (700 ka, France; Texier and Roche, 1995; de la Torre et al., 2003 ; Tyron et al., 2006; Moncel et al.,
617 2013; Chazan, 2015; Leader et al., 2018). In the past, the different Victoria West methods have been
618 considered as para-, proto- or pre-Levallois evidence, with large, wide asymmetrical flakes removed
619 through planning from the core edge by radial or centripetal flaking (Bordes, 1950; McNabb, 2001;
620 Mourre, 2006; Sharon et al., 2009). Similarly, the Tabelbala-Tachenghit method or the Kombewa
621 technique used the bulb of the ventral face of a flake and were described as a ‘preferential-flake
622 method’ (Boëda, 1995). The onset of actual Levallois technology is also observed in East Africa by early
623 modern humans with embedded roots as early as 500 ka with local, gradual changes in the Middle

624 Stone Age (Douze and Delagnes 2016; Deino et al., 2018; Potts et al., 2018). Meanwhile at Misliya cave
625 (Israel), at around 200 ka, there is full Levallois with modern human remains (Hershkovitz et al., 2018).
626

627 4.6. Emergence of Neanderthals or adaptation of hominins to climatic and environmental changes?

628 If we consider the paleoanthropological record in Europe from MIS 13 to 9, data indicate complexity
629 in the acquisition over time of Neanderthal characteristics among *H. heidelbergensis* and Middle
630 Pleistocene populations (Hublin, 2009; Manzi et al., 2010). In western Europe, the anatomical diversity
631 of fossils suggests pre-Neanderthal regional groups, perhaps persistent forms of *H. heidelbergensis*
632 (Ceprano skull dated to 350 ka), as shown by the genetic variability (Rightmire, 2008; Fabre et al., 2009;
633 Manzi et al., 2010; Walker et al., 2011; Stringer, 2012; Meyer et al., 2016; Rightmire, 2017).

634 Neanderthal characteristics were evolving in Europe as far back as MIS 11 and possibly earlier
635 (Hublin, 2009; Stringer, 2012). An earlier divergence time (>430 ka) between Neanderthals and
636 Denisovans was inferred from the nuclear DNA sequence from Sima de los Huesos, whereas mtDNA
637 places these populations closer to one another (Meyer et al. 2014). During the time span of MIS 12 to
638 MIS 7 (ca. 460–250 ka), Neanderthal populations may have experienced a period of isolation, but
639 contact with African lineages postdating the divergence from the Denisovans is also suggested
640 (Arsuaga et al., 2014; Meyer et al., 2016; Hublin et al., 2017; Richter et al., 2017; Bermúdez de Castro
641 et al., 2019).

642 At the moment, correlations between types of hominin and technological innovations are not
643 evident (see Levallois evidence in the Ceprano basin contemporaneous with the skull; Pereira et al.,
644 2018). Technological convergence could exist in many places with a variety of hominins, such as *H.*
645 *heidelbergensis*, *Homo neanderthalensis* and *Homo* sp. (DeBono and Goren-Inbar, 2001; Tyron, 2006;
646 Adler et al., 2014). Neanderthal anatomical features developed in parallel, as with other hominins at
647 this time, with an increase in brain size, but also changes in life history, such as an extended childhood
648 and an adolescent phase (Kyriacou and Bruner, 2011). This allowed an increase in the capability to
649 transmit more complex technological behaviors through social learning (Nowell and White 2010;

650 White et al. 2011). Similar developments in East Africa could explain the onset of Levallois technology
651 among modern human populations. If we consider the low number of 'Levallois' pieces or the
652 eventuality of an event by chance in parallel to some innovations (hierarchical organization on some
653 cores), the phenomenon would indicate (1) a progressive development of the use of mental templates
654 and (2) a technological shift in some areas. This progressive development could have found its roots
655 among *H. heidelbergensis* (and Middle Pleistocene populations), not just after the speciation to
656 Neanderthals.

657 The numerous paleoclimatic archives show a transition from 1.25 Ma up to 0.7 Ma (Mid-Pleistocene
658 Revolution) with a change of the dominant periodicity of climate cycles from 41 ka to 100 ka.
659 Combining different archives over the last 800 ka, some particularly marked interglacials (MIS 19, 15,
660 11, 9 and 5) and glacial maxima (MIS 16, 12 and 2) have been identified (Jouzel et al., 2007). Some of
661 the earliest Levallois evidence is during MIS 11 (Schreve, 2001; Geyh and Müller, 2005; Nitychoruk et
662 al., 2006; Roe et al., 2009; Rohling et al., 2010; Blain et al., 2015; Limondin-Lozouet et al., 2015; Picin,
663 2017). This period of time (post MIS 12, MIS 11) is crucial, characterized by a large biodiversity, large-
664 scale faunal dispersion associated with the regionalization of mammal communities and hominin
665 morphological variability (Stiner, 2002; Bar-Yosef and Belmaker, 2011; Dennell et al., 2011; Palombo,
666 2015). Such a long-lasting interglacial (MIS 11) after a harsh glacial (MIS 12) could have favored more
667 sustained vegetational systems and hence more stable hominin occupation and connections between
668 groups in Europe dependent on latitude (Guthrie, 2001; Ashton et al., 2017, 2018). However, climate
669 does not seem to play a great role in the earliest onset of Levallois from MIS 12-9. It appears during
670 both cold and temperate events in various areas. But climate change was certainly important for
671 diffusion and some breaks in occupation in some areas due to climatic constraints, and could explain
672 the introduction of this new technology such as the UK during periods of lowered sea levels.

673

674 **5. Conclusions**

675 Between MIS 12 and 9, elements of Levallois technology, some probably intentional, are found
676 intermittently over a vast area in both northern and southern Europe, and are sometimes
677 accompanied by a trend towards the production of elongated blanks. The lithics seem to be evidence
678 of a technological shift in some areas rather than production by chance. Levallois core technology
679 before the end of MIS 9 to the beginning of MIS 8 remains rare (Fig. 1). From MIS 8, it was diffused all
680 over Europe and appears to have been a phase of diversification rather than the initial stage. A
681 discontinuity between the earliest and youngest phases during MIS 7–6 is open to question, as in East
682 Africa with the isolated early appearance of laminar debitage at 500 ka (Roure Johnson and McBrearty,
683 2010). Is there a progressive phenomenon preceded by a preparation phase, i.e., a protostage
684 ('prepared core technology' and invasive removals on bifaces)? Due to the small number of sites and
685 their distribution over a large area, we do not know if there is clear evidence of a transition. It is not
686 known whether the isolated evidence of Levallois is due only to innovation (*in situ*), with multiple
687 convergence or roots in the Acheulean in a variety of environments and geographic situations, or also
688 to invention from outside Europe that by its diffusion may have certainly been enhanced by contacts
689 and exchanges of experiences between different groups (Foley and Mirazón Lahr, 1997; Hublin, 2009;
690 Stringer, 2012).

691 The only certainty is the apparent parallel development with the earliest appearance of Levallois
692 core technology and some behavioral changes affecting subsistence, land use and mobility of
693 populations during and after MIS 12 in Europe as shown by the longer distances for raw material
694 procurement and more specialized hunting. Cultural and technical expertise of these populations
695 allowed integration of strategies for making, using, transporting and discarding tools, and the materials
696 needed for their manufacture and maintenance. However, the development of the Early Middle
697 Paleolithic through Europe is not only related to the innovation of Levallois, which appeared later in
698 some regions, indicating a diversity of trajectories.

699 To conclude, it is important to note that these isolated onsets of Levallois are associated with an
700 increase of archaeological data and human activity all over Eurasia after the Anglian or Elsterian

701 glaciation (MIS 12), which is considered as a major turning point. The increase in the quantity of sites
702 raises the question of whether this is due to better preservation or reflects larger populations, while
703 genetic data indicates a decrease of the population size after 500 ka (Meyer et al., 2014). Cultural
704 complexity in the form of Levallois technology does not necessarily reflect demographic expansion
705 (Vaesen and Collard 2016), just as an increase in population does not always lead to diffusion of
706 behavioural changes if populations are poorly connected (Premo and Hublin, 2009; Roger, 2017). Data
707 on the Early Middle Paleolithic (MIS 8–6) indicate both a large diversity of technical expertise among
708 groups and some trends of regionalization before a more pronounced regionalization of traditions
709 during the Late Middle Paleolithic (MIS 5–3; Baena et al., 2017; Carmignani et al., 2017). Middle
710 Paleolithic features emerged as a mosaic as early as MIS 12, including a more complex management
711 of local resources and the use of long-distance lithic raw materials in short-term recurrent occupations.
712 This suggests local innovations. The degree of mobility of human groups and connections between
713 different groups is difficult to estimate, depending on topography and climate, and estimating the type
714 and size of the European population is open to discussion, ranging from a well-connected
715 metapopulation or to more isolated networks of sites with small populations (Bocquet-Appel and
716 Degioanni, 2013; Collard et al., 2013; Derex and Boyd, 2016; Fogarty and Creanza, 2017; Grove, 2016,
717 2017; Ríos et al., 2019).

718 Finally, we have to keep in mind that from at least 500 ka, two technological worlds existed in
719 Eurasia with western Europe standing in contrast to a large area from central Europe to central Asia.
720 In western Europe, the Acheulean and other Lower Paleolithic behaviors are commonly referred to *H.*
721 *heidelbergensis* and early Neanderthals from 700 ka, while in central Europe, the traditions are
722 considered as ‘Micro and Pre-Mousterian’ without bifacial technology (Kozłowski, 2014; Moncel et al.,
723 2015; Golovanova and Doronichev, 2017). Regional differences persisted in Middle Paleolithic
724 traditions from MIS 6 between these two areas (for instance Micoquian in Central Europe) and perhaps
725 between populations (human colonization from Asia from the Middle Pleistocene?) despite a common
726 technical background in core technologies. This feature is unexplained so far and may be due to at

727 least some late exchanges between populations. The pre-existing Lower Paleolithic certainly had a
728 structuring effect on the different adaptive options selected by hominin groups over Europe. The key
729 question now is why Levallois technology became the dominant technological strategy even if other
730 technologies were also used during the Early Middle Paleolithic.

731

732 **References**

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1283 **Figure captions**

1284

1285 **Figure 1.** Location of the sites with some early evidence of Levallois core technology (black rounds).

1286 The gray surface indicates the Levallois extension at the end of the MIS 9. The dark gray surface

1287 indicates the extension from the MIS 8.

1288

1289 **Figure 2.** Cagny-la-Garenne I. Level I3 (Middle of the alluvial sequence): preferential Levallois cores.

1290 The numbers indicate the order of the removals. Drawings and pictures: A. Lamotte.

1291

1292 **Figure 3.** Cagny-La Garenne I – Level I4 (Middle of the alluvial sequence): preferential Levallois cores.

1293 The numbers indicate the order of the removals. Drawings and pictures: A. Lamotte.

1294

1295 **Figure 4.** 1) Cagny-La-Garenne II – Level J (beginning of the alluvial sequence). 2) Cagny-la-Garenne I

1296 – Level CXV (final alluvial sequence). Both preferential Levallois cores. Drawings and pictures: A.

1297 Lamotte.

1298

1299 **Figure 5.** Guado San Nicola: n°1-3 recurrent Levallois core on flint. Arrows indicate the direction of
1300 the removals (thick arrows for the “Levallois” removals and thin arrows for the striking platform).

1301 Drawings B. Muttillio, modified.

1302

1303 **Figure 6.** Guado San Nicola: 1) Levallois flake on silicified limestone; 2–10) recurrent Levallois flakes

1304 and points on flint. Drawings B. Muttillio, modified.

1305

1306 **Figure 7.** Orgnac 3: flakes described as Levallois (level 5b). n° 1 flake with centripetal removals and

1307 convexity scars, curved cross-section; n° 2 flake with convexity scars; n°3 backed flake with

1308 centripetal removals and convexity scars; n°4 flake with centripetal removals, curved cross-section
1309 Drawings: M.H.M., modified from Moncel (1999).

1310

1311 **Figure 8.** Orgnac 3: n° 1, 2, level 4b, n° 3 level 5a; n° 1 core with an invasive removal; n° 2 flake
1312 described as Levallois; n° 3 core with bipolar invasive removals. Arrows indicate the direction of the
1313 removals (thick arrows for the “Levallois” removals and thin arrows for the convexities scars).
1314 Drawings: M.H.M., modified from Moncel (1999).

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1316 **Figure 9.** Orgnac 3 - Level 4b: n° 1, 3, 4, 5, 6 flakes described as Levallois; n° 2 backed flake. Arrows
1317 indicate the direction of the removals. Drawings: M.H.M., modified from Moncel (1999).

1318

1319 **Figure 10.** Orgnac 3: Level 4a: n° 1 core with centripetal removals; n° 2, 3, 4 Flakes described as
1320 Levallois. Arrows indicate the direction of the removals (thick arrows for the “Levallois” removals and
1321 thin arrows for the striking platform/convexities scars). Drawings: M.H.M., modified from Moncel
1322 (1999).

1323

1324 **Figure 10.** Cave dall’Olio, Levallois cores and blanks: 1) bidirectional core; 2) unidirectional
1325 convergent core; 3) lineal core; 4–6 Levallois blanks. Arrows indicate the direction of the removals
1326 (thick arrows for the “Levallois” removals and thin arrows for the striking platform/convexities scars).
1327 Drawings and pictures: F. Fontana.

1328

1329 **Figure 12.** British sites: n°1–4 simple prepared flint cores at Purfleet Botany Pit (Essex); n°5 group of
1330 refitting flakes from Frindsbury (Kent). Pictures: N. Ashton.

1331

1332 **Figure 13.** Local innovations of an Early Levallois core technology over time in Europe.

1333

1334 **Figure 14.** Cagny-la-Garenne I - level CXB: invasive removal on a biface. Photo A. Lamotte

1335

1336 **Figure 15.** Comparison of length of Levallois flakes and the other flakes for the levels 4a to 5b at

1337 Orgnac 3.

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