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A view of the Lower to Middle Paleolithic boundary from the Northern France, far from the Near East?

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1 A view of the Lower to Middle Paleolithic boundary from Northern France, far from the Near East?

2

3 **Abstract**

4 Northern France and the Near East play and have played a central role in the debate around the  
5 Lower Paleolithic (LP) to Middle Paleolithic (MP) boundary. In the early 1990s, the renewed Saalian  
6 record for Northern France began to outline a mosaic model of the LP to MP transition—mainly  
7 based on Tuffreau’s works. It implied the coexistence of Upper Acheulean assemblages (numerous  
8 bifaces with few standardized retouched flakes), ‘Epi-Acheulean’ assemblages (rare bifaces and  
9 diversified retouched flakes) and Mousterian assemblages (Levalloisian industries) during the Marine  
10 Isotopic Stage (MIS) 8–6 period. Since the 2000s, the discovery of new key sites and enhanced field  
11 and laboratory methods are challenging this model. We present first a brief historical summary of  
12 previous approaches to the LP to MP boundary in Northern France. A large dataset of Saalian  
13 archaeological units available from previous works has been updated and expanded to include  
14 additional sites. This allows us to demonstrate that the current Saalian record from Northern France  
15 is both rich and sparse, as it is heterogeneously biased through time and space, and that these biases  
16 limit the accuracy of any attempt to model the LP to MP transition. Nevertheless, we describe the  
17 differences between pre-MIS 9 and MIS 9 and MIS 8–6 records for lithic industries and discuss  
18 whether the current periodization is still relevant considering new data on technological, behavioral,  
19 and cultural changes. The comparison between Northern France and Near Eastern records allow to  
20 distinguish regional cultural patterns from global trends in lithic trajectories of change and determine  
21 how they slotted together. Our review of the available data from these two distant regions confirms  
22 that the LP to MP transition is probably one of the major cultural shifts in human evolution.

23

24 **Keywords:** Cultural trajectories; Late Middle Pleistocene; Levant; North-western Europe; Lithic  
25 technology; Taphonomy

26

## 27 1. Introduction

28 The adoption of Levallois debitage at the onset of the Middle Paleolithic in a large part of the Old  
29 World occurred from MIS 9 onward, from Western Europe to the Near East, but precise timing of this  
30 appearance varies regionally from Marine Isotopic Stages (MIS) 9 and 6 (Fontana et al., 2010; van  
31 Baelen and Ryssaert, 2011; White et al., 2011; Moncel et al., 2012; Picin et al., 2013; Adler et al.,  
32 2014; Hérison et al., 2016a; Malinsky-Buller, 2016a,b; Soriano and Villa, 2017). This implies that we  
33 need to focus our analysis on the Lower to Middle Paleolithic boundary across the continents, if we  
34 want to detect and understand the mechanisms involved. In this paper to aim to explore a long-  
35 distance comparison between two regional records, rarely compared. We show how can the  
36 archaeological record in Northwestern Europe, and more particularly in Northern France, contribute  
37 to enhancing our understanding of the Lower Paleolithic (LP) to Middle Paleolithic (MP) boundary in  
38 the Near East, even with distance separating Northwestern Europe from the Near East.

39 During the Pleistocene, Northwestern Europe and the Near East experienced very distinct  
40 anthropological and paleoenvironmental trajectories. In the current state of knowledge, a single  
41 lineage of hominins, referred to as the Neandertal lineage, is known in Western Europe during the  
42 Middle Paleolithic (Hublin 2009). The situation is more complex in the Near East, where at least two  
43 hominin lineages —*Homo sapiens* (anatomically modern humans [AMH]) and *Homo neanderthalensis*  
44 (Neandertals)—seem to have shared or to have successively occupied territories in this area during  
45 the whole Middle Paleolithic, and probably interbred several times (Simonti et al., 2016; Hershkovitz  
46 et al., 2018). From an environmental perspective, the Middle Pleistocene climatic oscillations had a  
47 profound impact in Northwestern Europe, as attested by the faunal record and other proxies. These  
48 paleoenvironmental changes greatly affected human settlement dynamics in the northern latitudes  
49 of Europe, and generated discontinuity in the settlement of these high European latitudes  
50 (Roebroeks et al., 1992; Tuffreau, 1992a; Tuffreau and Antoine, 1995; White and Schreve, 2000;  
51 Ashton and Lewis, 2002; Gamble, 2009; Roebroeks et al., 2011). At the same time in the Eastern  
52 Mediterranean area, environmental changes induced by climatic oscillations (Vaks et al., 2006;

53 Frumkin et al., 2011; Müller et al., 2011) were buffered compared to northern latitudes and are often  
54 difficult, or even impossible to detect by examining paleoenvironmental proxies in archaeological  
55 contexts. This environmental stability is particularly significant when we look at the constant faunal  
56 record in the Near East (Speth, 2012), unlike in Northern France where species migrations and  
57 replacements occurred at almost each climatic cycle (Auguste, 2009).

58 Such contextual differences must not be viewed as an obstacle to undertaking fruitful  
59 comparisons, but rather as a way of isolating evolutionary tendencies shared by these distant areas,  
60 especially in the field of technological repertoires. If common tendencies exist between the Near East  
61 and Northwestern Europe, then considering the nature and modalities of the transition between the  
62 Lower Paleolithic and the Middle Paleolithic may demonstrate that the weight of 'climatic driving', as  
63 viewed by Foley and Mirazón Lahr (1997, 2003; see also Mirazón Lahr and Foley, 1998) and/or the  
64 exclusive role of AMH in technological innovations at the LP to MP transition would be called into  
65 question. In this case and at the most, we could expect that the 'climatic driving' and the role of AMH  
66 only impacted regional cultural trajectories and not broader technological evolutionary trends. Thus,  
67 we must distinguish regional cultural patterns from global trends in lithic trajectories of change and  
68 determine how they slotted together.

69 In this paper, we propose examining the passage from the Lower Paleolithic to the Middle  
70 Paleolithic in Northern France with references to the broader Northwestern European record. Our  
71 review focuses on a narrow range, from MIS 9 to MIS 6, a period during which we observe the main  
72 changes in lithic repertoires in this region, moving from the Lower to Middle Paleolithic toolkit. This  
73 area is of particular interest for several purposes. Owing to the pioneering work of Commont (1913),  
74 Northern France has historically played a leading role in the recognition of Levallois debitage, which  
75 is now considered by numerous scholars as a hallmark of the Middle Paleolithic. The significance of  
76 Levallois debitage for the emergence of the Middle Paleolithic is a central issue of this paper.

77 Before the discovery and dating of Biache-Saint-Vaast in the mid-1970s (Sommé, 1978; Tuffreau,  
78 1978), the Middle Paleolithic was thought to have begun no earlier than the Last Interglacial, in

79 agreement with the chronocultural framework proposed several decades earlier by Bordes (1950,  
80 1981, 1984). In this latter model, the Upper Acheulean, described in brickyards from the Paris Basin  
81 (Bordes, 1954), developed up to the end of the Riss. From a historical point of view, it is interesting  
82 to recall that Tuffreau (1982) challenged this view at the 1980 Haifa symposium edited by Ronen  
83 (1982). Tuffreau (1982) emphasized the discrepancy between this traditional view of Lower  
84 Paleolithic and Middle Paleolithic chronology and the results from excavations at Biache-Saint-Vaast,  
85 which revealed industries similar to more recent assemblages from the late Middle Paleolithic. But  
86 the Biache industries were recovered from Saalian deposits, and undoubtedly predated the Last  
87 Interglacial leached brown soil (Tuffreau, 1982). A systematic review of the evidence from Northern  
88 France and the results from excavations carried out at Biache-Saint-Vaast allowed Tuffreau (1987) to  
89 propose a revised model where the Early Middle Paleolithic (EMP) from Northern France included  
90 Upper Acheulean industries with numerous handaxes (Gouzeaucourt, Vimy), industries with scarce  
91 handaxes associated with evolved tools on flakes described as Epiacheulean (Bapaume), and others  
92 included in the Mousterian complex (Biache-Saint-Vaast). According to him, the Mousterian  
93 industries from Champvoisy and La Cotte-de-St. Brelade level G seemed to emerge as early as the  
94 beginning of the late Middle Pleistocene. Nevertheless, Tuffreau (1987) wrote that the chronology of  
95 the Upper Acheulean and Epiacheulean was still difficult to ascertain and it was problematic to assess  
96 whether or not they persisted up until the end of the late Middle Pleistocene.

97 Later, industries from Gouzeaucourt and Longavesnes, characterized by numerous handaxes with  
98 an Acheulean morphology, in association with stable types of retouched tools on flakes announcing  
99 the Middle Paleolithic toolkit (Tuffreau and Bouchet, 1985; Marcy, 1989; Ameloot-Van der Heijden,  
100 1993) were called 'Paléolithique moyen de facies cambrésien' (PMC; Tuffreau et al., 1989). According  
101 to Lamotte (1992), the PMC industry from Gouzeaucourt associated technological and typological  
102 characters from both the Lower Paleolithic and Middle Paleolithic and could thus be considered to be  
103 transitional.

104 The Middle Paleolithic character of the PMC industries was not supported by Soriano either  
105 (2000), but he still considered that typical Middle Paleolithic industries and industries with a  
106 technological package inherited from the earlier Acheulean coexisted from MIS 8 to the end of the  
107 Saalian, and that this cultural diversity was also observed in the southwest of France (Soriano, 2005).  
108 As for Tuffreau (1987), he maintained that the transition from the Lower Paleolithic to the Middle  
109 Paleolithic involved a long coexistence of industries with very different toolkits.

110 The main problem is that this scenario allocates almost the same degree of confidence to all sites  
111 and their stratigraphy. The definition and chronology of the Upper Acheulean and Epiacheulean in  
112 Northern France rely exclusively on sites with stratigraphies and chronologies established 30 to 50  
113 years ago, prior to the development of dating methods (i.e., thermoluminescence [TL], optically  
114 stimulated luminescence [OSL], electronic spin resonance [ESR] dating), geoarchaeological analysis,  
115 and the use of taphonomy in archaeological studies. Understanding and interpreting the timing of  
116 changes is directly linked to the accuracy of this chronological framework. For these early moments  
117 of human prehistory, we are confronted with qualitatively heterogeneous chronological data that  
118 need to be considered hierarchically in order to build a secure scenario (Hérisson et al., 2016a). The  
119 introduction of a hierarchy in the late Middle Pleistocene evidences from Northern France was  
120 recently proposed by Hérisson et al. (2016a), following the method introduced for the Middle  
121 Paleolithic record in Southwestern France (Guibert et al., 2008).

122 Northwestern Europe, especially Northern France has developed geological and  
123 geomorphological research programs on fluvial and loess archives over the past decades. The  
124 enhanced chronostratigraphic sequence, resulting from the renewed excavation of sites discovered  
125 in the 19th century and the development of large-scale rescue excavations in accordance with  
126 heritage management policies, provides a robust framework for the timing of changes (Antoine et al.,  
127 2016a; Locht et al., 2016). With the growing body of evidence and with the secure chronological  
128 framework established by the long pedostratigraphic sequence from Etrécourt-Manancourt (Hérisson  
129 et al., 2016b), together with a discussion based on sites with the most accurate MIS correlations

130 (Hérisson et al., 2016a), we can ask whether most, if not all the evidence from Northern France  
131 previously described as Upper Acheulean, Epi-Acheulean or PMC and considered to date from MIS 8  
132 to early MIS 6 might now be pushed back to MIS 9 or earlier. This would lead us to move from a long  
133 transitional model to a more abrupt shift from the Lower Paleolithic to Middle Paleolithic in Northern  
134 France, as we argue below.

135 Why is the Lower to Middle Paleolithic transition so difficult to understand? An accurate  
136 chronological framework is necessary but insufficient because it does not guarantee the continuity  
137 and the representativity of the archeological record. The question of the transition from the Lower to  
138 Middle Paleolithic, like others relative to changes during the Pleistocene, is largely dependent on the  
139 degree of continuity in the available archaeological record. We hypothesize that the late Middle  
140 Pleistocene record (from early MIS 9 to late MIS 6) in Northern France is both geographically and  
141 chronologically biased due to diverse geological factors. We need to address the problem of  
142 continuity vs. discontinuity of technological traditions in order to determine whether typological and  
143 technological changes in lithic assemblages are abrupt or gradual. Our ability to examine where the  
144 archaeological record stands between these two opposed cases depends on the quality and the  
145 continuity of the archaeological record itself. The more discontinuous the archaeological record, the  
146 more we tend to surmise that the LP/MP boundary is marked by total technotypological turnover. Is  
147 the archaeological record at the LP/MP boundary in Northwestern Europe dense enough to overlook  
148 this problem? We develop a macrotaphonomic analysis (as in Soriano, 2005, 2013) and demonstrate  
149 that for the period of time considered here, the archaeological record from Northern France is  
150 characterized by a heterogeneous density of data throughout time and space depending on the  
151 geological context. In most, if not all, cases, the archaeological record is patchy, highly biased and it is  
152 impossible to evaluate the gap between the original density of occupations, the portions preserved  
153 from erosion and dismembering, and the (small) parts discovered to date. Preservation biases in  
154 Northern France, Northwestern Europe, but also elsewhere, cannot be ignored as they probably alter  
155 our perception of the progressiveness of changes in lithic industries at the LP/MP boundary. They



156 also call into question attempts to model population growth based on late Middle Pleistocene  
157 preserved and excavated sites.

158

## 159 **2. Materials and methods**

### 160 *2.1. Materials*

161 The main geographical area investigated in this paper is Northern France, as defined by Tuffreau  
162 (2001), less the southern part of the Seine Basin, in order to obtain a coherent area with the  
163 traditional intervention zones of research teams. Northern France thus defined includes the northern  
164 part of the Seine Basin, the basins of the Manche rivers (Somme, Authie, Canche) and the French part  
165 of the Escault and Lys basins (Fig. 1).

166 Rivers incised the calcareous plateau of the Paris Basin throughout the Pleistocene, forming an  
167 open landscape mainly made up of plateaus and valleys. Only the Boulonnais revealed Paleolithic  
168 occupations in rock shelter but the data from these old discoveries are no longer available (Fagnard,  
169 1988). The whole Paleolithic record comes from alluvial sequences, loess sequences, dolines, and  
170 local slopes or aeolian deposits (notably in Tertiary foothills). The sites referred to in this paper have  
171 undergone taphonomic, chronostratigraphic, chronoclimatic and paleoenvironmental studies, and  
172 have been published and summarized in recent papers with site-by-site references (Hérisson et al.  
173 2016a; Locht et al., 2016). The current corpus is based on a long process of data accumulation  
174 derived from sites discovered from the 19th century until today. Two complete regional summaries  
175 have also been established, including the early Middle Paleolithic (Tuffreau, 1987; Hérisson, 2012).  
176 The region includes reference sites for the end of the Lower Paleolithic and the beginning of the  
177 Middle Paleolithic, such as the Cagny complex, Biache-Saint-Vaast, Therdonne and Etricourt-  
178 Manancourt. These sites with high chronological resolution provide key evidence of the onset of the  
179 Middle Paleolithic and make a considerable contribution to the identification of all the facets of this  
180 crucial period. The record from Northern France is compared to the Northwestern European record  
181 based on the data collected and published in Hérisson et al. (2016a) and to the record in the Near

182 East, based on the data presented in recent publications (e.g., Malinsky-Buller 2016; Ron Shimelmitz  
183 et al., 2016a, b; Zaidner and Weinstein-Evron, 2016; Malinsky-Buller and Hovers, 2019; Meignen, Bar-  
184 Yosef, 2020; see also additional references papers cited below).

185

## 186 *2.2. Methods*

187 Building the regional chronoclimatic and paleoenvironmental scheme The chronoclimatic and  
188 paleoenvironmental framework for the Pleistocene in Northern France is founded on taphonomic  
189 and pedostratigraphic data, datings and environmental multiproxy analyses in continual  
190 development (Antoine et al., 2016). On the basis of the study and integration of hundreds of  
191 individual profiles, it has proved possible over the last thirty years to build a coherent  
192 pedostratigraphic scheme (Antoine et al., 1999, 2003, 2014, 2016; Locht et al., 2016) linking the  
193 alluvial terraces and associated deposits with the covering loess sequence. With this sequential  
194 regional scheme, a precise chrono-climatic phase can be assigned to the associated sites (Locht et al.,  
195 2014). According to Antoine et al. (2016a: 7), “Phases are structured on the basis of a chrono-climatic  
196 subdivision (Paepe and et Somme, 1970), relying on the definition of large and globally  
197 homogeneous periods from the perspective of the type of palaeoenvironmental and  
198 pedosedimentary response Interglacial/Early-glacial (EGL)/Lower Pleniglacial (LPG), Middle  
199 Pleniglacial (MPG), Upper Pleniglacial (UPG), Lateglacial (LGL)”. The analysis and correlation of all the  
200 sequences and sites resulted in a rich and complex terrace and loess soil reference sequence in which  
201 accurate correlations can be established between many marker horizons. In this way, a summarized  
202 regional record can be correlated with the MIS of the LR04 stack (Lisiecki and Raymo, 2005).

203 Macrotaphonomy of the late Middle Pleistocene record in Northern France Taphonomy is a branch  
204 of paleontology designed to understand and describe why, how and to what extent, remnants of the  
205 past, material objects or structures, were altered, disorganized or biased as a result of the effects of  
206 natural processes (geological, biological...) throughout time (Efremov, 1940). For decades, this field of  
207 research focused on mammalian faunas, in particular to discriminate the contribution of carnivores

208 and early hominins in bone accumulations (Boaz and Behrensmeyer, 1976; Shipman, 1981;  
209 Behrensmeyer and Hill, 1988; Lyman, 1994). It was later extended to all kinds of archaeological  
210 remains and not limited to the effects of natural processes on these remains (e.g., Théry-Parisot et  
211 al., 2010; Peresani et al., 2011), but also to anthropogenic modifications and their relationships with  
212 natural agents. This concept was also applied at the scale of archaeological sites themselves to  
213 evaluate their degree of reworking (Vallin et al., 2001), or even at a larger scale—landscape scale  
214 (Zilhão and d’Errico, 1999)—and can be considered in this case as macrotaphonomy. Our aim is to  
215 examine the late Middle Pleistocene sites from the area considered here (Fig. 1) using a  
216 macrotaphonomical approach in order to assess the representativeness of these sites and to  
217 determine to what extent the archaeological record is biased.

218 The dataset from North-eastern France in Hérison et al. (2016a: Table 5) was marginally adjusted  
219 to match with a geographic area including the territories delimited by the course of the Seine River,  
220 then by the lower Aube River, as in Hérison et al. (2015: Fig. 6) and completed by several  
221 archaeological units, with a low density of remains or with only a few remains, not included in this  
222 previous work. This dataset includes 68 archaeological units from 33 late Middle Pleistocene sites  
223 (Table 1). The archaeological levels were recorded using criteria available in the literature or  
224 determinable from available data, including chronological attribution, topographic position of the  
225 site at the time of occupation, chronoclimatic position (from Interglacial to Pleniglacial), excavated  
226 surface, density of lithic remains, sedimentary context (fluvial vs. loessic deposits) and number of  
227 archaeological levels of the site. Archaeological units with chronologies (MIS correlation) rated with a  
228 high degree of confidence (from 3 to 5) by Hérison et al. (2016a) were treated separately from less  
229 confident ones (rated 1 or 2).

230 Technological approach Most of the lithic assemblages from Northern France presented here were  
231 studied by the authors. The same methodology was applied to all the lithic assemblages, and is  
232 explained in depth in Soriano (2000) and Hérison (2012). We adopted a chaine opératoire approach  
233 in order to reconstruct the different steps of the lithic production systems and their internal links.

234 This concept derives from the “general proposition of Mauss (1968) to extend the field of ethnology  
235 to these humble and trivial human behaviors that are the techniques of the body, and, a fortiori, to  
236 any technical action. In order to understand how a material operation is specific to a particular  
237 group, first of all, we must try to decipher the way in which various elements (energies, tools,  
238 gestures, knowledge, actors, materials) are linked during processes that modify a material system”  
239 (Lemonnier, 2004: 1, our translation from the French language). In this paper, we apply a  
240 classification founded on the structure of cores and the technical characteristics of blanks, following  
241 Boëda (2013).

242 We also use the concept of ramification, recently developed in lithic studies in the French  
243 literature (Bourguignon et al., 2004; Mathias, 2016). It is pertinent to explain how it articulates with  
244 recycling. Schiffer (1987), then Shott (1996: 265), considered that “recycling extends the utility of  
245 tools beyond their original design or purpose”. On a broader level, a Paleolithic flint implement  
246 (retouched tool, blank, core) is recycled when it is treated almost in the same way as a raw material,  
247 i.e., independently of any previous structure and features of the object and planning. As explained by  
248 Rios-Garaizar et al. (2015), the term ramification was proposed as a way to bypass the usual rigid  
249 technological categories (cores, flakes, byproducts, tools, waste), aiming to describe a complex  
250 architecture of flint production where the status of any element can change to meet the functional  
251 and economic requirements of Middle Paleolithic societies. This was observed especially in Quina  
252 Mousterian industries where any volume of knappable material is managed as a matrix that can be  
253 exploited alternatively as a core or as a blank for tools, frequently transverse or déjeté scrapers  
254 (Bourguignon, 1997; Hiscock et al., 2009; Faivre, 2011). In this way, the term ‘ramification’ was  
255 retained to describe the treelike structure of blank production and use (Bourguignon et al., 2004). It  
256 is not opportunistic like recycling but planned within the frame of the lithic system. Not all  
257 Mousterian industries are structured that way so this can be considered as a particular feature of  
258 Middle Paleolithic technical identities. The whole lithic system can be ramified (as in the Quina

259 Mousterian) or only a component of the lithic system as evidenced by one of us in an EMP industry  
260 from Central Italy (Soriano and Villa, 2017).

261 With these technological elements, we can observe the temporal repartition of each chaîne  
262 opératoire in the Saalian record in Northern France and propose a schematic model of technological  
263 changes for the LP/MP boundary. This regional scheme is then compared to Northwestern Europe  
264 and the Near East and put into anthropological, sociocultural and environmental perspectives in  
265 order to interpret the observed changes and tendencies in the different regions.

266

### 267 **3. Results**

268 Most, if not all archaeological records are biased, including those from the most recent periods.  
269 Only small portions of archaeological occupations were fossilized and only some of them have been  
270 recovered to date. The preserved parts of these portions cannot necessarily be directly correlated  
271 with the age of the site (i.e., the oldest occupations are not always the least preserved). Due to the  
272 patchiness of Pleistocene deposits, we can also assume that site preservation is highly geographically  
273 variable. Our hypothesis is that the late Middle Pleistocene record (from early MIS 9 to late MIS 6) in  
274 Northern France is disparately biased. We aim to determine if this can alter our capacity to interpret  
275 changes in lithic traditions between the Lower and Middle Paleolithic.

276 The geological factor is the main source of depletion of the archaeological record, as it is  
277 responsible for the erosion of earlier deposits. Moreover, during some periods, there were no  
278 geological deposits to fossilize human occupations. However, other factors must also be taken into  
279 account. The strong impact of human activities on the landscape—notably since the beginning of the  
280 Industrial Revolution —induces more destruction of archaeological sites than geological factors.  
281 Heritage management policies and methods of preventive archaeology can also generate biases in  
282 our knowledge of the archaeological record when field research is intrinsically focused on specific  
283 geomorphological or topographical contexts, for example. More generally, the history of research  
284 has a non-neutral effect on the representativeness of the data we collect for Pleistocene periods.

285

### 286 *3.1. Tracking biases in the record*

287 We can first of all note that our data are unequally distributed throughout time and that this  
288 distribution is divided into two qualitative groups—one (Fig. 2A) clustering archaeological units from  
289 sites rated with a confident (5 to 3) MIS correlation value and the other (Fig. 2B) grouping  
290 archaeological units with uncertain chronological interpretations. This may mean that occupations  
291 and sites from certain periods of time provide more accurate chronologies than others. In particular,  
292 those from MIS 8 or 6 are more underrated than those from MIS 9 or 7. This could perhaps be  
293 explained by differences in depositional contexts as occupations preserved in fine-grained fluvial  
294 deposits, mostly those from MIS 9 or MIS 7, are much more represented in the first qualitative group  
295 (Fig. 2A). Occupations confidently dated to MIS 8 are very infrequent in Northern France compared  
296 to the previous MIS 9 period. On the other hand, MIS 7 occupations are just as represented as MIS 9  
297 occupations.

298 The pattern appears to be clearer when archaeological units (only those with MIS correlation  
299 values from 5 to 3) are organized according to the corresponding chronoclimatic phases (Fig. 3).  
300 Occupations fossilized in fine fluvial deposits cluster from Late Glacial to Late Interglacial/Late  
301 Interstadial phases, whereas from the Early Glacial to the Pleniglacial, occupations are only  
302 documented in loess or loess-derived deposits. This means that during temperate or cold/temperate  
303 phases during the Saalian in Northern France, the possibility of discovering preserved occupations  
304 outside fluvial formations is reduced. If we consider that fluvial terraces are very patchily preserved  
305 and not preserved at all in some watercourse sections, we can begin to measure the extent of biases.

306 In addition to the deposition patterns of different types of Pleistocene sediments in Northern  
307 France according to chronoclimatic phases, the preservation of Paleolithic occupations can be due to  
308 natural hazards or to the very localized development of some deposits. We know that some types of  
309 geological deposits that occur during restricted periods of time under specific climatic conditions, as  
310 exemplified by observations from earlier or later periods, have not yet been observed in the region

311 during the Saalian. Below, we describe cases of chronological and spatial unevenness of deposits for  
312 each chronoclimatic phase, illustrating the sources of the biases observed.

313 Early Glacial At Cagny–La Garenne 1 in the Somme Valley, excavations evidenced the preservation of  
314 remnant slope deposits with interbedded fluvial silt levels below the fluvial gravels from terrace IV  
315 (Antoine and Tuffreau, 1993; Antoine et al., 2007), along the chalky slope. They were deposited at  
316 the onset of fluvial aggradation in the early glacial phase of the MIS 12/11 cycle and they contained  
317 several archaeological levels from the Acheulean. Such deposits were usually dismembered before  
318 the deposition of gravels and in the Somme Valley they have only been observed at La Garenne 1 to  
319 date. Equivalent fluvial deposits from Early Glacial MIS 8 and MIS 6 are still unknown. Therefore, the  
320 fossilization potential of Early Glacial occupations is low in the valley bottom. The pedostratigraphic  
321 record of the Weichselian in Northern France is now extremely well documented and the Early  
322 Glacial is characterized by humic soil horizons and soil complexes (Antoine, 1989; Antoine et al.,  
323 1999, 2016). Former and more recent observations at La Longueville, Cagny-Ferme de l'Épinette or  
324 Therdonne, for example (Sommé and Tuffreau, 1976a; Tuffreau et al., 1997; Locht et al., 2010),  
325 suggest that earlier periods sometimes experienced similar pedologic developments for the Early  
326 Glacial phase. However, such soils were rarely observed for the Saalian. Recently, a grey forest soil on  
327 colluvial deposits confidently dated to MIS 9c was described in the long stratigraphic sequence from  
328 Etricourt-Manancourt with a preserved Acheulean occupation (Hérisson et al., 2016b). This soil was  
329 only preserved on the middle and lower part of the slope, as a result of being buried under thick later  
330 deposits and consequent modifications of the local topography. Generally, in Early Glacial loessic  
331 contexts, occupations appear to be reworked on erosional surfaces truncating the  
332 interglacial/interstadial soil and unconformably overlain by loess or colluvial deposits.

333 Pleniglacial In fluvial contexts, the in situ preservation of occupations under Pleniglacial conditions in  
334 Northern France is unlikely. Industries were recovered in the Somme Valley at the beginning of the  
335 20<sup>th</sup> century in the bulky MIS 8 Pleniglacial gravels from Argoeuvres terrace (alluvial formation III in  
336 Antoine et al., 2007; Agache, 1976), and in the early 1970s in contemporaneous gravels from La Selle

337 River, a tributary of the Somme River (Ameloot-Van der Heijden et al., 1996). In this latter site,  
338 industries with different degrees of alteration are clearly mixed together (D.H., pers. obs.) and some  
339 of them may be reworked from older deposits. Loess deposits from MIS 8 or 6 have been described  
340 in several sites from Northern France but up to mid-MIS 6; these deposits were mainly derived from  
341 local earlier sediments, especially Tertiary sands, and they are unevenly distributed and very  
342 discontinuous. In several cases, as in Gentelles (Tuffreau et al., 1999, 2008), it seems that industries  
343 included in MIS 8 and 6 Pleniglacial loess or loess-derived deposits are reworked. Nevertheless, at  
344 Saint-Valéry-sur-Somme, in the lower valley of the Somme River, an assemblage was recovered in  
345 aeolian sands dated to MIS 8, according to the pedostratigraphic record (Heinzelin and Haesaerts,  
346 1983). Several refits were made from an assemblage collected from a small-scale excavation,  
347 suggesting that the occupation was preserved in primary position. This site is the only one  
348 considered to be in primary position in MIS 8 Pleniglacial deposits.

349 Late Glacial–Early Interglacial/Interstadial In the Somme Valley, paleoenvironmental proxies suggest  
350 that the deposition of carbonated fluvial silts above gravels and coarse sands occurred under a cold  
351 to cool continental climate corresponding to the Late Glacial phase of the climatic cycle (Munaut  
352 1988a, b; Tuffreau et al., 1986; Antoine, 1990; Antoine et al., 1995, 2003). The transition towards a  
353 wet land system in the valley bottom with the channeling of the watercourse resulted in the  
354 development of organic soils with the onset of milder conditions. These contexts provide the best  
355 conditions for the fossilization of late Middle Pleistocene occupations, as demonstrated by several  
356 well-known sites such as Cagny–L’Epinette (Tuffreau et al., 1986, 1995; Tuffreau and Ameloot-Van-  
357 der-Heijden, 1991), Biache-Saint-Vaast (Tuffreau and Sommé, 1988), or Soucy (Lhomme et al., 1996;  
358 Chaussé et al., 2000; Lhomme, 2007).

359 Interglacial/interstadial In the Somme Valley, the Last Interglacial optimum is recorded at Caours  
360 with the deposition of calcareous tufas (Antoine et al., 2006), but also in several localities (Saint-  
361 Acheul in the Somme Valley, La Celle in the Seine Valley) for the earlier MIS 11 interglacial optimum  
362 (Limondin-Lozouet et al., 2015). This type of deposit is still lacking or remains undocumented in



363 Northern France from MIS 9 to 6. Archaeological material has been recovered in this type of deposit  
364 in Europe (Brunnacker et al., 1982; Wagner, 1992; Mania, 1995; Preece et al., 2006). Under  
365 interglacial/interstadial conditions, brown soil developed on loessic deposits but the ensuing erosion  
366 towards the Glacial phase, associated with the degradation of climatic conditions, induced the  
367 systematic reworking of interglacial occupations, as observed in many sites: Roissel (inf.), Fransures,  
368 Combles, Sourdon, Busigny (Antoine, 1993). This is why so few fully interglacial late Middle  
369 Pleistocene occupations are known in Northern France (Tuffreau and Roebroeks, 2002).

370

### 371 *3.2. When researchers themselves and research opportunities bias the record*

372 Late Middle Pleistocene loess accumulation is much more developed in the eastern part of  
373 Northern France (e.g., Cambrésis, Vermandois) than in the western part (Sommé, 1976, 1977;  
374 Antoine, 1990; Antoine et al., 1998). From the beginning of the 1970s to the late 1980s, several late  
375 Middle Pleistocene sites were discovered and studied in this area, frequently in brickyards with  
376 loessic stratigraphic sequences predating the Last Interglacial, as at Vimy (Sommé and Tuffreau,  
377 1976b), Bapaume (Tuffreau, 1976), Beaumetz-lès-Loges (Hurtrelle et al., 1972), Gouzeaucourt  
378 (Tuffreau and Bouchet, 1985), Longavesnes (Ameloot-Van der Heijden, 1993), or further south, in the  
379 Tardenois at Champvoisy (Chertier and Hinout, 1988; Tuffreau, 1989). At the same time, a large  
380 rescue excavation was undertaken at Biache-Saint-Vaast in late Middle Pleistocene fluvial deposits  
381 from the Scarpe River (Tuffreau and Sommé, 1988). From the mid-1990s, the development of rescue  
382 archaeology, and then preventive archaeology, resulted in the displacement of most of the research  
383 and fieldwork to the western loessic area, particularly along major road and rail works (TGV railway,  
384 highway, bypass, etc.; Locht and Depaepe, 2011). As a consequence, the pedosedimentary record  
385 from the western province is now finely documented (Antoine et al., 2002), together with numerous  
386 late Middle Paleolithic sites (Locht and Depaepe, 2015; Locht et al., 2016), whereas our knowledge of  
387 the late Middle Pleistocene is still limited due to this disparate geographic development of fieldwork.  
388 This induces another type of bias. Fortunately, over the past decade, the Seine-Nord-Europe canal

389 project allowed researchers to conduct large excavations in late Middle Pleistocene loessic deposits  
390 in the eastern province, filling this geographic bias in our data. At Havrincourt 2 (Goval and Hérissou,  
391 2012; Antoine et al., 2014), a single late Middle Pleistocene level was discovered, whereas at  
392 Etricourt-Manancourt, now considered as a key site, the extensive excavation revealed a long  
393 pedosedimentary sequence covering the whole Saalian (Hérissou et al., 2016b).

394 Biases introduced by our methods of investigation can be less visible. Locht and Depaepe (2011)  
395 reminded us that the rules and regulations in effect in France in preventive archaeology impose  
396 maximum excavation depths in relation with future land use planning. Along large linear works, the  
397 excavation of sites where the route lies on embankments is prohibited as the sites are not destroyed  
398 by road and rail works. As a consequence, deeply buried sites cannot be excavated and downslope  
399 sites are never excavated. These biases regularly affect sites of the same age. Moreover, large linear  
400 works are often located in similar topographical contexts, thus providing access to Pleistocene  
401 formations of the same age or type. Human activities also impact the archaeological record. In the  
402 Somme Valley, town and country planning since the 19<sup>th</sup> century have definitively prevented access  
403 to some fluvial deposits bearing late Middle Pleistocene occupations. Furthermore, recent field  
404 observations near Amiens concluded that fluvial deposits from some pre-MIS 9 terraces were almost  
405 totally depleted to provide railway ballast in the late nineteenth to the early twentieth centuries,  
406 thus preventing or at least considerably limiting any reappraisal of the stratigraphic context of the  
407 Paleolithic occupations.

408

### 409 *3.3 A gap in the archaeological record at a crucial moment*

410 Based on the descriptions and analysis presented above, we can conclude that the archaeological  
411 record from the late Middle Pleistocene in Northern France is strongly biased. The preservation of  
412 occupations is directly linked to the development of geological formations under determined climatic  
413 conditions. Pleniglacial phases are marked by unfavorable conditions for the fossilization of  
414 occupations, especially in a fluvial context. On the one hand, settlement is expected to be more

415 discontinuous in harsh environments, and on the other hand, occupations could hardly be fossilized.  
416 This explains the sharp contrast between the frequent occupations from early to late MIS 9 and the  
417 few occupations firmly dated to MIS 8 (Fig. 2). Unfortunately, it is precisely at this moment that a  
418 major change in technological repertoires is expected to occur according to the characters of  
419 industries before and after this cut-off point (Hérisson et al., 2015, 2016a). We can thus conclude  
420 that biases in the archaeological record in Northern France impact our comprehension and  
421 interpretation of cultural changes between the Lower Paleolithic and Middle Paleolithic. A  
422 reappraisal of the chronology and context of 19th and early 20th century discoveries through  
423 renewed fieldwork may improve our knowledge of this crucial moment.

424

#### 425 *3.4. Pre-MIS 9 archaeological record: an Acheulean world around Saint-Acheul*

426 The oldest traces of human occupations in Northern France appear around the famous city of  
427 Abbeville and in the Somme Valley. From MIS 16 to 10, all the discoveries were classified as  
428 Acheulean, except for the site of Rue du Manège. The oldest lithic assemblage comes from the well-  
429 known site of Moulin-Quignon, studied by J. Boucher de Perthes in 1863–1864 (Hurel et al., 2016),  
430 where recent investigations and analysis are currently awaiting publication. At the Carpentier quarry,  
431 also situated in Abbeville, two Acheulean handaxes found in a karstic depression (Fig. 4) may be  
432 attributed to the end of MIS 15, or possibly MIS 14 (Antoine et al., 2014).

433 At Amiens, an excavation at Rue du Manège yielded 23 artifacts attributed to MIS 14/13, around  
434 550 ka (Locht et al., 2013). Most of the assemblage consists of thick cortical flakes with unworked  
435 butts. The only core indicates discoid reduction (Fig. 4). A single scraper and a denticulate are the  
436 only retouched tools of the series (Fig. 4). Due to the absence of bifaces in this small assemblage, it  
437 was suggested that it is difficult to classify it as 'classic Acheulean', but the hypothesis cannot be  
438 definitively abandoned, as bifaces could originally have been part of this assemblage and may occur  
439 outside the excavation area (Locht et al., 2013). This is a recurring problem for assemblages from this  
440 time period (Wenban-Smith, 1998).

441 For MIS 12, our knowledge of human occupation stems from the site complex of Cagny-la  
442 Garenne. Cagny-la Garenne I is correlated with the beginning of MIS 12 at around 430–450 ka  
443 (Tuffreau et al., 1997), in an Early Glacial landscape (temperate wooded steppe, inhabited by large  
444 herbivores: bovids and cervids). In contrast, the occupation of la Garenne II could be placed in a Late  
445 Glacial context (Tuffreau et al., 2008). The characteristics of the assemblages of both sites are very  
446 similar, with a low percentage of bifaces with diversified morphologies depending on raw material  
447 block forms, flakes produced by a Clactonian system or ‘système par surface de débitage alternée’  
448 (SSDA; Forestier, 1993), and retouched flakes dominated by denticulates and notches (Tuffreau et al.,  
449 2008; Fig. 4).

450 For MIS 11/10, an Acheulean occupation was identified in a slope context, in loess deposits  
451 overlying the alluvial sheet at Cagny-Ferme de l’Epinette during excavations by Tuffreau in 1994 and  
452 1995, over an area of 2500 m<sup>2</sup>. The archaeological level MS is attributed to the Early Glacial phase of  
453 the beginning of MIS 10 (Tuffreau et al., 1997). The assemblage consists of bifaces and refits showing  
454 the production of cortical thick flakes from short unipolar sequences (Tuffreau et al., 2008; Fig. 4).  
455 Level CO at Gentelles, preserved in a sinkhole, also appears to be contemporaneous with MIS 10  
456 (Tuffreau et al., 2008, 2017). This excavation, led by Tuffreau between 1998 and 1999 over an area of  
457 6177 m<sup>2</sup>, yielded bifaces (nearly 25% of the lithic assemblage) and flakes produced by short unipolar  
458 sequences described as SSDA (Tuffreau et al., 2001).

459

460 *3.5. The MIS 9 archaeological record: a Lower Palaeolithic technological toolbox with innovative*  
461 *elements*

462 Bifacial shaping Bifacial shaping is represented in all the MIS 9 sites (Cagny-l'Épinette, Etricourt-  
463 Manancourt, Plachy-Buyon, Revelles and Clairly-Saulchoix). Bifacial shaping by-products account for a  
464 substantial proportion of the assemblages, although bifaces always represent a very minor  
465 percentage (often around 1–2%). As shown in Figure 5, the morphology of bifaces varies drastically,  
466 even within the same level. This can be explained by the conception and the method used for  
467 obtaining the desired bifacial tools, as revealed by technofunctional analysis (i.e., Nicoud, 2013). The  
468 bifacial shaping chaîne opératoire appears to be highly spatiotemporally segmented and bifaces  
469 seem to be highly mobile elements, not just at the site scale, but also at the landscape scale.

470 Common flake production Up until recently, little attention was paid to flake production for MIS 9, or  
471 for older assemblages, due to the low number of debitage elements recovered on the main site  
472 (Cagny-l'Épinette) and the low degree of estimated technical investment visible on cores and end  
473 products. It therefore remains difficult to obtain an accurate idea of the methods used. However, the  
474 recent study of level HUD at Etricourt-Manancourt revealed a system of debitage producing  
475 standardized cortical backed knives (Hérisson et al., 2016; Fig. 5). These cortical backed knives were  
476 produced by short secant unipolar sequences (2 to 5 removals per sequence), repeated or not on  
477 different parts of the original block volume. The use-wear analysis on level HUD of Etricourt-  
478 Manancourt shows that a large proportion of the rough cortical knives were intensely used. A current  
479 question is to determine whether the same standardization and intense use also exist in other MIS 9  
480 sites. Previous analyses seem to show that the same method, or a relatively similar method was  
481 used, with short secant unipolar sequences, but this remains to be confirmed by future reanalysis.

482 Earlier, but late, occurrence of Levallois concept The use of the Levallois method was proposed at  
483 Cagny-la Garenne, with the presence of Levallois cores around 450 ka (Tuffreau et al., 2008; Moncel  
484 et al., 2020), but this appears to be a case of morphological convergence rather than an isolated  
485 example of this production system (Soriano, 2000). Unlike the la Garenne case, in level HUD of  
486 Etricourt-Manancourt, two refits show a completely different chaîne opératoire to the one producing  
487 cortical backed knives (Hérisson et al., 2016b). As all the criteria defining the Levallois according to

488 Boëda (1993) are present, these refits could be considered as the oldest convincing use of this  
489 concept in Northern France. This implies that the Levallois method was applied for the first time in  
490 typical Lower Paleolithic assemblages and represented a low percentage of flake production. It also  
491 suggests that the innovative Levallois process might be rooted in the 'regional' Acheulean and not  
492 imported by settlers from afar. It also suggests that the Levallois developed here independently and  
493 does not derive from bifaces recycled as cores (Degorce, 1992; Lamotte, 1992; Rolland, 1995;  
494 DeBono and Goren-Inbar, 2001).

495 Retouched blanks Very few blanks are retouched in MIS 9 assemblages, and retouched elements are  
496 mainly notches, denticulates and single scrapers (Fig. 5).

497

### 498 *3.6. The MIS 8-6 record: the childhood and youth of the Middle Paleolithic*

499 Levallois flake production All the EMP sites and levels contain Levallois flakes, apart from the site of  
500 Saint-Valéry-sur-Somme. Levallois flake production is thus a hallmark and a common component of  
501 these lithic assemblages, from the end of MIS 8 to the end of MIS 6. The Levallois concept was  
502 defined by Boëda (1994) after the study of Biache-Saint-Vaast and Bagarre, two Saalian sites in  
503 Northern France. Levallois flakes can be produced using a preferential method or a recurrent  
504 method. The latter method is divided into three modalities: unipolar, bipolar or centripetal. All the  
505 modalities are present in the EMP record but it is still difficult to establish a precise scenario for the  
506 first appearance of each schema. The preferential method was mainly used to obtain large suboval  
507 flakes by the centripetal preparation of the flaking surface in most cases (Fig. 6). The Levallois  
508 recurrent unipolar or bipolar schema produces elongated flakes and rectangular flakes, typical of the  
509 Biache-Saint-Vaast industries (Fig. 7). The Levallois recurrent centripetal schema is employed to  
510 obtain suboval flakes, mainly in a final phase of core reduction during the Saalian, as demonstrated  
511 for Biache-Saint-Vaast (Hérisson, 2012). Numerous Levallois flakes were left unretouched for direct  
512 use, as shown by technofunctional and use-wear analyses.

513 Blade production At the end of MIS 8, the first evidence of well-controlled blade production appears  
514 at Saint-Valéry-sur-Somme (Heinzelin and Haesaerts, 1983; Fig. 8). We use the term blades only for  
515 the end products from a specific chaîne opératoire dedicated to the production of blades from  
516 prismatic cores, as defined by Révillion (1994), notably to distinguish them from the elongated  
517 Levallois flakes stemming from the Levallois method (recurrent unipolar or bipolar). Blades are very  
518 rare in the EMP record compared to MIS 5 industries (Goval, 2012; Locht et al., 2016). Blade  
519 production is attested by the famous Saint-Valéry-sur-Somme refits and some other elements,  
520 including three cores at Therdonne (level N3; Locht et al., 2010, Hérissou, 2012). The core is  
521 initialized by preparing two opposed striking platforms, followed by the removals of elongated  
522 cortical flakes, thanks to the elongated form of the selected block (Fig. 8). Then, during blade  
523 production, the two opposed twisted striking platforms are used to turn around the block and  
524 maintain the curved and carinated profile of the flaked surface.

525 Levallois point production/Levallois recurrent unipolar convergent Levallois point production (Fig. 9)  
526 is only attested at Therdonne (level N3; Locht et al., 2010; Hérissou, 2012; Hérissou and Locht, 2014)  
527 and at le Puceuil (level B; Delagnes and Ropars, 1996), at the end of MIS 7 and the beginning of MIS  
528 6. Points are produced following a Levallois recurrent unipolar convergent schema. Sometimes, a  
529 second striking platform is used to better control or rectify the distal convexities and thus the distal  
530 morphology of the point, but this is a minor variation of the schema (Hérissou, 2012). As already  
531 pointed out by Hérissou et al. (2015), Levallois points are present in lithic assemblages without  
532 convergent retouched blanks and absent in lithic assemblages containing numerous convergent  
533 retouched blanks, such as Biache-Saint-Vaast (Hérissou, 2012). A similar function for these two tool  
534 types has been proposed. High mobility and a strong spatiotemporal fragmentation of the point  
535 chaîne opératoire have been established based on numerous refits and spatial distribution analysis  
536 from the site to landscape scale (Hérissou, 2012; Goval et al., 2016).

537 Discoid flake and point production Discoid production (Fig. 10) always forms a minor part of the few  
538 Saalian assemblages bearing this chaîne opératoire, namely Therdonne (Locht et al., 2010; Hérissou,

539 2012; Hérissou and Locht, 2014) and Plachy-Buyon (Locht et al., 1995). This method is only known at  
540 the end of the Saalian, from the end of MIS 7 to MIS 6. Discoid production in EMP assemblages is  
541 discreet and poorly used, compared to its later exclusive use at the MIS 4 site of Beauvais (Locht,  
542 2004). Discoid cores, as defined by Boëda (1993, 1997) and Locht (2004), show one to three secant  
543 production surfaces, with a variability practically inherent to the method. The three main types of  
544 end products known for discoid production (Bourguignon, 1997; Locht, 2004) are present at  
545 Therdonne and Plachy-Buyon, i.e., backed flakes, large flakes and pseudo-Levallois points.

546 Ramification and small flake production Ramification is poorly documented in Lower Paleolithic  
547 assemblages in Northern France, and only the Kombewa method seems present (Tixier and Turq,  
548 1999). In contrast, the organization of the EMP chaînes opératoires appears to be almost  
549 systematically ramified. In the EMP record in Northern France, only simple ramification is attested,  
550 according to the definition of Brenet (2011). The core-on-flake method is essentially used to obtain  
551 small flakes by recycling elements from a previous production stage of the chaîne opératoire (Fig.  
552 11). Except the Kombewa method, which is frequently used on cortical flakes, the same schema is  
553 often reproduced in the second stage of production. If the same schema is not reproduced, slightly  
554 predetermined methods are employed. Another specific method was recognized by Delagnes (1993;  
555 see also Lazuén and Delagnes, 2014) at Le Pucueil and some years later at Therdonne (Hérissou,  
556 2012; Fig. 11). Small flake production and the systematic ramification of the chaînes opératoires  
557 (particularly in Levallois assemblages) appear to be a novel characteristic of the lithic assemblages,  
558 compared to those of the Lower Paleolithic.

559 Retouched blanks Blanks are rarely retouched in MIS 8–6 assemblages. Retouched blanks are  
560 dominated by single convex scrapers and a new tool type: double convergent scrapers. The toolkit is  
561 completed by a few denticulates, notches and rarely by Nahr Ibrahim, which was totally unknown  
562 during the Lower Paleolithic. The typology does not show any particular chronological distribution of  
563 tool types during the EMP.



564 Bifacial shaping If PMC sites are pushed back earlier than MIS 8 (see the Introduction), then the EMP  
565 record appears almost devoid of bifaces. Only levels C/A and B of le Pucueil (Delagnes and Ropars,  
566 1996) present sparse bifaces, dated to the end of MIS 7 or the beginning of MIS 6 for the latter and  
567 to the late MIS 8/early MIS 7 for the first one. There is absolutely no evidence of bifacial shaping at  
568 major sites like Biache-Saint-Vaast and Therdonne. The role and function of EMP bifaces is still poorly  
569 known and the evolutionary link with Acheulean bifaces remains an open question.

570

#### 571 **4. Discussion**

572 Finally, we address the crucial questions we raised in the Introduction to discuss our current view  
573 of the LP/MP boundary based on the well-established record from Northern France, in the  
574 Northwestern European framework. We also propose a cross-interpretative view with the Near East  
575 record of this key period in human cultural evolution.

576

##### 577 *4.1. A revised model for the LP/MP boundary in Northern France*

578 What are the consequences of the new discoveries, new studies and reanalyses on the previous  
579 transition model(s) established for Northern France? Since the previous models of transition for the  
580 LP/MP developed by Tuffreau from the 1970s to the 1990s (Fig. 12), discoveries of new sites,  
581 reanalyses and the inclusion of taphonomic and detailed litho-chronostratigraphic approaches have  
582 yielded new data. This renewed record offers the opportunity to reappraise the nature of the LP/MP  
583 boundary in Northern France with many more elements.

584 Tuffreau's (1982) model established that, after the Acheulean complex, Late Acheulean (Epi-  
585 Acheulean/Upper Acheulean) and Mousterian assemblages coexisted during the Saalian (oldest  
586 definition of the Saalian corresponding to MIS 8–6). He specified that “at present transitional  
587 industries [...] are unknown” (Tuffreau, 1982: 148). He later inserted (Tuffreau et al., 1989) a  
588 transitional complex of industries called PMC in his model (Fig. 12), following discoveries of lithic

589 assemblages comprising numerous handaxes with an Acheulean morphology in association with  
590 stable types of retouched tools on flakes announcing the Middle Paleolithic tool kit.

591 Currently, considering all the elements developed above, we can propose the following model or  
592 scenario for the Northern France (Fig. 13). The Lower Paleolithic assemblages mainly consist of  
593 'Acheulean' bifaces, associated with thick and often cortical flakes mainly stemming from short  
594 secant unipolar sequences of production and rare retouched tools (mainly denticulates, notches and  
595 single scrapers). The Lower Paleolithic comes to an end at the close of MIS 9, around 277 ka (after  
596 Railsback et al., 2015 for the MIS 9a/8 boundary setting). After a long process of technical  
597 maturation, a more standardized flaking method seems to emerge at the end of MIS 9, producing  
598 normalized cortical backed-knives on one hand, and probably what can be considered as the first  
599 convincingly, if discreet use of the Levallois method, on the other hand. The PMC complex could  
600 perhaps be placed during this innovating cultural period of MIS 9, with all the limits explained above.  
601 No reliable archaeological data are available for the Pleniglacial phase of MIS 8 (277–250 ka), but  
602 Levallois-dominated industries are observed in secondary position in Pleniglacial fluvial gravels. After  
603 this Pleniglacial phase, the transformation of lithic assemblages is already totally completed. From  
604 around 250 ka onwards, lithic systems are based on well-predetermined flaking methods producing  
605 normalized end products (flakes, points and blades). Bifacial shaping does not disappear from the  
606 technical repertoire but becomes marginal in the EMP record. The LP/MP boundary and threshold  
607 could thus be situated, if it is really necessary to define a time frame for the shifting, between 277  
608 and 250 ka. From 250 ka to 180 ka, we observe the development of several innovative knapping  
609 methods (Levallois method and its numerous modalities, blade, discoid), which compose the whole  
610 technical identity and variability of the Middle Paleolithic inventory. This growing diversity of  
611 knapping methods and end products reaches its apogee at the end of MIS 7 and the beginning of MIS  
612 6. This phase can be interpreted as a technological radiation phase, following proposals by Boëda  
613 (2013) and Chazan (2016). In parallel, the internal organization of flaking methods evolves with the  
614 widespread development of the ramification process, mainly for producing small flakes. The

615 spatiotemporal distribution of chaînes opératoires is also more fragmented than previously (and  
616 particularly than pre-MIS 9 chaînes opératoires). Evidence of the use of fire at EMP sites is also much  
617 more frequent than in Lower Paleolithic sites (Roebroeks and Villa, 2011; Hérison et al., 2013).

618 Is our periodization still relevant in the light of new data on technological, behavioral and cultural  
619 changes? We still follow the proposal of Tuffreau (1982: 137), who defined periodization, not from a  
620 geological chronological viewpoint but “in terms of technological and typological characteristics of  
621 the lithic assemblages.” He added that “other data (evidence concerning living floors, bone  
622 industries) are too poor to be used” (Tuffreau, 1982: 137). It is still true, despite new excavations,  
623 that other behavioral elements are too scarce to accurately chart changes. But these elements must  
624 necessarily be taken into account to propose a broader view of the sociocultural process, as recently  
625 demonstrated (Hérison, 2012). This periodization appears to be the least worst option, considering  
626 current data from Northern France and the model we proposed, and also seems to be applicable and  
627 relevant at a broader scale.

628

#### 629 *4.2. The record from Northern France in a Northwestern European context*

630 What does the record from Northern France tell us about settlement and innovative dynamics  
631 compared to neighboring areas, and in particular Northwestern Europe? The proposed scenario for  
632 Northern France does not seem so different from surrounding areas when we take a look at the  
633 Northwestern record (i.e., Scott and Ashton, 2011; Hérison et al., 2016a). Nearby, the site of Saint-  
634 Illiers (Blaser and Chaussé, 2016) shows that bifaces can play a more important role in EMP  
635 assemblages, and moderate the near absence of bifaces observed in Northern France. The site of  
636 Kesselt Op-de-Schans, dated to the end of MIS 9 shows a combination of the Levallois flaking method  
637 with discoidal production systems, simple prepared core technology and a multiple platform core  
638 and other techno-economic aspects of the assemblage, suggesting a Middle Paleolithic character (Van  
639 Baelen, 2014). If this dating is confirmed by future analysis, it could attest the coexistence of groups

640 using the Lower Paleolithic package and others using the Middle Paleolithic package at the end of the  
641 MIS 9 in Northwestern Europe.

642 A brief look at the record from Southern France (Delpech et al., 1995; Djema, 2010; Turq et al.,  
643 2010; Soriano, 2005; Brenet et al., 2014a, b; Hérissou et al., 2016; Mathias, 2018) reveals that  
644 another scenario exists for the LP/MP boundary. It is not a remarkably different scenario, particularly  
645 as far as dating is concerned, but some technological elements differ, such as the use of the Quina  
646 method or the late presence of 'Acheulean' bifaces. This reinforces the impression of global trends  
647 through time in lithic trajectories of change in Western Europe but with strong regional cultural  
648 patterns.

649

#### 650 *4.3. A view of the Near East from Northern France*

651 What does the record from Northern France tell us about settlement and innovative dynamics  
652 compared to more distant regions such as the Near East? We will not detail here each LP/MP  
653 boundary site in the Near East. They are fully presented in recently published syntheses (i.e., Chazan,  
654 2016; Malinsky-Buller 2016; Shimelmitz et al., 2016a, b; Zaidner and Weinstein-Evron, 2016;  
655 Malinsky-Buller and Hovers, 2019).

656 The LP/MP boundary record from the Near East often comprises long sequences with numerous  
657 archaeological units, providing invaluable data on the relative succession of technological facies and  
658 assemblages in each site. Despite recent discoveries and huge efforts to produce dating sequences,  
659 the regional chronological framework of the Near East remains fragile (Chazan, 2016). This is due to  
660 the early excavation of reference sites, difficulties with dating methods in some fields, the rare  
661 opportunities for cross-checking dating results and biostratigraphy to reconstruct detailed  
662 paleoenvironments and thus establish chronoclimatic correlations with specific MIS. Correlations  
663 between sequences remain difficult and still hinder the construction of a regional chronoclimatic  
664 framework for human occupations and the development of secure detailed scenarios for the LP/MP  
665 boundary period at a regional scale (Bar-Yosef and Meignen, 2001). Moreover, the

666 representativeness of currently available data is questionable, as the distribution of known sites is  
667 extremely disparate. Indeed, no data are available for vast geographical areas of whereas  
668 concentration of sites are recorded in other aera, such as the Mount Carmel.

669 After the widely diffused chronocultural model proposed by Bar-Yosef (1994, 2002; Fig. 12),  
670 Malinsky-Buller and Hovers (2019) recently published a revised model for the LP/MP boundary in the  
671 Levant (Fig. 13). According to this model, the Acheulo-Yabrudian (around 350–250 ka) follows the  
672 Late Acheulean (until around 400–350 ka). A shift is observed around 250 ka, marking the limit  
673 between Lower and Early Middle Paleolithic assemblages.

674 The Late Acheulean of the Near East contains hierarchical cores, cores-on-flakes and, handaxes in  
675 relative low frequencies (Malinsky-Buller, 2016). This is not very different to Lower Paleolithic  
676 assemblages in Northern France or Western Europe (Fig. 13). Viewed from the Near East, the LP to  
677 MP transition in Northern France seems straightforward: the old-style Acheulean is replaced by fully  
678 Middle Paleolithic industries and this replacement matches with the onset of the Levallois method.  
679 The typological and technological variations observed in the latest Acheulean industries in Northern  
680 France appear minor when compared to what is described in the Near East from MIS 9 to MIS 7. With  
681 the Acheulo-Yabrudian, the Near East have experienced much more diversified assemblages than  
682 Europe at the end of the LP. Chazan (2016) perceived this episode as a ‘technological radiation’  
683 which ended later than the Acheulean in Western Europe (Fig. 13). The Acheulo-Yabrudian shows  
684 huge variations between assemblages with numerous blades from unprepared cores usually referred  
685 to as Amudian, or with low frequencies of blades or no blades at all, closer to the Yabrudian.  
686 Nevertheless, it is now established that the Amudian and the Yabrudian shared common  
687 technological characters and Quina or demi-Quina scrapers are a major component of the tool kit  
688 (Zaidner and Weinstein-Evron, 2016). The frequency and typology of handaxes or bifacial pieces are  
689 highly variable. There is general agreement that Levallois methods are absent (Parush et al., 2016;  
690 Shimelmitz et al., 2016b). Use-wear studies at Qesem suggest that Quina/demi-Quina scrapers from  
691 the Acheulo-Yabrudian were either hand-held, hand-held with wrapping or hafting (Zupancich et al.,

692 2016). It is considered that a sharp break occurs around 250 ka between the Acheulo-Yabrudian and  
693 the following Early MP (Malinsky-Buller and Hovers, 2019), but Shimelmitz et al. (2016b) suggest that  
694 there is some continuity between LP and MP assemblages, particularly looking in terms of blank  
695 production.

696 According to Meignen (2011), two groups of industries can be distinguished within the EMP (also  
697 called 'Early Levantine Mousterian'; Fig. 13). Both are blade-based, but Levallois blades can be  
698 dominant or not, alongside short blanks, flakes and points (Meignen, 2007). The toolkit is usually  
699 dominated by Mousterian types, including scrapers and above all, various types of elongated points  
700 (Zaidner and Weinstein-Evron, 2012). Upper Paleolithic types can be frequent, especially burins and  
701 nucleiform burins (Wojtczak, 2015). Classical Levantine Mousterian flake and point industries, almost  
702 produced with Levallois methods (Meignen, 1998), occur no earlier than 150/160 ka, as exemplified  
703 at Hayonim (Mercier et al., 2007).

704 Viewed from Northern France, the LP to MP transition appears less abrupt, with more gradual  
705 stages between the two periods. The degree of technological diversity also seems higher in the  
706 Acheulo-Yabrudian than in the Late LP in Northern France (Fig. 13). The importance of scrapers with  
707 scalar retouch and the association of several methods of blank production in the Acheulo-Yabrudian  
708 can be viewed as a preliminary step towards the MP, but blanks were not yet standardized. The  
709 standardization of blanks and toolkits occurred during a second step in the Early Levantine  
710 Mousterian. Not surprisingly, one of the oldest uses of bitumen for hafting was observed on a  
711 pointed blade from a Hummalian level at Hummal (Boëda et al., 1998).

712 In Northern France, in many respects, the transition involved an almost complete turnover of  
713 technical productions and elements of continuity are scarce, but they nonetheless exist. MIS 9  
714 Acheulean groups experimented different solutions for the standardization of the flake component  
715 of their toolkits. In the HUD level from Etrécourt-Manancourt (280 ka), debitage is structured in order  
716 to obtain flakes with thick cortical backs and use-wear analysis confirms their use as backed knives,  
717 mainly for butchery cutting (Hérisson et al., 2016b). In this case, standardization is oriented towards

718 the handled part of the tool. At Gouzeaucourt (MIS 9/8?), especially in the most recent level R,  
719 several retouched tool types (transverse and déjeté scrapers, Mousterian points) are standardized  
720 (Lamotte, 1995; Devresse, 1997; Soriano, 2000). A low degree of blank predetermination was  
721 balanced by a high intensity of retouch. Some of these retouched tools seem to have been imported  
722 to the site with handaxes. Considered as a whole, these changes in flake tools can be viewed as an  
723 announcement of the oncoming Middle Paleolithic. Nevertheless, this shift occurred abruptly in  
724 Northern France and Acheulean efforts to fit with Middle Paleolithic standards were swept away by  
725 the sudden adoption of the Levallois system.

726       What is so special about the Levallois that its adoption resulted in the more or less rapid  
727 disappearance of handaxe-based industries in Northwestern Europe, when such toolkits had been a  
728 reference for at least 300 ka? Many scholars have emphasized the increased control of morphology,  
729 size, technical and functional features with Levallois flaking compared to other flake productions  
730 (Boëda, 1994, 2013; Dibble and Bar-Yosef, 1995; Bonilauri, 2015). The effectiveness of the cutting  
731 edges of retouched or unretouched tools on Levallois blanks might not be so different from tools on  
732 blanks from LP productions and overall, the daily tasks performed with lithic tools were not so  
733 different in the LP and in the MP, as shown by use-wear studies for decades (i.e., Beyries, 1988;  
734 Keeley, 1993; Lemorini et al., 2016). Through a combination of use-wear, residue analysis and the  
735 technofunctional analysis of a Levantine MP industry, Bonilauri (2015) proposed that the high degree  
736 of predetermination of the Levallois system allows for the control of the morphology and technical  
737 features of the cutting edges but also of the prehensive part of the tool. The standardization of this  
738 latter tool part is an early and direct response to forthcoming hafting constraints. There is a growing  
739 body of direct or indirect evidence for hafting tools on Levallois blanks, especially in the Near East  
740 (Boëda et al., 1996; 2008; Goval et al., 2016; Monnier et al., 2013; Rots, 2013; Rots et al., 2011; Rots,  
741 2015; Roler and Clark, 1997). To date, undisputable evidence of hafted stone tools in the Acheulean  
742 in Northwestern Europe is lacking. Like Boëda (2013), we hypothesize that the standardization of  
743 hafting is the key issue in the emergence and successful adoption or diffusion of Levallois technology.

744

## 745 **5. Conclusion**

746 This comparison shows how different and similar the Near Eastern archaeological record and the  
747 record from Northern France are, considering the main chaînes opératoires and technocomplexes.  
748 The timing of changes and shifts between LP and MP technological packages in both regions seems  
749 to be between 280 and 250 ka, and follows a near-similar overall trend (White and Ashton, 2003;  
750 Shimelmitz et al., 2016b), even though it remains difficult to compare the two regional archaeo-  
751 chronosequences. But, when we go into more detail and examine the specific composition and  
752 proportions of each chaîne opératoire and their distribution through time, we observe marked  
753 differences between both regional repertoires. This trend is particularly well-expressed for the Late  
754 Acheulean period from 400 to 250 ka, with the Acheulo-Yabrudian period in the Near East, and the  
755 last occurrence of the Lower Paleolithic in Northern France.

756 On one hand, these elements seem to attest to a possible pseudosynchrony of technological  
757 trajectories at a continental scale for the LP/MP time period. On the other hand, and up until now,  
758 no convincing elements in the archaeological record allow us to propose a global explanation for this  
759 pseudosynchrony. In fact, each region shows specific technological traits and trajectories strongly  
760 linked to regional cultural patterns, in agreement with recent syntheses (i.e., Adler et al., 2014;  
761 Hérison et al., 2016a; Malinsky-Buller, 2016; Malinsky-Buller and Hovers, 2019). The simultaneity of  
762 the timing of changes across Europe, Asia and Africa is perceived when we examine global data with  
763 an error margin of more or less 10 ka, a third of the duration of the Upper Paleolithic. Common or  
764 global drivers of evolution of these technological and cultural changes at the LP/MP boundary are  
765 still difficult to pinpoint, even if current data presented here tend to reduce the impact of biological  
766 human species (presence, arrival or not of AMH in certain regions) and environmental factors, and to  
767 highlight internal societal factors associated with behavioral and technical changes.

768 More detailed data (in particular, behavioral), sites, and accurate dates are still required to  
769 enhance our understanding of the mechanisms of this key period, currently called the Lower



770 Paleolithic to Middle Paleolithic boundary, and perceived as a major cultural shift in human  
771 evolution. However, when we look back to the cutting-edge research presented in Ronen (1982) and  
772 this volume, we can measure both the considerable advances and the potential future discoveries.

773

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1589 **Figure captions:**

1590 **Figure 1.** Distribution map of sites in Northern France from MIS 9 to MIS 6. Background map: image  
1591 Landsat, courtesy of the U.S. Geological Survey.

1592 **Figure 2.** Chronological distribution of archaeological units (i.e., individual archaeological levels) from  
1593 late Middle Pleistocene sites from Northern France relative to their depositional context (dataset in  
1594 Table 1). A) Archaeological units with a MIS correlation value from 5 to 3 after Hérissou et al. (2016a).  
1595 B) Archaeological units with a MIS correlation value of 2 or 1 after Hérissou et al. (2016a). The  
1596 accuracy of each correlation is assessed and expressed as a score between 0 and 5 (Hérissou et al.,  
1597 2016a): 0 = no correlation; 1 = uncertain correlation, very scant proof; 2 = uncertain correlation,  
1598 some proof; 3 = good correlation but lack of convergent proof; 4= precise and convergent  
1599 correlation; 5 = perfect, precise and convergent correlation. The highest accuracy is reached for  
1600 occupation levels in primary position that are preserved in long sedimentary sequences and where  
1601 different independent proxies are available for relative, indirect and direct dating. Taking these

1602 elements into account, each occupation is assigned to an isotopic stage or, where possible, substage  
1603 (question marks are used in case of uncertainties). 'MIS 7c-7a' means occupations from both these  
1604 substages, 'late MIS7a/early MIS 6' means occupations from one or the other of these  
1605 stages/substages.

1606 **Figure 3.** Chronoclimatic distribution of archaeological units (i.e., individual archaeological levels)  
1607 from late Middle Pleistocene sites (MIS 9 from MIS 6) from Northern France relative to their  
1608 depositional context (dataset in Table 1). Archaeological units are stacked according to their  
1609 chronoclimatic context independently of their MIS age. A MIS 9 interglacial archaeological unit is  
1610 recorded in the same category than a MIS 7 interstadial. Only archaeological units with a MIS  
1611 correlation value (Hérisson et al., 2016a) from 5 to 3 are considered here. 'MIS 7c-7a' means  
1612 occupations from both these substages, 'late MIS7a/early MIS 6' means occupations from the one or  
1613 the other of these stages/substages.

1614 **Figure 4.** Pre-MIS 9 lithic industries from Northern France. a) Carrière Carpentier (Abbeville), biface in  
1615 flint recovered in unit 3D1 overlying the White Marl (drawing A. Theodoropoulou, after Antoine et  
1616 al., 2016b). b) Cagny la Garenne 2, biface from level I4 (drawing A. Lamotte, after Tuffreau et al.,  
1617 2008). c) Cagny la Garenne 1, biface from level CXV (drawing A. Lamotte, after Lamotte, 1995). d–f)  
1618 Rue du Manège: d) discoid core; e) denticulate; f) cortical backed flake (drawing S. Lancelot, after  
1619 Locht et al., 2013). g, h) Cagny la Garenne 1: g) SSDA core; h) cortical backed flake from the level CXV  
1620 (drawing A. Lamotte, after Lamotte, 1994), i) Ferme de l'Épinette, flake refitting on a unipolar core  
1621 from level MS (drawing A. Lamotte, after Lamotte, 1994).

1622 **Figure 5.** MIS 9 lithic industries from Northern France. a, b) Cagny-l'Épinette: a) biface in  
1623 allochthonous flint from level I1 (Tuffreau et al., 1995); b) refits showing bifacial shaping from levels I  
1624 (Lamotte, Tuffreau, 2001). c–g) Etrécourt-Manancourt, level HUD: c, d) bifaces; e) core exploited by  
1625 short unipolar secant sequences; f) cortical backed knife; g) single convex scraper on cortical flake  
1626 (drawing E. Boitard, after Hérisson et al., 2016b and unpublished).

1627 **Figure 6.** MIS 8–6 lithic industries from Northern France, Levallois preferential flake production. a–e,  
1628 g) Levallois preferential flakes: a) Biache-Saint-Vaast, level IIA; b, c) Biache-Saint-Vaast, level D0; d)  
1629 Biache-Saint-Vaast, level D1; e) Therdonne, level N3 (drawing S. Lancelot, after Hérissou, 2012); g)  
1630 Etricourt-Manancourt, level LRS (drawing E. Boitard, after Hérissou et al., 2016b). f, h) Levallois  
1631 preferential core: f) Therdonne, level N3 (drawing S. Lancelot, after Hérissou, 2012); h) Etricourt-  
1632 Manancourt, level LRS (drawing E. Boitard, unpublished).

1633 **Figure 7.** MIS 8–6 lithic industries from Northern France, Levallois recurrent flake production. a)  
1634 Biache-Saint-Vaast, level IIA, Levallois recurrent opposed bipolar core (drawing J. Airvaux, after  
1635 Hérissou, 2012). b, c) Biache-Saint-Vaast, level IIbase, elongated Levallois flakes (drawing J. Airvaux,  
1636 after Hérissou, 2012). d–i) Etricourt-Manancourt, level LRS: d) Levallois recurrent unipolar core; e–g)  
1637 elongated Levallois flakes; h) Levallois recurrent opposed bipolar core; i) refits of elongated flakes  
1638 from Levallois recurrent opposed bipolar schema (drawings E. Boitard, after Hérissou et al., 2016b  
1639 and unpublished).

1640 **Figure 8.** MIS 8–6 lithic industries from Northern France, blade production. a, b) Croix-l'Abbé at Saint-  
1641 Valéry-sur Somme, refits showing blade production (de Heinzelin and Haesaerts, 1983). c)  
1642 Therdonne, level N3, blade core (drawing S. Lancelot, after Locht et al., 2010).

1643 **Figure 9.** MIS 8–6 lithic industries from Northern France, Levallois point production. a–e) Le Pucueil,  
1644 level B: a, b) Levallois recurrent convergent unipolar cores; c–e) Levallois points (Delagnes and  
1645 Ropars, 1996). f–h) Therdonne, level N3, Levallois points (drawings S. Lancelot, after Locht et al.,  
1646 2010).

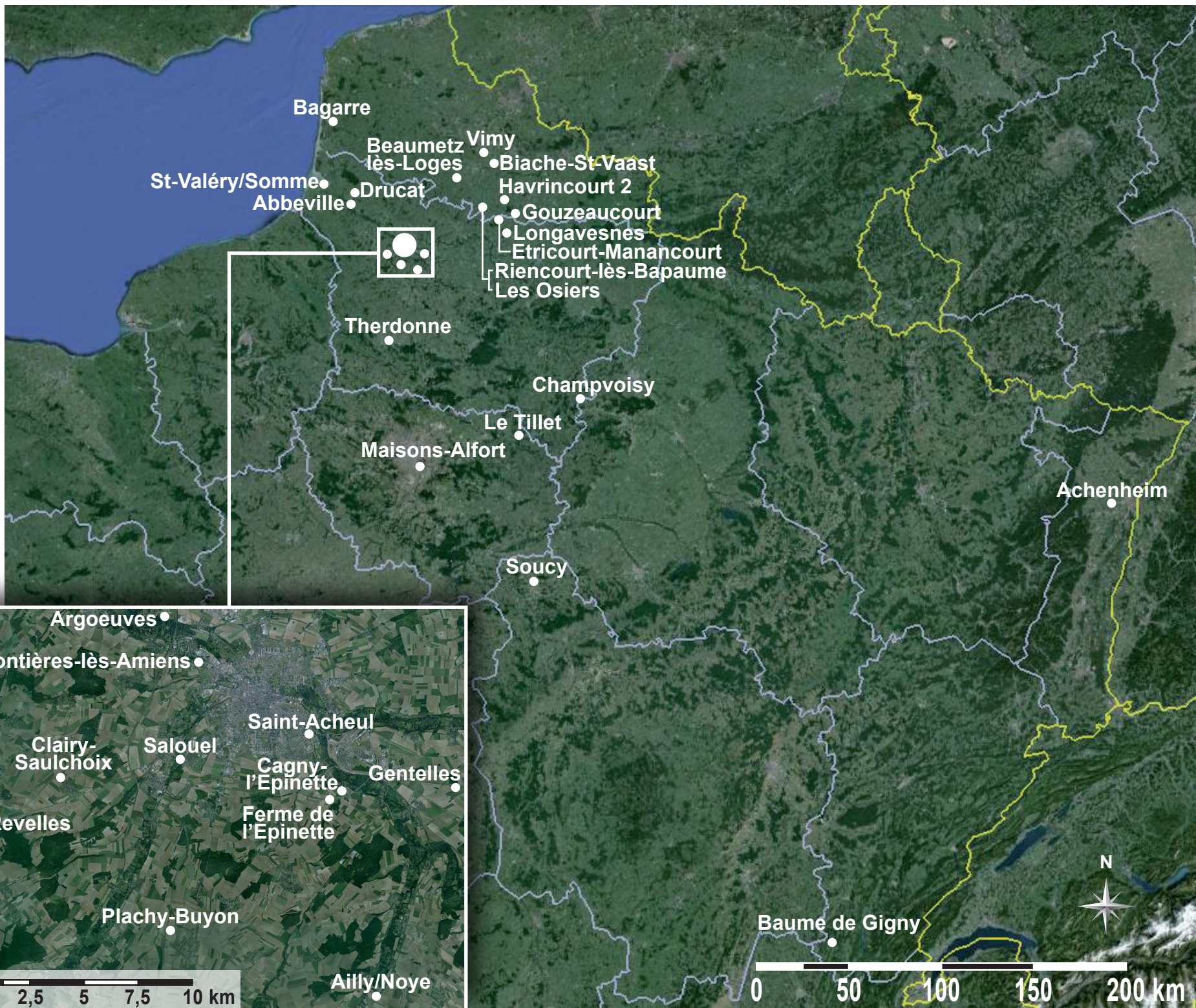
1647 **Figure 10.** MIS 8–6 lithic industries from Northern France, discoid production. a–f) Therdonne, level  
1648 N3: flakes (a–c) stemming from discoid refits e, f and d respectively (drawings S. Lancelot, after  
1649 Hérissou, 2012).

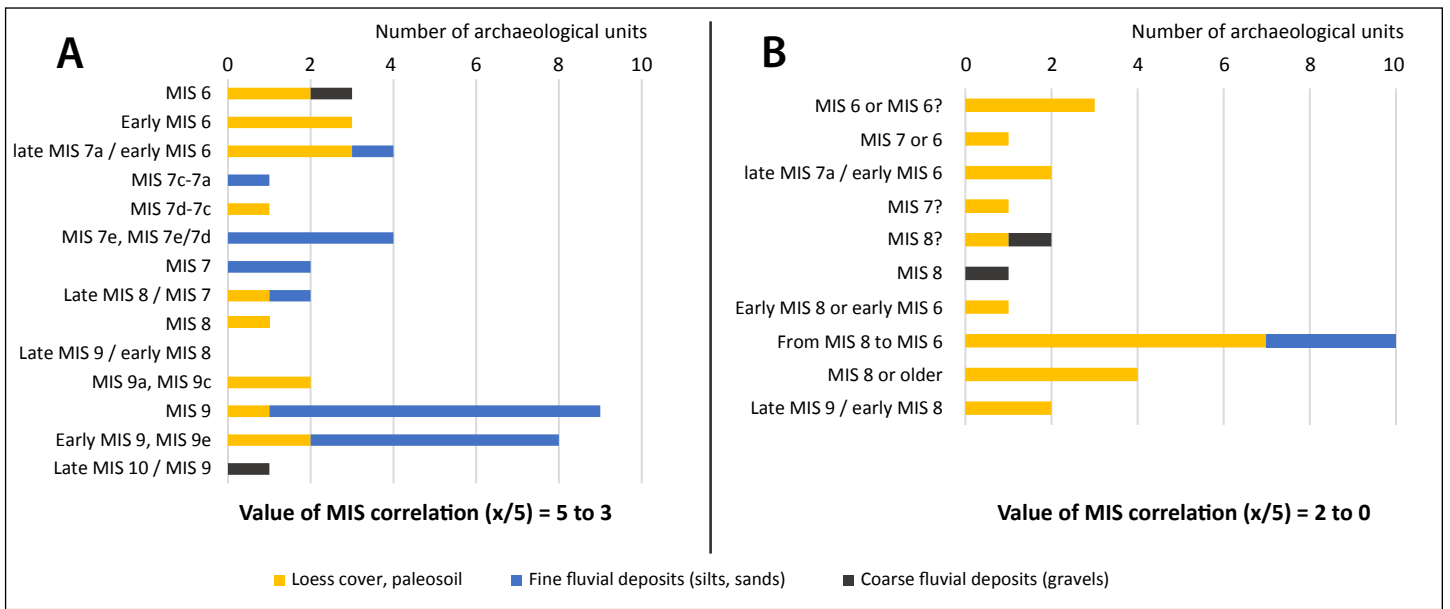
1650 **Figure 11.** MIS 8–6 lithic industries from Northern France, small flake production and ramification. a–  
1651 k) Le Pucueil, level B: a) refits of a cortical flake exploited after a le Pucueil schema; b–j) le Pucueil  
1652 type flakes from the refit a; k) le Pucueil core from refit a (Delagnes, 1993). l–r) Therdonne, level N3:

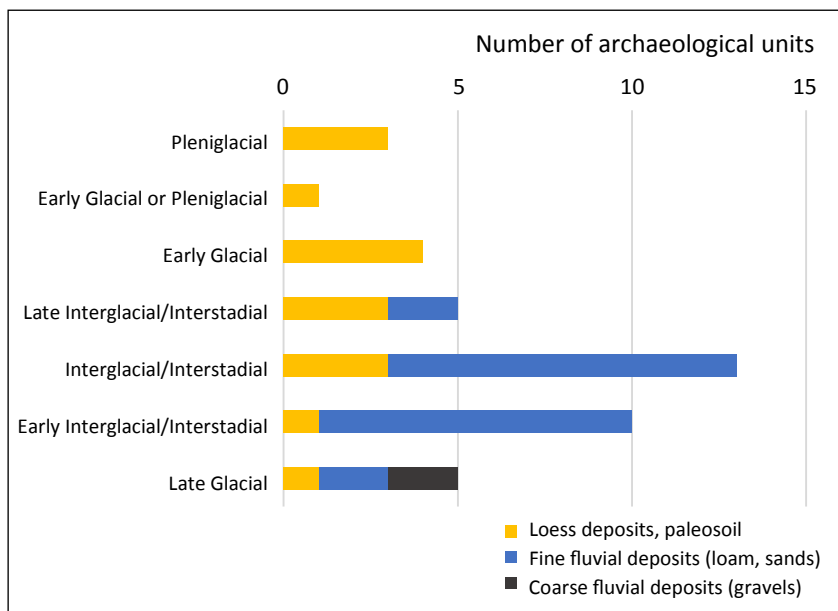
1653 l-n) le Pucueil type flakes; o) refits of a Levallois flake exploited by a le Pucueil schema; p) le  
1654 Pucueil core from refit o; q, r) le Pucueil type flakes from refit o (drawings S. Lancelot, after  
1655 Hérisson, 2012). s-v) Biache-Saint-Vaast, level E: s, t) cores on flakes exploited by a unipolar  
1656 sequence of removals; u, v) small flakes produced by ramification (drawing J. Airvaux, after Hérisson,  
1657 2012).

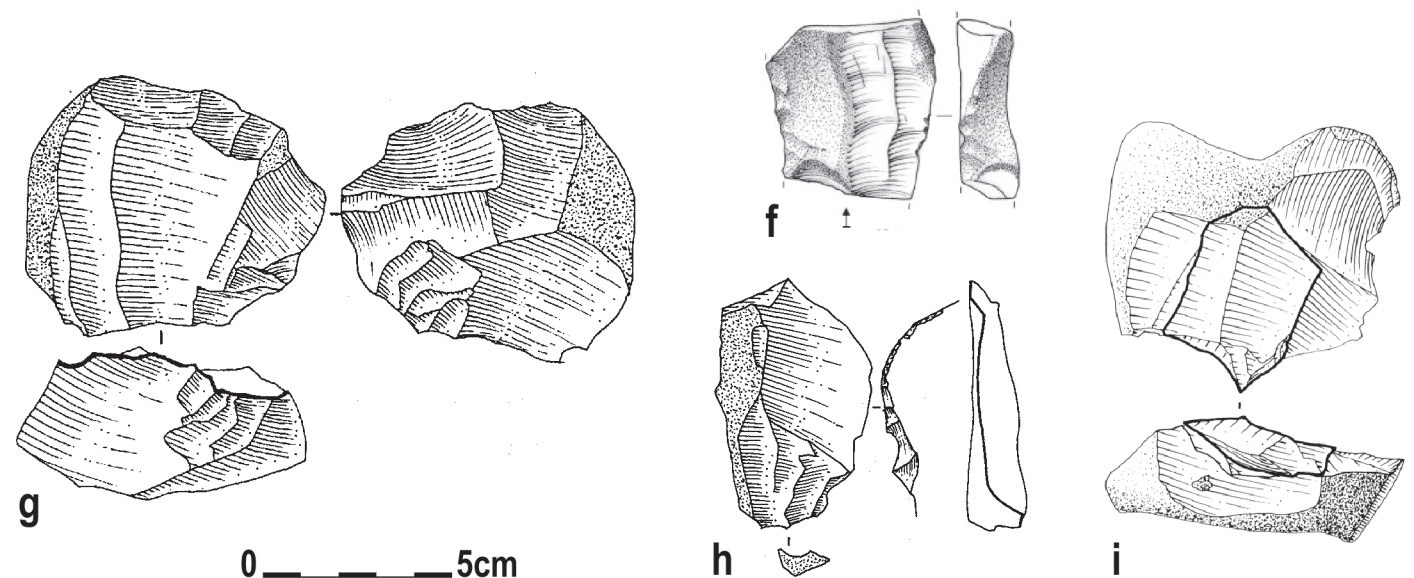
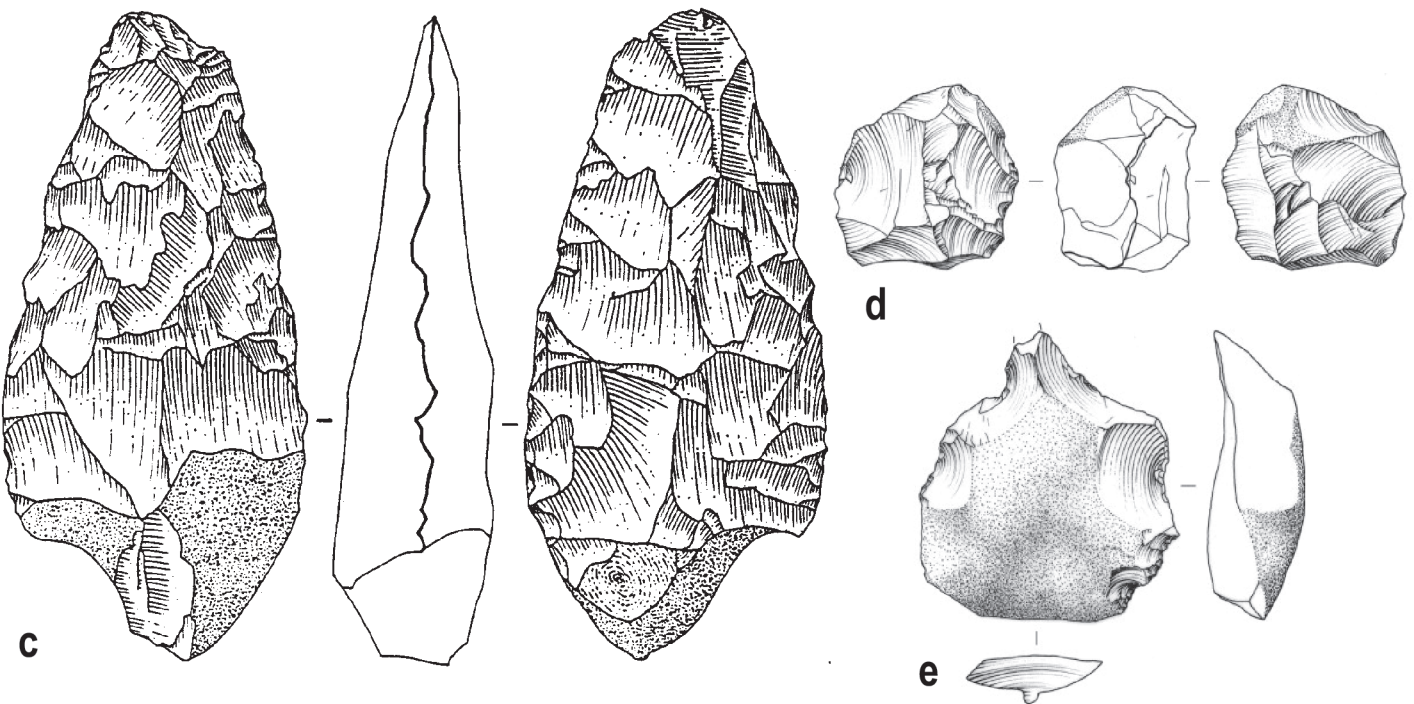
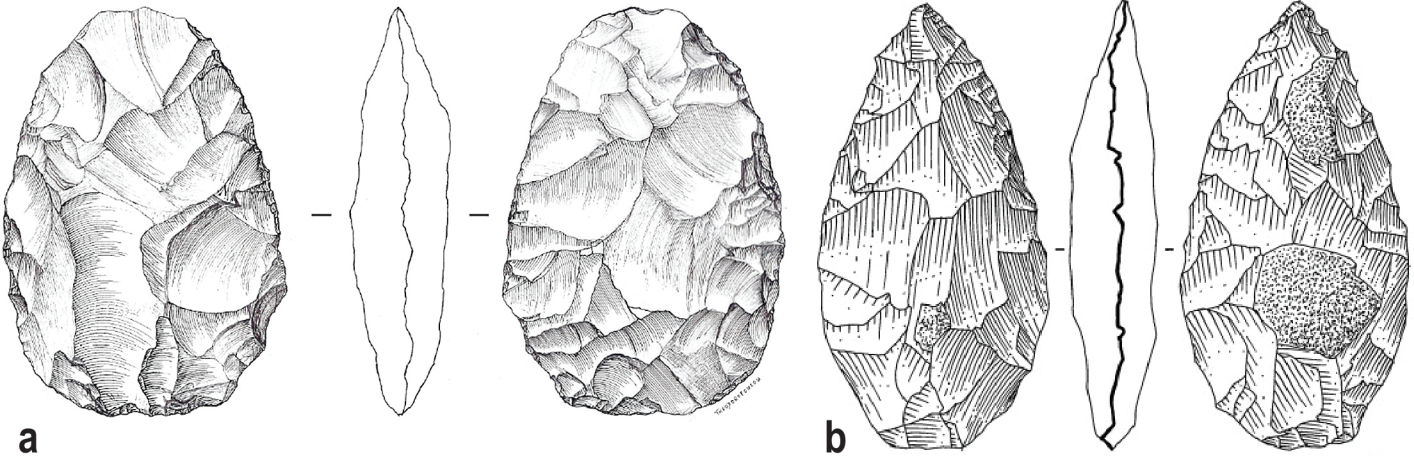
1658 **Figure 12.** A) Schematic model of the LP to MP boundary period in Northern France after Tuffreau  
1659 (1982) and Tuffreau et al. (1989). B) Schematic model of the LP to MP boundary period in Near East  
1660 after Bar-Yosef (1994, 2002). C) Extract of the LR04 benthic stack of  $d^{18}O$  (‰) after Lisiecki and  
1661 Raymo (2005), ages and ages of MIS boundaries expressed in ka after Lisiecki and Raymo (2005).

1662 **Figure 13.** A) Current schematic model of the LP to MP boundary period in Northern France after  
1663 Hérisson et al. (2016a ,b). B) Schematic model of the LP to MP boundary period in Near East mainly  
1664 after Malinsky-Buller and Hovers (2019), and also after Meignen (2011), Shimelmitz et al. (2016a),  
1665 Chazan (2016). C) Extract of the LR04 benthic stack of  $d^{18}O$  (‰) after Lisiecki and Raymo (2005), ages  
1666 and ages of MIS boundaries expressed in ka after Lisiecki and Raymo (2005).

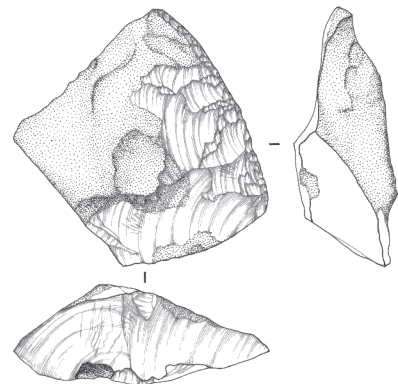
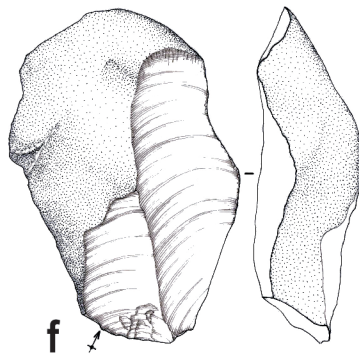
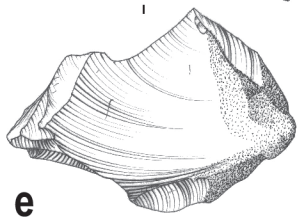
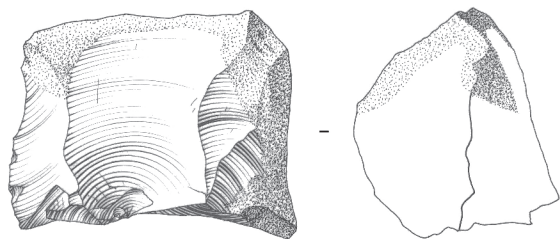
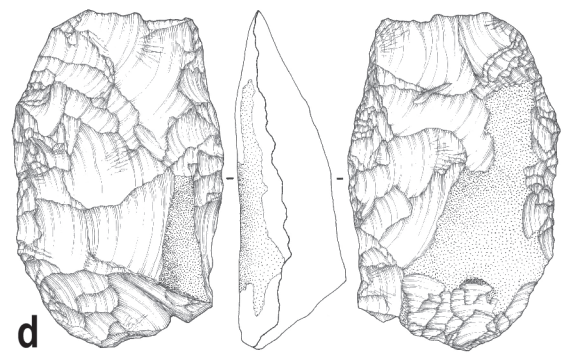
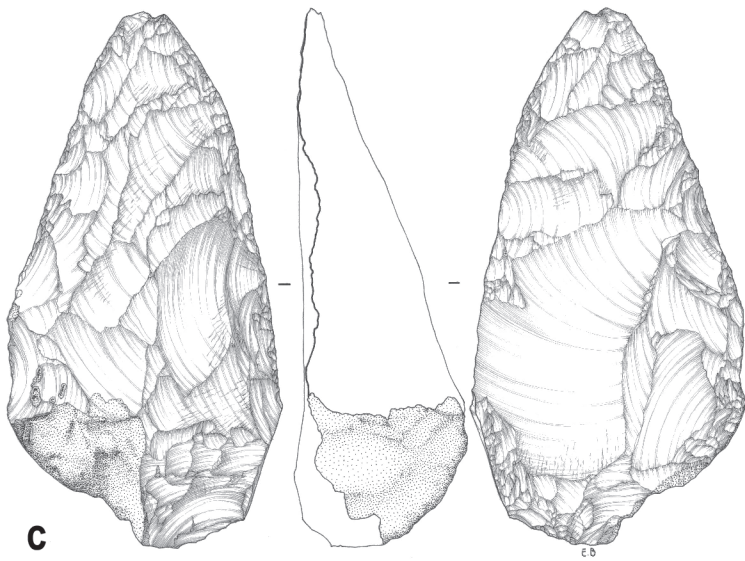
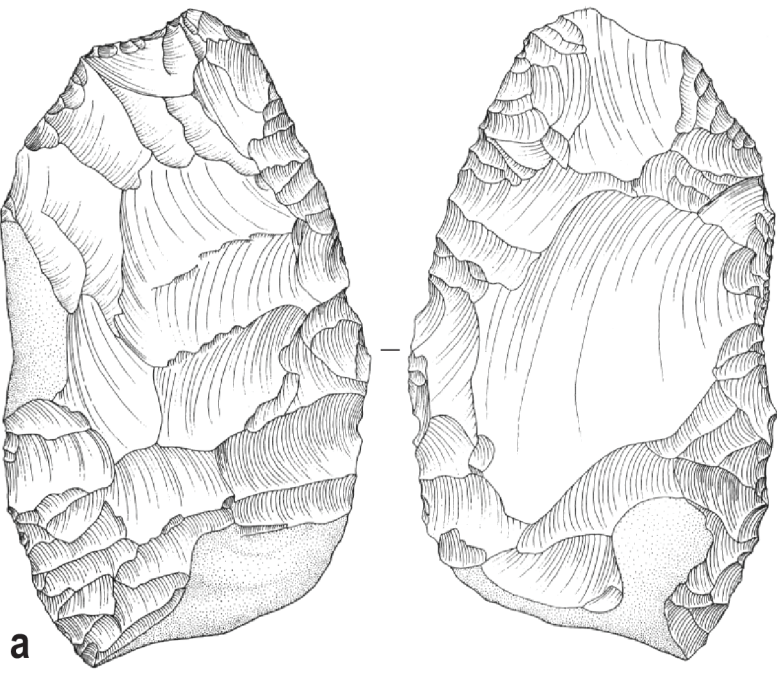




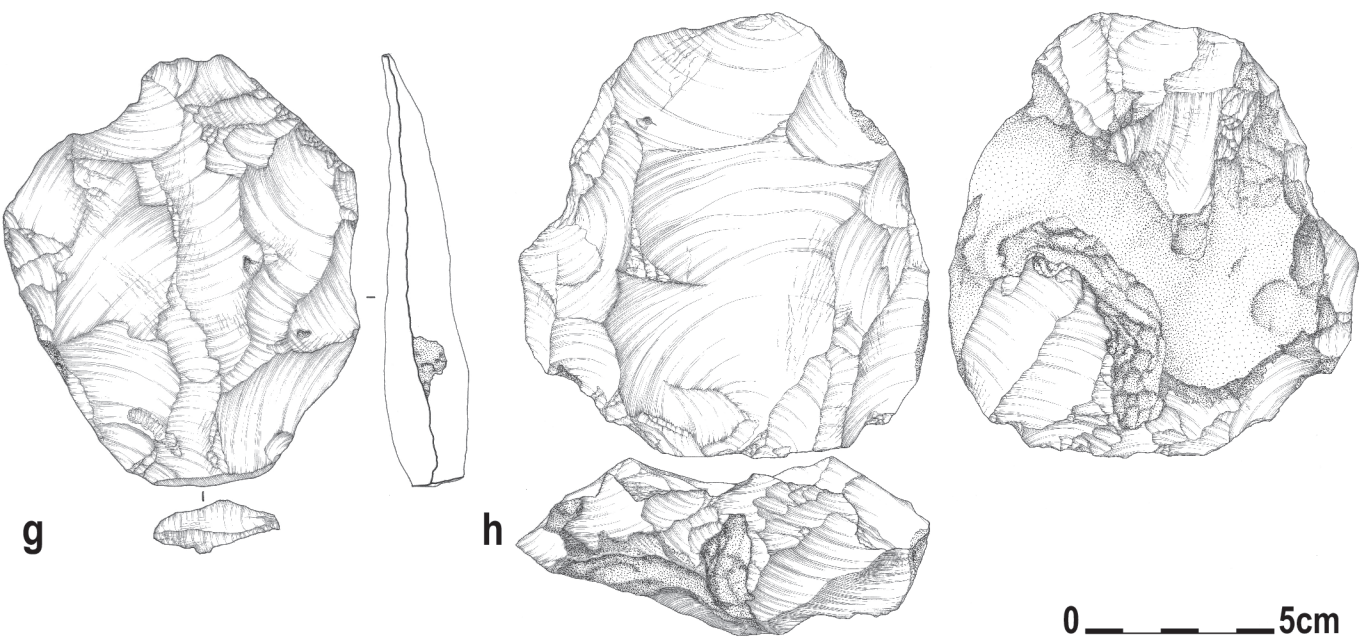
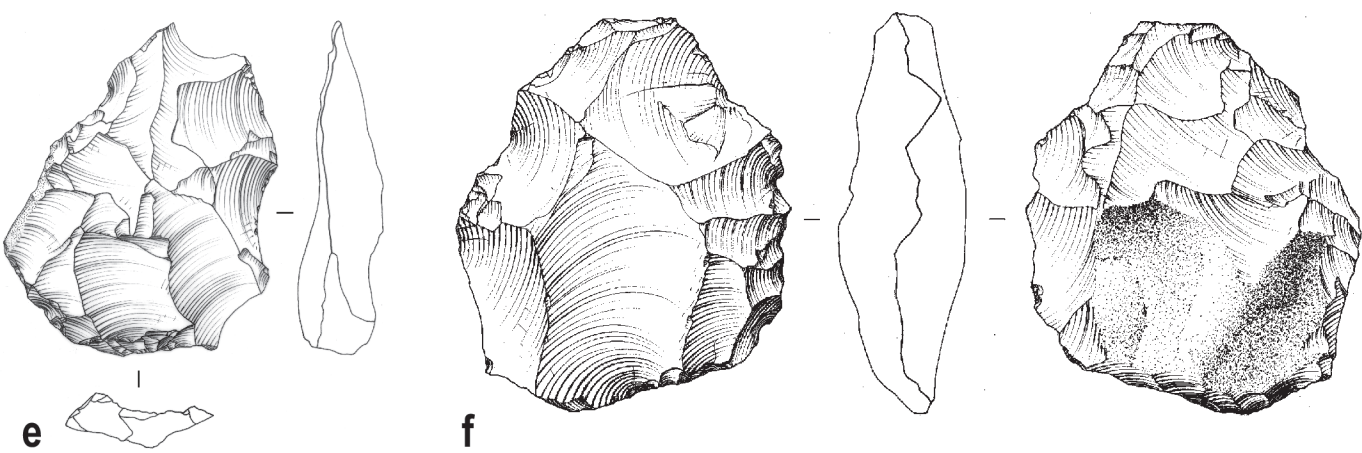
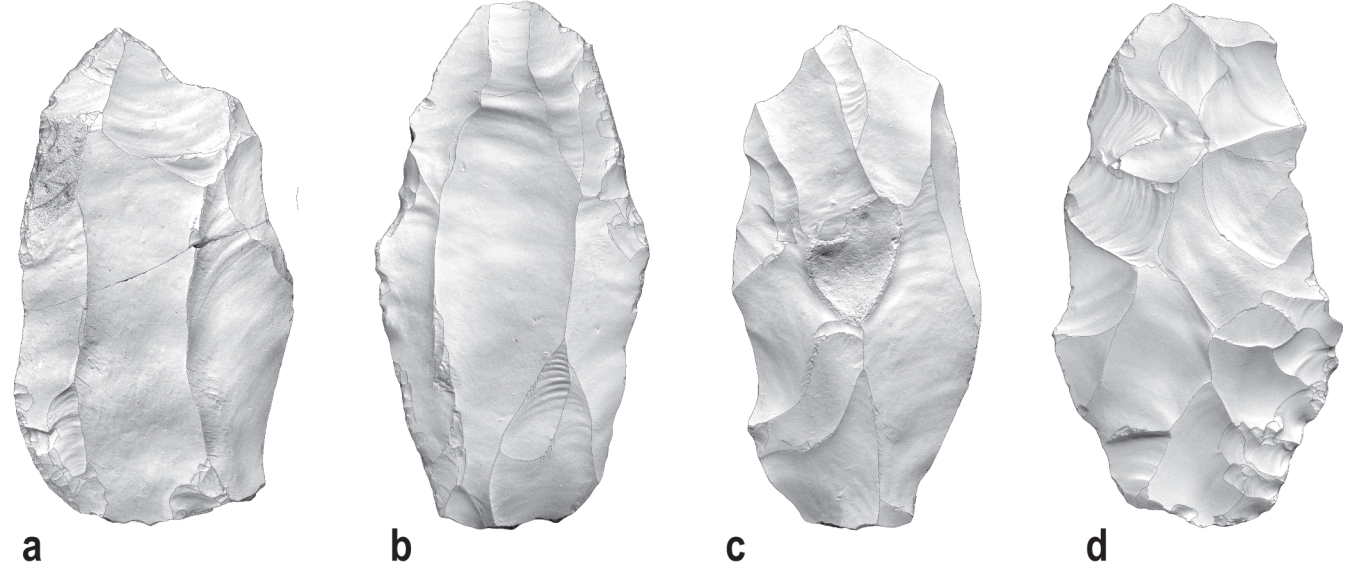




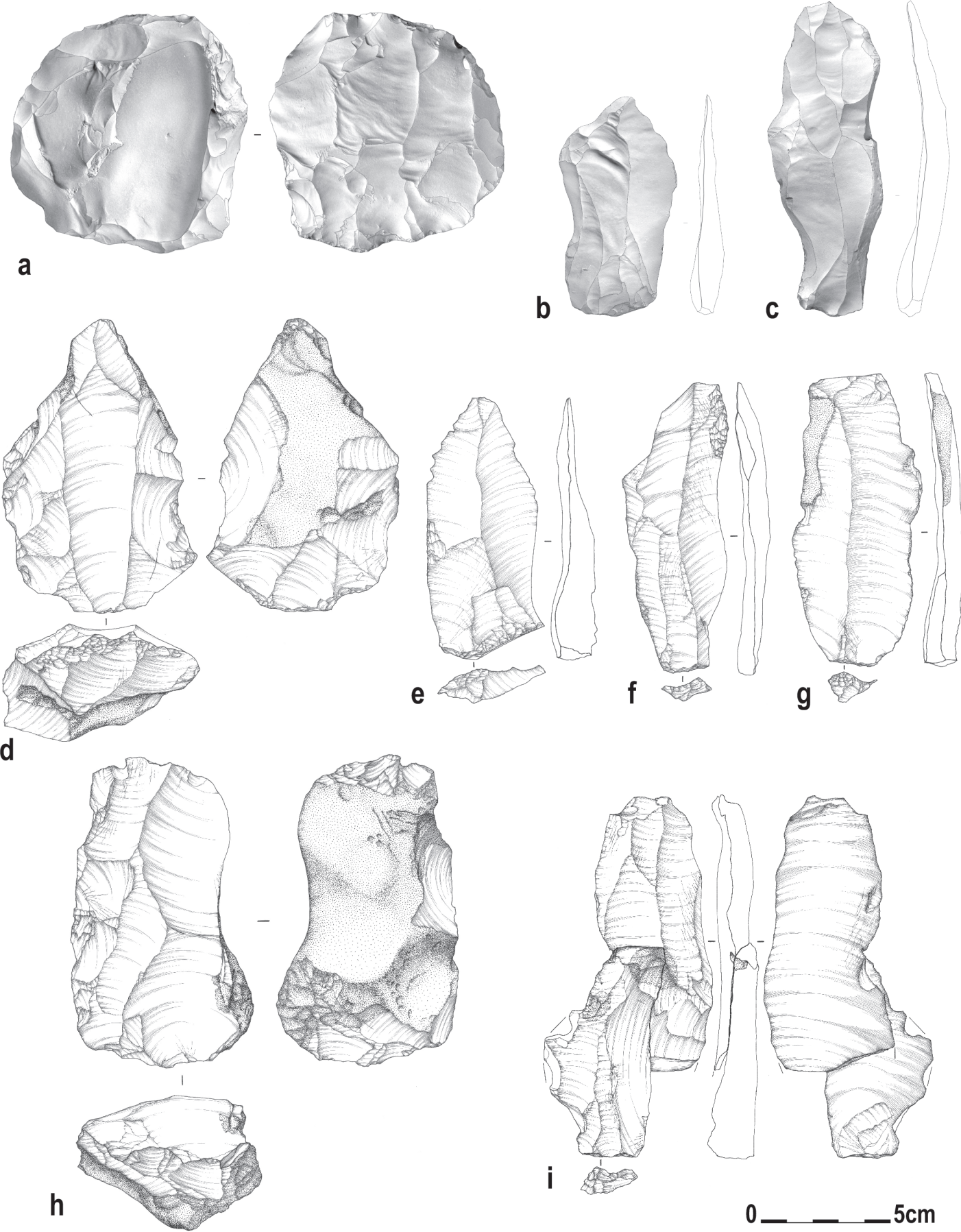


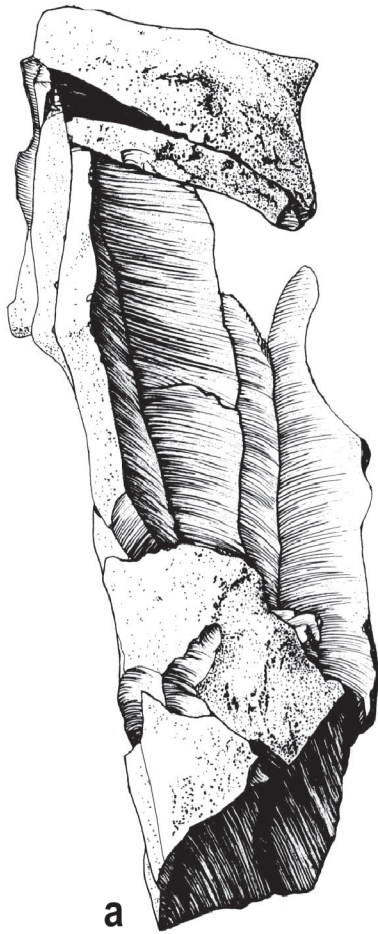


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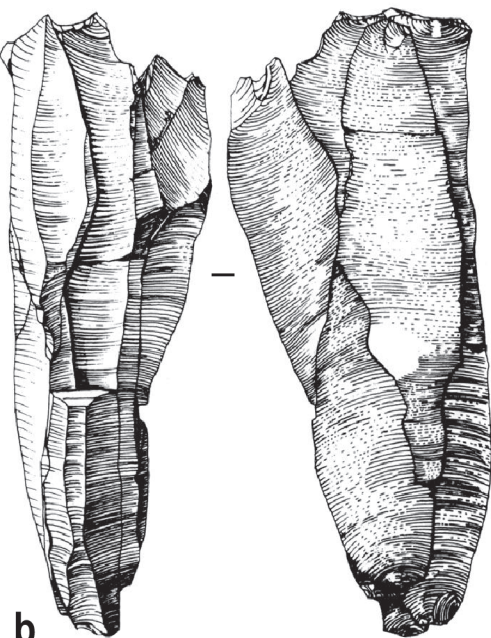
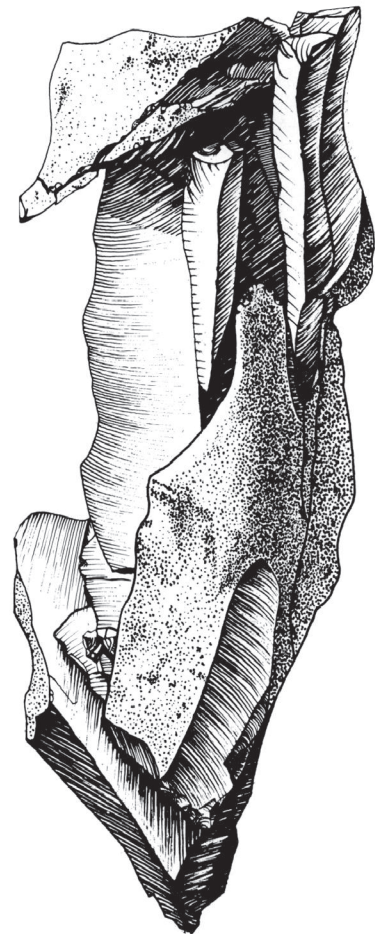
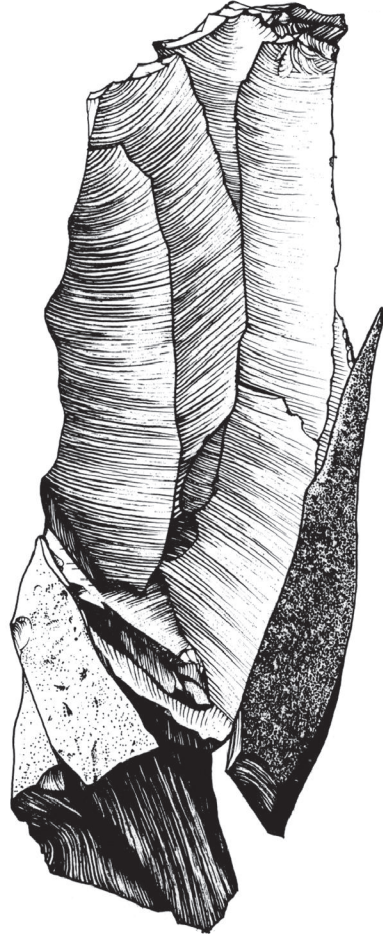


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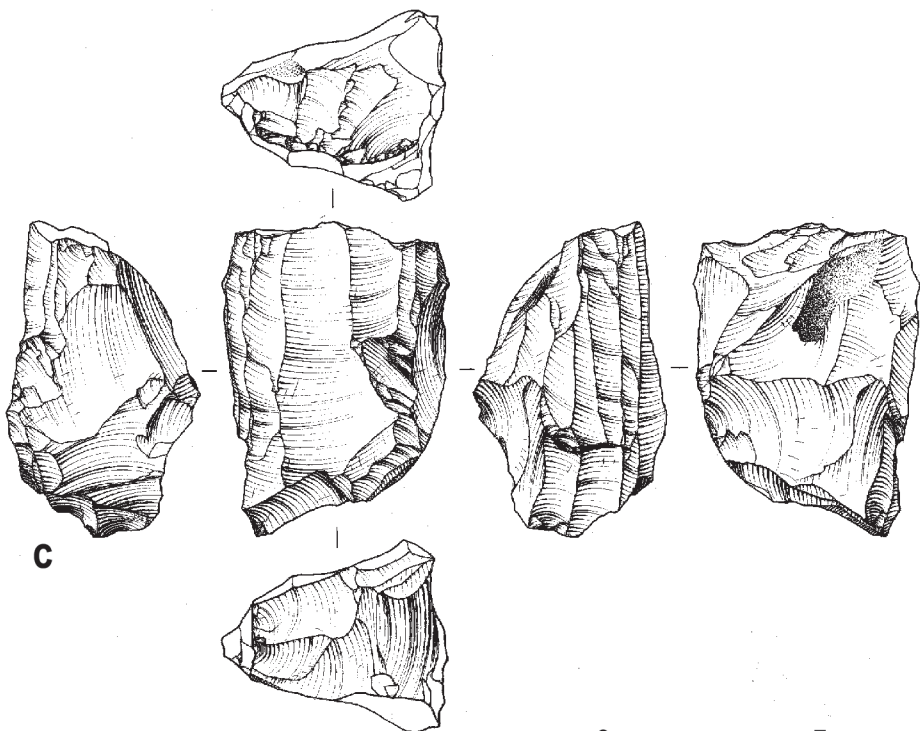




**a**

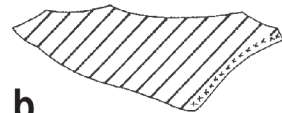
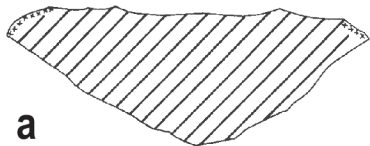
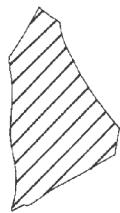
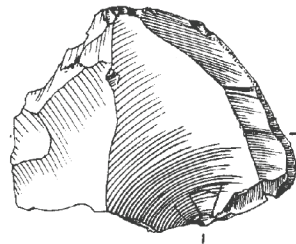
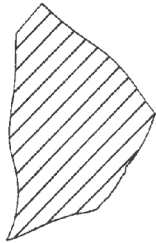
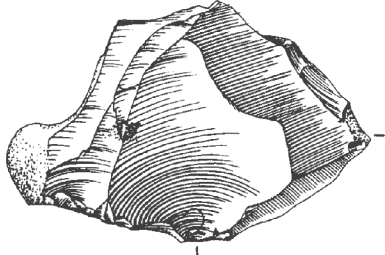


**b**



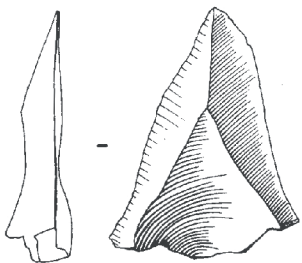
**c**

0 5cm

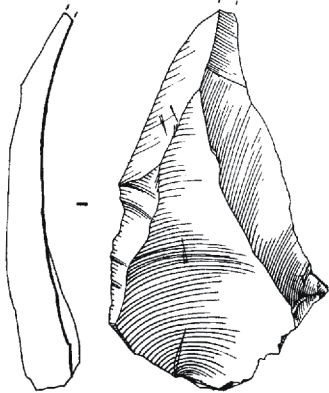


**a**

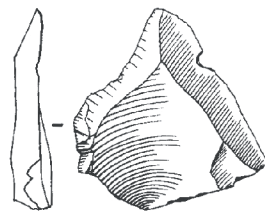
**b**



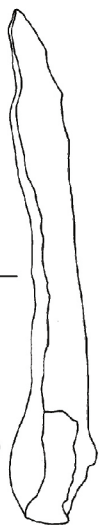
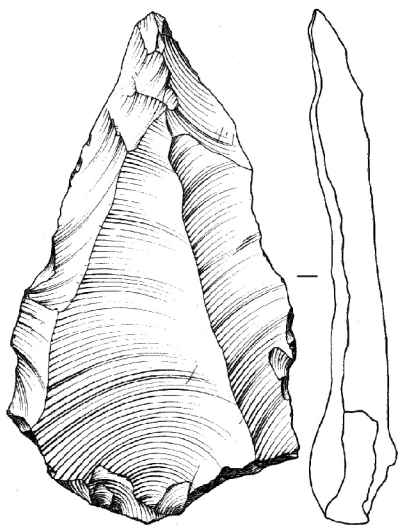
**c**



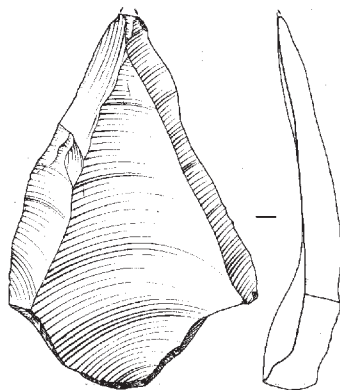
**d**



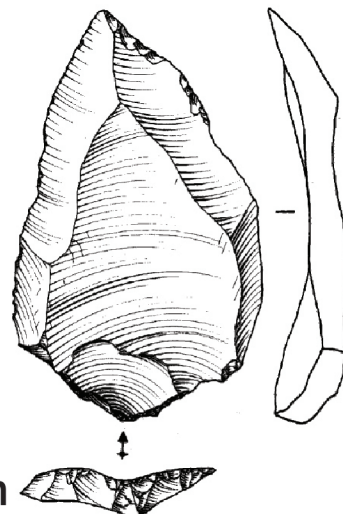
**e**



**f**



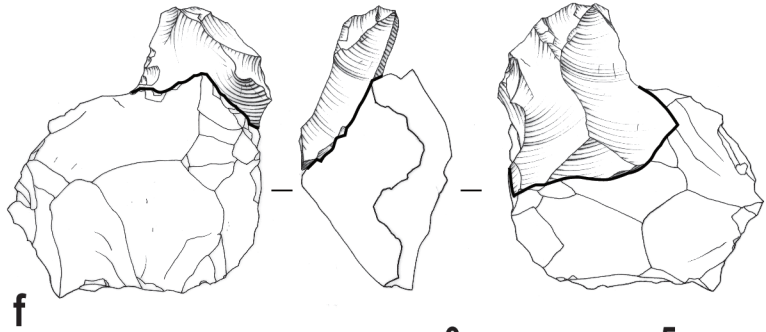
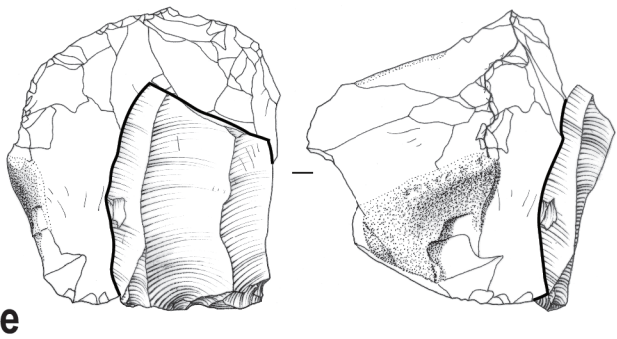
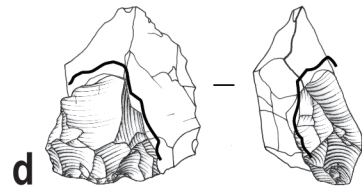
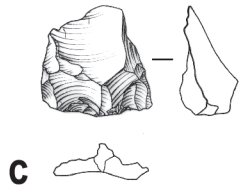
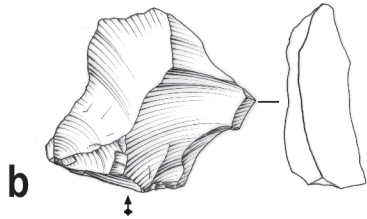
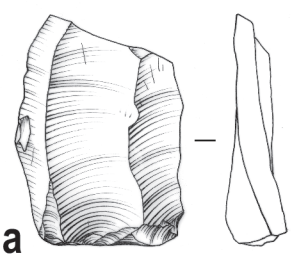
**g**



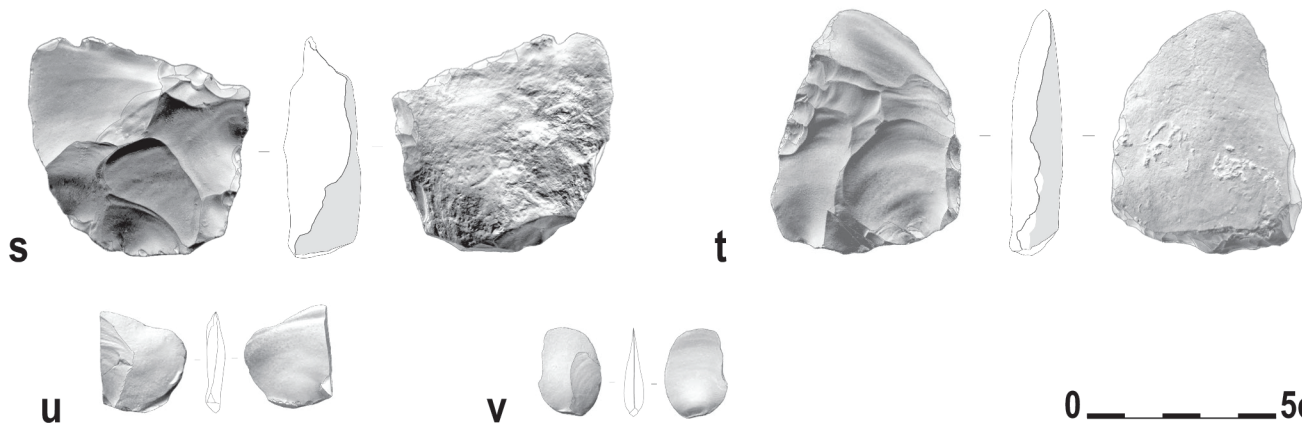
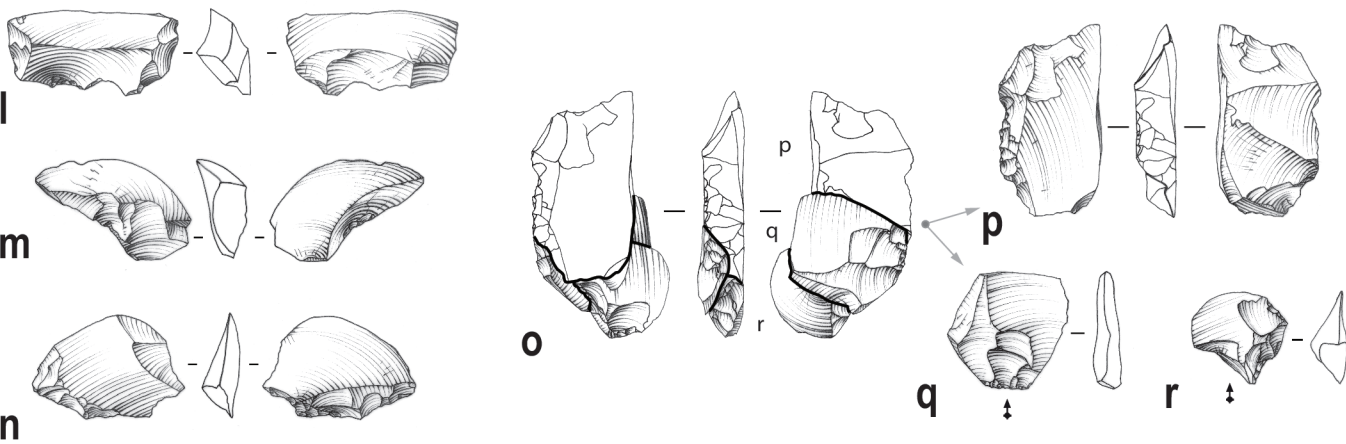
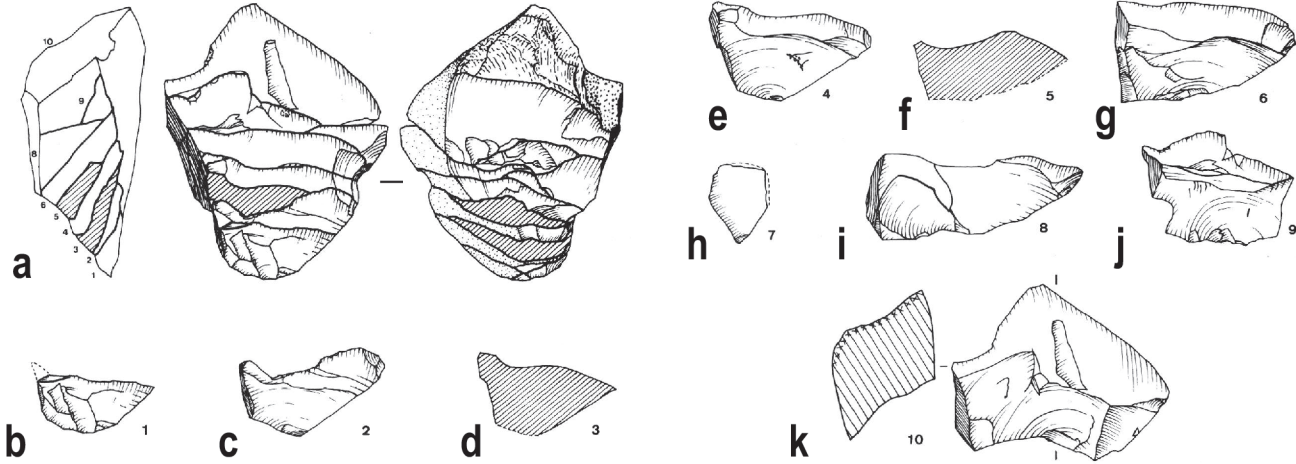
**h**



0 ————— 5cm

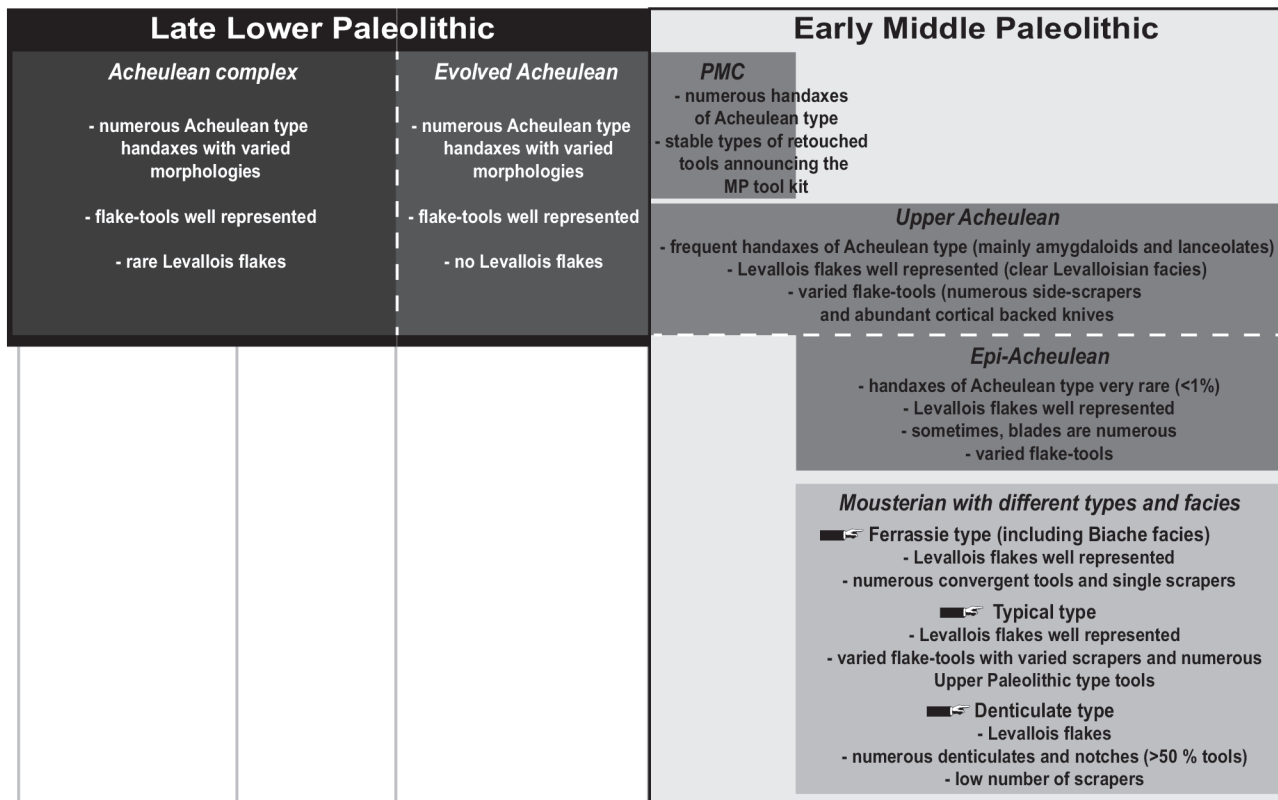


0 5cm

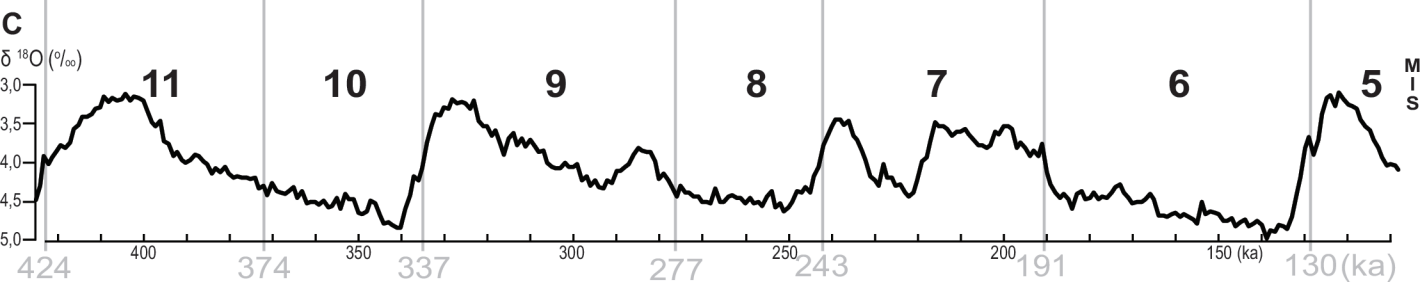
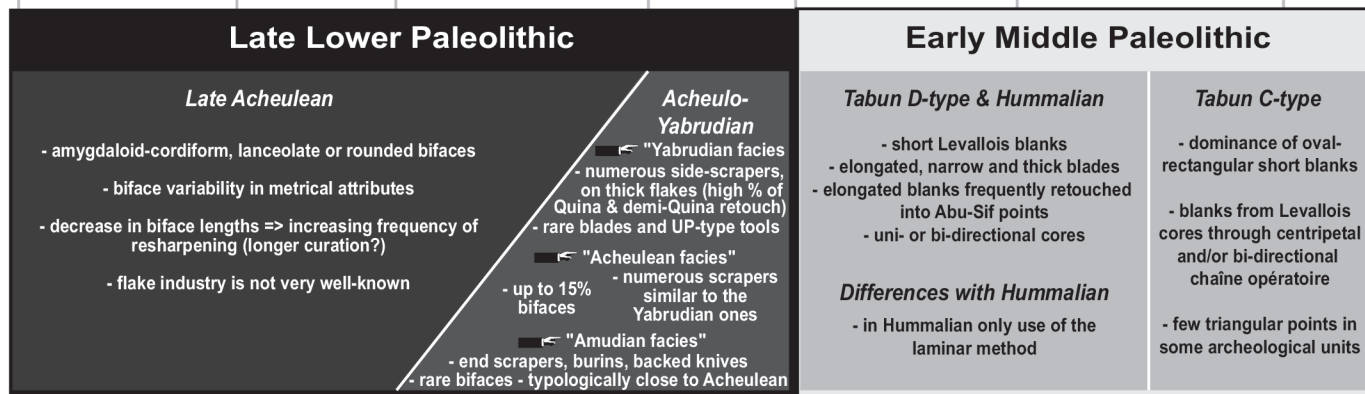


0 5cm

**A - Northern France: a coexistence, then transitional model, after Tuffreau (1982) and Tuffreau et al. (1989)**



**B - Near East: a chronocultural model, after Bar-Yosef (1994, 2002)**





**A - Northern France: current model, after Hérisson et al. (2016 a, b)**

### Late Lower Paleolithic

- Acheulean type handaxes with varied morphologies and sizes
- production of cortical thick flakes (backed knives) from short unipolar sequences
- absence of use of Levallois concept
- very rare indirect clues for fire use
- fine attention on the handeld part during bifacial shaping
- bifacial chaîne opératoire highly spatio-temp. fragmented
- standardized cortical backed knives from short secant unipolar reduction sequences
- first discreet use of Levallois concept
- bone retouchers for shaping stone tools

MIS 9 and particularly end of MIS 9 = innovating period

**PMC?**

- numerous handaxes with generalized integrated UTF
- low degree of blank predetermination balanced by a high intensity of retouch

←-----?-----→

NO DATA

### Early Middle Paleolithic

- dominant Levallois flake production (preferential or recurrent)
- punctual presence but well defined blade production from 'volumetric' blade cores (since 250 ka)
- punctual discoid flake and point production (since 190 ka)
- first Levallois point production around 190 ka
- very rare bifaces
- frequent/systematic ramification of the chaînes opératoires
- high spatio-temporally fragmentation of flake chaîne op.
- small flakes notably produced through ramification
- rare retouched tools, dominated by convergent tools and single scrapers
- frequent use of bone retouchers for shaping stone tools
- frequent use of fire (Hérisson et al., 2013)

EMP = period with a technological radiation with an apogee of diversity around 190 ka

**B - Near East: current model, mainly after Malinsky-Buller & Hovers (2019)**

### Late Lower Paleolithic

*Late Acheulean variability*

- frequent hierarchical cores
- frequent cores-on-flakes
- handaxes in low frequencies
- varied shapes, sizes and modes of production of bifaces

*Acheulo-Yabrudian variability*

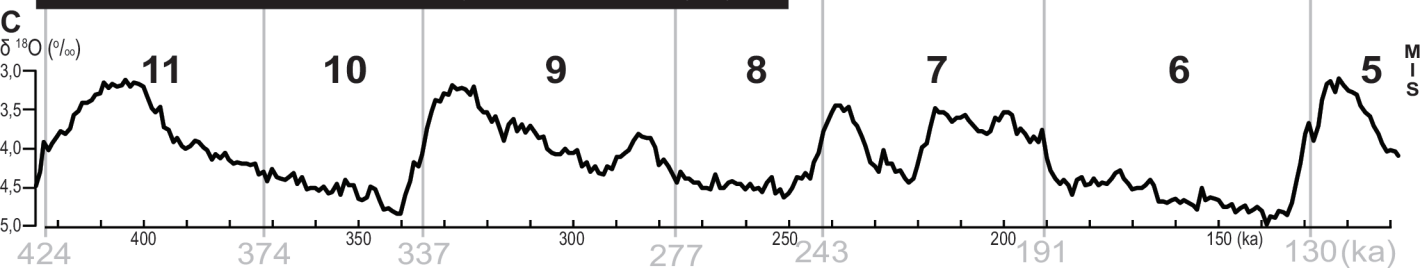
- frequent non-Levallois hierarchical reduction sequences for flakes
- frequent cores-on-flakes
- scrapers shaped by Quina retouch in Yabrudian facies
- well defined procedures for blade production in Amudian facies
- handaxes in low frequencies
- varied shapes, sizes and modes of production of bifaces as in Late Acheulean
- + After Shimelmitz et al. (2016a)
- habitual use of fire and central hearth
- hunting and sharing of game meat
- bone retouchers for shaping stone tools
- flint procurement from deep underground sources
- diverse and intensive flint recycling

Late Lower Paleolithic = period with a technological radiation after Chazan (2016)

### Early Middle Paleolithic

*Early Levantine Mousterian*

- dominant Levallois flake production (uni- and bidirectional)
- first systematic production of pointed items
- frequent new varied laminar production systems
- cores-on-flakes = main on-site core reduction method
- typological hallmark = elongated Abu Sif or Hummal points
- high frequencies of the retouched blades and points



1 **Table 1**

2 Dataset included in the study, including site name, archaeological level, topographical position of the site at the time of occupation, sedimentary context of  
 3 the archaeological level, chronology based on Marine Isotope Stage (MIS), value of MIS correlation, climatic phase of the occupation, taphonomic context of  
 4 the site, number of archaeological levels of the site, excavated surface of the archaeological level (m<sup>2</sup>), number of lithic remains (excluding chips, usually <15–  
 5 20 mm), and density of lithics.

Site	Level	Topography <sup>a</sup>	Sedimentary context <sup>b</sup>	Chronology (MIS)	Value of MIS correlation <sup>c</sup>	Climatic phase <sup>d</sup>	Taphonomic context	Number of levels	Surface (m <sup>2</sup> )	Number of lithics	Lithic density	References
Abbeville, Rte de Paris/rue de l'abreuvoir		J	2a	7	3	IS	P	1	na.	na.	na.	Locht et al., 2013
Ailly-sur-Noye	N3	J	2b	late 6/early 5	5	TGL	P	3	na.	316	na.	Blondiau et al., 2009; Locht et al., 2013
Argoeuves		J	2b	8	2		S	na.	na.	na.	na.	Bourdier, 1969; Bourdier et al., 1974; Agache, 1976; Tuffreau, 1979; Tuffreau et al., 1981; Antoine, 1990; Soriano, 2000
Bagarre	c.5	J	2a	8 to 6	1		S	3	20	521	26.1	Tuffreau and Zuate Y Zuber, 1975; Tuffreau et al., 1981; Boëda, 1994
Bagarre	c.7	J	2a	8 to 6	1		S	3	na.	na.	na.	
Bagarre	c.10	J	2a	8 to 6	1		S	3	na.	na.	na.	
Bapaume, Les Osiers	C.8 sér. B2	A	1	late 7a/early 6?	2		S	1	15	499	33.3	Tuffreau, 1971, 1976, 1979, 1987; Balescu and Tuffreau, 2004; Koehler, 2008, 2011
Beaumetz	sér. Lustrée	B	1	8 to 6	1		S	1	na.	na.	na.	Hurtrelle et al., 1972; Tuffreau, 1974, 1987;
Beaumetz	sér. Jaune	B	1	8 to 6	1		S	1	na.	na.	na.	Sommé and Tuffreau, 1976c
Biache-saint-Vaast	C	D3	1	6	2		S?	8	na.	na.	na.	Piningre, 1978; Vandermeersch, 1978;
Biache-Saint-Vaast	D	D3	1	early 6	4	DGL	P	8	260	431	1.7	Marcy, 1984, 1985, 1986, 1988; Boëda, 1986, 1988a,

Biache-Saint-Vaast	D1	D3	1	early 6	4	DGL	P	8	260	3071	11.8	1988b, 1994; Bouchet, 1986; Tuffreau, 1986, 1988a, 1988b; Auguste, 1988, 1990, 1994, 1995a, 1995b, 2003, 2012; Beyries, 1988; Huxtable and Aitken, 1988; Marcy and Tuffreau, 1988a, 1988b; Tuffreau and Marcy, 1988; Ameloot-Van der Heijden, 1989, 1991; Yokoyama, 1989; Leroy, 1990; Burie, 1992, 1996; Bahain et al., 1993; Auguste and Patou-Mathis, 1994; Dibble, 1995; Leblanc, 1999; Rougier, 1999, 2003; Marx, 2001; Louguet, 2004, 2006; Auguste et al., 2005; Guipert, 2005; Louguet-Lefebvre, 2005; Bahain, 2007; Liouville, 2007; Goubel, 2011; Hérisson, 2012; Hérisson et al., 2013; Rots, 2013
Biache-saint-Vaast	D0	J	2a	7e/7d	4	late IS	P	8	107	1186	11.1	
Biache-Saint-Vaast	IIbase	J	2a	7e	5	IS	P	8	340	3772	11.1	
Biache-Saint-Vaast	IIA	J	2a	7e	5	IS	P	8	170	25105	147.7	
Biache-saint-Vaast	E	J	2a	7e	4	IS	P	8	114	5570	48.9	
Biache-saint-Vaast	H	J	2a	8/7	5	TGL	P	8	45	1082	24	Antoine and Tuffreau, 1993; Laurent, 1993; Tuffreau et al., 1995, 2008; Dibble et al., 1997; Lamotte, 1999; Bahain et al., 2001, 2007
Cagny L'Epinette	H	D3	1	early 8?	2		P	9	180	2174	12.1	
Cagny L'Epinette	I	J	2a	early 9	5	early IGL	P	9	72	223	3.1	
Cagny L'Epinette	I0	J	2a	early 9	5	early IGL	P	9	40	716	17.9	
Cagny L'Epinette	I1	J	2a	early 9	5	early IGL	P	9	75	776	10.3	
Cagny L'Epinette	I1A	J	2a	early 9	5	early IGL	P	9	37	544	14.7	
Cagny L'Epinette	I1B	J	2a	early 9	5	early IGL	P	9	32	647	20.2	
Cagny L'Epinette	I1B/I2	J	2a	early 9	5	early IGL	P	9	23	167	7.3	
Cagny L'Epinette	J	J	2b	10/9	4	TGL	P	9	na.	na.	na.	

Champvoisy		A	1	early 8 or early 6?	2		S	1	na.	na.	na.	Balescu, 1988; Chertier and Hinout, 1988; Tuffreau, 1989; Balescu and Tuffreau, 2004
Clairy Saulchoix	inf	B	1d	9e	3	IGL	S	1	530	443	0.84	Lhomme et al., 2002; Rocca, 2005; Sellier, 2005
Drucat		J	2a	7	3	IS	P	1	na.	na.	na.	Locht and Kiefer, 2009; Loch et al., 2013
Etricourt-Manancourt	LGS	D	1	7/6	5	late IS	P	13	1500	52	0.039	Hérisson and Goval, 2013, 2015; Hérisson et al., 2016
Etricourt-Manancourt	LRS	D	1	7d/7c	5	early IS	P	13	2100	96	0.046	
Etricourt-Manancourt	HUD	D	1	9a	5	late IGL	P	13	4200	1894	0.45	
Etricourt-Manancourt	HUZ	BD	1d	9c	5	IGL	P	13	300	185	0.62	
Gentelles	LBN	B	1d	late 7a/early 6	2		S	7	na.	na.	na.	Tuffreau et al., 1999, 2001, 2008, 2017; Balescu and Tuffreau, 2004; Goval, 2005
Gentelles	LGC	B	1d	6?	2		S	7	na.	na.	na.	
Gentelles	LBP	B	1d	7?	2		S	7	na.	na.	na.	
Gentelles	CLG	B	1d	8?	2		S	7	na.	na.	na.	
Gentelles	CSI	B	1d	late 9/early 8	2		S	7	na.	na.	na.	
Gouzeaucourt	D	BD	1d	6	2		S	5	na.	na.	na.	Tuffreau and Bouchet, 1985; Marcy, 1989;
Gouzeaucourt	R	BD	1d	8 or >8	2		S	5	38	1394	36.7	Tuffreau et al., 1989;
Gouzeaucourt	G	BD	1d	8 or >8	2		S	5	186	10042	54.0	Tuffreau, 1992b; Lamotte,
Gouzeaucourt	H	BD	1d	8 or >8	2		S	5	183	5467	29.9	1995; Soriano, 2000
Gouzeaucourt	I	BD	1d	8 or >8	2		S	5	na.	na.	na.	
Havrincourt 2	NO	D	1	late 6	5	PGL	P	3	na.	na.	na.	Goval and Hérisson, 2012, 2018; Goval, 2013; Hérisson and Goval, 2013
Le Puceuil	série B	AB	1d	7/6	3	DGL	S	2	na.	na.	na.	Delagnes, 1993; Delagnes and Ropars, 1996; Lasuén and Delagnes, 2014
Le Puceuil	série C/A	B	1d	late 8/early 7?	3	TGL	S	2	na.	na.	na.	
Le Tillet	Série grise	B	1	8 to 6	1		S	2	na.	na.	na.	de Givenchy, 1911; Bordes, 1954
Le Tillet	Série blanche	B	1	8 to 6	1		S	2	na.	na.	na.	
Longavesnes		B	1d	8 to 6	1		S	1	na.	na.	na.	Tuffreau et al., 1989; Ameloot-Van der Heijden, 1991, 1993

Maisons-Alfort		J	2a	late 7a/early 6	3	late IS	P	1	350	168	0.48	Durbet et al., 1997; Hadjouis, 1998
Montières - Boutmy Muchembled		J	2a	7c/7a	4	IGL	na.	1 ?	na.	na.	na.	Common, 1913; Tuffreau et al., 1981; Tuffreau, 1983; Bordes, 1984; Antoine, 1990; Laurent, 1993
Plachy-Buyon	N1	D	1	6	4	PGL	P	3	525	na.	na.	Locht et al., 1995
Plachy-Buyon	N2	D	1	early 6?	4	DGL or PGL	P	3	525	na.	na.	
Plachy-Buyon	N3	D	1	9	3	DGL	P/S	3	525	206	0.39	
Revelles, Les Terres-Sellier	niv. 3	B	1d	9e	3	IGL	P	3	980	339	0.35	Guerlin et al., 2005
Riencourt-lès- Bapaume, chantier Sud	niv. III	A	1	7 or 6?	1		S	2	na.	na.	na.	Tuffreau, 1993
Saint-Acheul, Atelier Commont		D3	1	8 to 6	2		na.	1	na.	na.	na.	Common, 1909a, 1909b, 1911; Bordes and Fitte, 1953
Saint-Valéry- sur-Somme	SO	D	1	8	3	PGL	P+S	1	3	133	44.3	Heinzelin and Haesaerts, 1983
Salouël	1974/1976	J	2b	late 8?	2		S	1	na.	na.	na.	Antoine, 1990; Ameloot- Van der Heijden, 1991; Ameloot-Van der Heijden et al., 1996
Soucy 1		J	2a	9	5	IGL	P	1	394	1790	4.5	Chaussé et al., 2000;
Soucy 2		J	2a	9	5	IGL	P	1	2	180	90	Lhomme et al., 2000, 2003, 2004; Chaussé, 2003;
Soucy 3	niv. S	J	2a	9	5	IGL	P	2	92	58	0.6	Lhomme, 2007)
Soucy 3	niv. P	J	2a	9	5	early IGL	P	2	510	11980	23.5	
Soucy 5	niv. 0	J	2a	9	5	IGL	P	3	170	99	0.6	
Soucy 5	niv. I	J	2a	9	5	early IGL	P	3	110	1595	14.5	
Soucy 5	niv. II	J	2a	9	5	early IGL	P	3	80	1433	17.9	
Soucy 6		J	2a	9	5	TGL	P	1	24	137	5.7	
Therdonne	N3	E	1	late 7a/early 6	5	late IS	P	4	305	9989	32.8	Locht et al., 2000, 2010; Gadebois, 2006; Hérisson, 2012; Coudenneau, 2013; Hérisson et al., 2013; Hérisson and Loch, 2014

Vimy	c.17	B	1	8 to 6	1	S	1	na.	na.	na.	Tuffreau, 1974, 1979; Sommé and Tuffreau, 1976b
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6 Abbreviations: na. = non-available data.

7 <sup>a</sup> Coding for topographical position: A = plateau; B = depression; D = slope; D3 = lower portion of slope; E = hill foot; J = valley bottom.

8 <sup>b</sup> Coding for sedimentary context: 1 = loess, loess-derived deposits, or paleosol; 1d. = same as 1 but infilling a sinkhole; 2a = fine fluvial deposit; 2b = coarse  
9 fluvial deposit.

10 <sup>c</sup> Value of MIS correlation. Each occupation is assigned to an isotopic stage or, when possible, substage. The accuracy of each correlation is assessed and  
11 expressed as a score between 0 and 5: 0 = no correlation; 1 = correlation uncertain, very scant proof; 2 = correlation uncertain, some proof; 3 = good correlation  
12 but lack of convergent proof; 4 = precise and convergent correlation; 5 = perfect, precise and convergent correlation. See Hérissou et al. (2016a) for further  
13 details.

14 <sup>d</sup> Code for climatic phase (only for occupations with MIS correlation from 5 to 3): PGL = Pleniglacial; TGL = Late Glacial; DGL = Early Glacial; IGL = Interglacial;  
15 IS = Interstadial

16 <sup>e</sup> Coding for taphonomic context: P = primary; S = secondary.