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2 **Biface industries in southern France during the middle Pleistocene: a mosaic of**
3 **technical behaviours**

4 **Cyril Viallet, Cyrielle Mathias, Dominique Cauche, Tony Chevalier, Loic Lebreton,**
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10 **ABSTRACT**

11 Bifaces, emblematic Lower Palaeolithic tools, have been present in Eurasia for at least
12 1.7 Ma. These bifacially shaped tools are found over a vast spatio-temporal range and
13 variable environmental contexts. Their manufacture is also associated with different
14 hominin species. These factors raise questions about the origins of these tools: do they
15 stem from the same technical lineage, or are they the result of reinventions that remain
16 to be identified and traced? Bifaces appeared relatively late in the west of Europe (0.78
17 Ma) and persist until 0.12 Ma. Given the marked variability of chronostratigraphic
18 contexts and archaeological assemblages containing bifaces, the scientific community
19 has called into question the techno-cultural unity of bifacial shaping. Against this
20 backdrop, we propose to examine techno-cultural data from archaeological sites in
21 southern France. This area is a potential crossroads of influences. The sites are
22 correlated with various geographical and climatic contexts that may have influenced
23 the technical expression of hominins. We present an overview of the *chaînes*
24 *opératoires* involved in bifacial shaping which we compare with those of heavy-duty
25 and lightweight tools in order to discuss the consistency of technical choices. Our
26 results highlight the variability of techno-economical behaviours within the 'bifacial
27 industries' of southern France.

28 **KEYWORDS Middle Pleistocene; biface technologies; paleoenvironmental**
29 **fluctuations**

30 **Introduction**

31 Tool production by bifacial shaping of a rock volume has been documented since 1.75
32 Ma in human technical behaviour, following discoveries made at the East African sites
33 of Kokiselei 4 and Konso Lepré et al., 2011; Beyene et al., 2013). This production
34 system is considered mark a change in hominins' cognitive and abstract thinking
35 abilities (Muller et al., 2017; Shipton, 2019; Shipton & White, 2020). It allows different
36 types of tools to be produced depending on the period and geographical area (Boëda,
37 2013; Inizan et al., 1995). In the Lower Palaeolithic, the tools produced are called
38 'bifaces' (Vayson de Pradenne, 1920). Their functional status has been debated since
39 their discovery in the nineteenth century, due to their morphological variability and the

40 absence of technical memory. Some authors believe that biface shape variations
41 represent adaptations to raw material quality or differences in flaking skills, while for
42 others, they characterise different functions (see in particular: Leroyer, 2016; Nicoud,
43 2011; Viallet, 2016).

44 Whether they represent a production method or a functionally invariant tool, bifaces
45 have been found across a lot of Africa, Asia and Europe, after the first known
46 archaeological occurrence of bifaces in East Africa. Bifaces date from around 1.5 Ma
47 in South Africa, around 1.4 Ma in the Near East (Ubeidiya, Ronen, 2006), around 1.5
48 Ma in the Indian subcontinent (Attirampakkam, Pappu et al., 2011) and around 1.3 Ma
49 in North Africa (Carrière Thomas L1, Gallotti et al., 2023). The oldest bifaces in Europe
50 are documented in the early Middle Pleistocene, in the west of the continent. They
51 have been found in France: La Noira (Moncel et al., 2021), Moulin Quignon (Moncel et
52 al., 2022); in England: Brandon Fields and Fordwich (Davis et al., 2021; Key et al.,
53 2022) and in Italy at Notarchirico (Moncel, Santagata et al., 2020). The Barranc de la
54 Boella site could be the earliest example of techno-complexes with Large Cutting Tools
55 in Europe (Ollé et al., 2023). Human population mobility is generally put forward to
56 explain the spread of this production method, but the possibility of evolutionary
57 convergence should not be overlooked (Boëda, 1997, 2013; Pigeot, 1991).

58 In Europe, bifaces are found north of the 45th parallel (Davis et al., 2021; Moncel et
59 al., 2016) and archaeological occurrences multiply from the second half of the Middle
60 Pleistocene onwards (Nicoud, 2013), possibly linked to the MIS 11 warming (Moncel
61 et al., 2016). This observation is based on data from Western Europe, as biface sites
62 are generally absent in Central Europe and the Balkans (Rocca et al., 2023).
63 Furthermore, in the western territories of the Iberian and Italian peninsulas, in France
64 and in England, sites without bifaces coexist with biface sites, and this observation also
65 applies to the different archaeological levels of the same site (Aureli et al., 2016;
66 Gallotti & Peretto, 2015; Rocca et al., 2016; Moncel, Santagata et al., 2020).

67 In the context of the Middle Pleistocene, southern France (south of the 45th parallel
68 north) has yielded several archaeological sites containing bifaces, from the eastern tip
69 of the Mediterranean territory to the Atlantic coast, passing through the Rhône valley
70 and the foothills of the Pyrenees. Chronological data calibrate these human
71 occupations from MIS 14 or 12 to the end of MIS 6 (Falguères et al., 2015; Michel et
72 al., 2022). At most sites, the bifaces are associated with palaeontological and
73 palaeoanthropological remains. At the crossroads of human occupations in the Iberian
74 Peninsula, Italy and northern Europe, the proxies from southern France are therefore
75 major witnesses to the bifacial technologies used by human populations during the
76 Middle Pleistocene.

77 This article provides a summary of the data acquired on bifacial *chaînes opératoires* in
78 southern France during the Middle Pleistocene, based on 11 key archaeological sites.
79 These data are supplemented by information on other toolmaking sequences and
80 flaking sequences. This contextualisation aims to question the homogeneity of

81 technical behaviour in this geographical area, using mineralogical, climatic and
82 anthropological data, alongside an overview of links with neighbouring regions.

83 **Material**

84 Eleven archaeological sites were selected here to present presumed Acheulean
85 behaviour (or behaviour historically classified as such) in the southern half of France.
86 Most of them comprise several archaeological levels, which we have chosen to group
87 together by isotopic stages. They were chosen for their consistent stratigraphic integrity
88 and reliable chronological data, probably between MIS 14 and 6 (Table 1).

89 La Caune de l'Arago is a karstic cavity in the southern end of the Corbières massif.
90 Excavated since 1964, the site fill reaches a depth of about 15 metres, subdivided into
91 four main complexes, on a stalagmitic floor dated to MIS 17 (Yokoyama et al. 1982).
92 The middle complex, containing most of the Acheulean lithic remains, is divided into
93 three stratigraphic ensembles. Ensemble III is dated to between 407 and 469 ka and
94 linked to MIS 12 (Falguères et al., 2015). Ensemble II represents a phase of global
95 warming compared to the overlying ensemble III and underlying ensemble I, and is
96 correlated with MIS 13, whereas ensemble I is attributed to MIS 14 (Falguères et al.,
97 2015). However, given the high confidence interval for ensemble I, these correlations
98 have recently been called into question. The analysis of micromammal remains
99 suggests that the entire middle complex could be correlated with MIS 12, with
100 ensemble II corresponding to an interstadial (Lebreton & López-García, 2023). We
101 identified 32 bifaces in levels P and Q of Ensemble I and 15 bifaces in levels E, F and
102 G of ensemble III.

103 Terra Amata is an open-air site located on the slopes of Mont Boron, on the
104 Mediterranean coast. Excavated in 1966 by H. de Lumley and his team, the site
105 comprises two main stratigraphic complexes: the marine beach (C1a) and the dune
106 level (C1b). Digital dating by ESR was carried out on quartz samples from complex
107 C1a, giving an age of 380 ± 80 ka (Yokoyama et al. 1985), while TL dating on burnt
108 flint provided ages of 214 ka and 244 ka (Wintle & Aitken, 1997). Human occupation
109 would therefore be associated with MIS 12 to 7. However, biostratigraphic data and a
110 recent re-examination of the dates have led to an attribution to MIS 11 (Michel et al.,
111 2022). Thirteen bifaces come from units C1a and C1b.

112 La Terrasse site and Coupe-Gorge are located in the Montmaurin karst massif, on the
113 right bank of the Seygouade, in the Pyrenean foothills. They were discovered during
114 limestone quarrying just after the Second World War and were excavated by L. Méroc
115 (Violet, 2019). The middle karst level of the Coupe-Gorge cavity yielded a fill
116 approximately 7 m deep, the lower levels of which (ensemble 3) were recently dated
117 to 300 ka (Falguères et al. in Violet 2022). No numerical dating has yet been carried
118 out for the archaeological levels of La Terrasse, a cave with a collapsed vault located
119 at the upper karst level. However, the faunal assemblage, which included horse (*E.*
120 *mosbachensis*) and wolf (*C. lupus maximus*) remains, appears to be older than that of
121 the lower levels of Coupe-Gorge ensemble 3. The archaeological artefacts from

122 Coupe-Gorge come from the latter (3 U-T-S), but also from more recent levels of
123 ensemble 3 attributed to MIS 7 (3 W-Y) and 6 (3 Z) (Falguères et al. in Vialet 2021).
124 As the deposits at La Terrasse are older, a correlation with MIS 9 or 11 is likely. Ten
125 bifaces were found in these levels. A total of 18 bifaces from Coupe-Gorge are
126 examined here, from layer 3, mainly 3z.

127 La Micoque lies at the foot of a cliff in the Manaurie valley, a tributary of the Vézère in
128 the Dordogne in south-western France. This historic site was first excavated by G.
129 Sauvet and E. Rivière in 1896, and subsequently by numerous prehistorians: L.
130 Capitan, E. Harlé, D. Peyrony, E. Cartailhac, O. Hauser and F. Bordes (Mathias et al.,
131 2017; Rosendahl, 2006). The most recent excavations were carried out by A. Debénath
132 and J.-Ph. Rigaud from 1983 to 1997. The accumulation consists of a succession of
133 slope deposits and fluvial inputs and is subdivided into three nested sedimentary units
134 (Texier, 2006a). The main archaeological levels, comprising faunal remains and lithic
135 objects, are found in the middle unit. Comparisons with the deposition dynamics of
136 alluvial deposits in the Vézère valley and other neighbouring valleys suggest that the
137 middle unit can be attributed to MIS 10, which is broadly confirmed by numerical dating
138 (Falguères et al., 1997; Texier, 2006a).

139 Orgnac 3 is a karst cavity located on the Saint Remèze plateau in the Rhône valley
140 that evolved over time into a rock shelter after the roof collapsed. The site was
141 excavated from 1959 to 1972 by J. Combier. Although incomplete, the exploration
142 identified 10 archaeological levels rich in faunal and lithic material, associated with rare
143 hominin remains in the lower levels. Several dating campaigns, involving different
144 researchers, proxies and methodologies, have been carried out. The latest work, which
145 revisits and completes the previous data, attributes levels 9 and 8 to MIS 10, levels 7
146 and 6 to MIS 9, and levels 5 to 1 to MIS 8 (Bahain et al., 2022). However, a comparison
147 of all the numerical dating results with biochronological and sedimentological data
148 (Khatib, 1989) suggested a potentially older attribution of the levels (with the exception
149 of level 1): levels 9 and 8 to MIS 12, levels 7 to 6 to MIS 11 and levels 5 to 2 to MIS 10
150 (Lewis et al., 2022). However, the most recent work carried out on a speleothem
151 supports the first chronological range (Vandevælde et al., 2025). This article focuses on
152 70 bifaces from levels 5 to 2.

153 The Petit-Bost site is an open-air site located on a plateau in the Isle valley in the
154 Dordogne. It was excavated during preventive archaeology operations directed by L.
155 Bourguignon in 2001. It comprises three sedimentary levels, including two
156 archaeological levels (Bourguignon et al., 2006). TL dating of overlying level 2 provided
157 dates of 338 ± 43 ka and 312 ± 23 ka, correlating human occupation with MIS 9 or 8
158 (Lahaye et al. *in* Bourguignon et al., 2006). In the absence of biostratigraphic data, it
159 is not possible to further define this chronological attribution.

160 Le Pech-de-l'Azé II cave site is situated in the Coniacian limestone Farge valley in
161 Dordogne. It was excavated by F. Bordes from 1949 to 1969. Four lithostratigraphic
162 units have been identified (Texier, 2006a). ESR and OSL dating of the levels of Unit 2

163 (6 to 9), containing human occupation, links them to MIS 6 (Grün et al., 1991; Jacobs
164 et al., 2016). The lower levels were used to define F. Bordes' southern Acheulean
165 (Bordes, 1971).

166 The Combe Brune 2 site is located on a plateau on the edge of the Caudeau valley
167 (Dordogne). It was excavated as part of preventive archaeology by M. Brenet between
168 2006 and 2007. It comprises several levels in a doline fill (Brenet et al., 2008). The
169 archaeological levels from the western excavation area are well preserved (Bertran *in*
170 Brenet et al., 2008) and are presented here. Numerical dating gives an age of $234 \pm$
171 25 ka, correlating human occupation with the end of MIS 7 or the beginning of MIS 6
172 (Frouin et al., 2014), in keeping with stratigraphic interpretations.

173 Lazaret Cave opens to the south, 23 m above the current sea level, on the slopes of
174 Mont Boron, near the Terra Amata open-air site. The fill, approximately 7 metres thick,
175 contains two fossil beaches at the base, evidence of two marine transgressions during
176 the Middle Pleistocene (Lumley et al. 2004, 2018). Above this is a continental fill
177 consisting of colluvial sandy-silty clays and gravel and blocks detached from the cave
178 walls. This stratigraphic complex (C) contains the human occupations. ESR and U/Th
179 dating of the stalagmitic floor and mammal teeth place complex C in MIS 6 (Michel et
180 al., 2018, 2022). UA 26, dated to over 160,000 years ago (Lumley, 2018), yielded 34
181 bifaces, which form part of this study.

182 **Method**

183 Analyses of biface *chaînes opératoires* from European Middle Pleistocene sites
184 highlight the variability of technical choices and spatio-temporal management. The
185 series are described following a comprehensive analysis of the operational sequences
186 (Boëda et al., 1990; Inizan et al., 1995) in order to identify the criteria underlying the
187 techno-cultural distinctions in the scientific literature.

188 The systematic production of large flake blanks for shaping bifaces defines a specific
189 techno-cultural complex: the Large Flake Acheulean (LFA), which is most often
190 implemented on hard rocks (Sharon, 2010). These petrographic choices have
191 implications for the flaking aptitudes of raw materials for hominins, but also for the
192 effectiveness of the cutting edges produced (Viallet et al., 2025), and are therefore
193 important characterisation parameters. In the operational processes involved in biface
194 production, the techniques and methods used are also indicative of particular
195 behaviours: the use of tangential percussion gestures, with or without a soft hammer
196 (mineral or vegetal) (Clément, 2019), the use of the '*coup du tranchet*' or tranchet blow
197 (Limondin-Lozouet et al., 2006; Roberts & Parfitt, 1999), the functionalisation of the
198 object from the moment it is shaped, or the addition of a retouching phase. *The*
199 *functionalisation corresponds to the final technical operation that shapes the cutting*
200 *edge* (Brenet, 1996).

201 Some bifaces were produced in different areas to those where they were used, and/or
202 used for long periods with varying degrees of re-sharpening, or show evidence of

203 changing functional status (denaturation), for example, through reuse in production
204 matrices. We focus on evidence of such behaviours and the causal criteria (distance
205 from raw material sources, deliberate fracturing, flake removal scars indicating flake
206 production, re-sharpening, on-site shaping flakes, mental refits, etc.). Finally, the
207 petrographic, volumetric and construction characteristics of the cutting edges are
208 recorded for comparison with the operational sequences of other heavy-duty tools, *i.e.*,
209 choppers and chopping tools, including Large Cutting Tools (picks, unifaces, cleavers),
210 and those of lightweight tools or tools made on flakes (scrapers, denticulates, notches,
211 etc.), in order to investigate biface complementarity (similar functional potential,
212 through different technical choices) or supplementarity (different functional potential)
213 (Soriano, 2000).

214 Consequently, we assess the choice of raw materials (initial volume, rock type and, in
215 particular, mechanical properties, distance from the site), the operational sequences
216 used and the techno-economic choices made. Based on mechanical tests of hardness,
217 we consider limestone, basalt and quartzite to be hard rocks, as opposed to tougher
218 rocks such as flint and quartz (Viallet et al., 2025). For shaped tools, various elements
219 are used to characterise production diversity: the use of large flake blanks, integration
220 into long production cycles, with or without final denaturation, on-site shaping or
221 importation, tool structure, type of association with lightweight tools and non-retouched
222 elements (complementarity/ supplementarity). The functional potential of the different
223 products is inferred from an analysis of tool structure and is based on a description of
224 the causal relationship between technical gestures and morphological consequences
225 (Boëda, 1997; Bourguignon, 1997; Lepot, 1993).

226 **Results**

227 The results presented here stem from a re-examination by some of the authors of all
228 the bifaces described in this paper and their correlation with the operational sequences
229 of heavy-duty tools and the production of lightweight blanks (Table 2). When such
230 results are not derived from a new study, we refer to the works used in the bibliography.

231 ***Acheulean occurrences in the eastern Mediterranean basin at the foothills of the*** 232 ***Pyrenees***

233 The highly diversified petrographic choices for biface shaping at la Caune de l'Arago
234 are broadly similar for the levels of ensembles I or III (Figure 2). Flint is slightly
235 dominant, but quartzite and quartzite sandstone are frequently used, whereas
236 limestone, quartz and volcanic rocks are more marginal. It should be noted here that
237 hornfels is frequently associated with the production of large tools but can only rarely
238 be assigned to a typological category due to its very poor preservation, inducing a bias
239 in raw material analysis. The flints were collected from deposits located more than 30
240 km from the site. Other materials were collected in areas between 5 and 15 km from
241 the site, and only a few limestones and quartzes can be attributed to local sources
242 (Grégoire, 2012; Viallet et al., 2022). When blanks can be identified, they are most
243 often pebbles with part of the original morphology preserved at the biface base. The

244 use of flake blanks is attested in two cases in ensemble I and in ensemble III. Shaping
245 with a hard hammer is largely predominant. In level Q, the use of tangential gestures
246 is observed on the bifaces and confirmed by retouching flakes with a lip between the
247 butt and the ventral surface (Viallet et al., 2022). This technique is not attested in the
248 levels of ensemble III, but a re-examination of shaping waste could be beneficial. In
249 most cases, shaping and sharpening phases are indissociable. In level Q, the high
250 proportion of fragments (37.5%), several of which show traces of use prior to fracturing
251 (itself linked to a knapping accident), and others reconfigured into tools or denatured
252 into production matrices, points to a long cycle of biface use (Viallet et al., 2022).
253 Combined with the presence of raw materials from distant sources, this may support
254 the idea that hominins were already anticipating their needs in ensemble I. A case of
255 deliberate fracturing of a flint biface, followed by reuse with a new function, still as a
256 biface, is also documented in level G (Viallet et al., 2022).

257 In ensemble I, most of the bifacial production aimed to create tools with a latero-distal
258 cutting edge consisting of a series of notches creating a sinuous edge formed by the
259 convergence of the notches to the right and left (hereafter referred to as sinuous
260 notched edge) (Viallet, 2023). This functional objective differs from that of other heavy-
261 duty tools, mainly represented by choppers made from hard rocks, with a straight distal
262 cutting edge (Lumley, 2015). Lightweight tools on flakes are dominated by tools with a
263 straight lateral cutting edge (scrapers *s.l.*) and notches (Lumley, 2015). Bifacial
264 production therefore complements heavy tools and lightweight tools. In ensemble III,
265 bifaces can also have sinuous notched latero-distal cutting edges, but they also feature
266 open, more or less convergent angular cutting edges in the distal position, which do
267 not appear to be related to cutting activities (Viallet, 2016, 2023). The other component
268 of heavy-duty tools consists mainly of limestone choppers, as in ensemble I. The
269 lightweight tools are dominated by tools with a straight lateral cutting edge (scraper
270 *s.l.*) and notches. The presence of Tayac and Quinson points is noteworthy (Lumley,
271 2015). Bifaces, heavy-duty tools and lightweight tools therefore represent
272 complementary functional objectives, with the exception of two flint bifaces from soil G
273 with a notched edge.

274 At Terra Amata, all the bifaces are made from non-silicified limestone containing
275 varying degrees of marl or clay (Lumley et al., 2014). Blank modules are always
276 pebbles, never flakes. This is a deliberate technical choice made by hominins, as this
277 raw material is conducive to the production of large flake blanks, as evidenced by the
278 more recent Observatoire site (Porraz et al., 2014). Shaping is always carried out with
279 a hard hammer, by a series of shaping sequences involving few directly functionalising
280 removals. Two cases of a marginal retouching phase were observed. The bifaces
281 produced at this site either display a convergent end with relatively blunt edges or a
282 transverse edge with an acute angle (Figure 3). The latter case is produced by very
283 tangential percussion gestures; on one piece, the transverse cutting edge is created
284 by a double alternating tranchet blow. This percussion technique is also used in the
285 production of 'Terra Amata-type cleavers' (Lumley et al., 2014). These tools are made

286 on oval to quadrangular limestone pebbles, with or without lateral facets, with a very
287 acute transverse cutting edge created by a very tangential gesture allowing the
288 detachment of an invasive removal from the edge. This technique can be completed
289 by a few long removals from the opposite edge. The cleaver attribution is based on the
290 presence of a transverse cutting edge. However, there is only one cleaver *sensu* Tixier
291 (1956), on a large flake, at Terra Amata. Other heavy-duty limestone tools at the site
292 include pebbles shaped by long and, more rarely, invasive bilateral removals on a
293 meso-distal portion, creating a convergent end. This category, referred to as 'picks' in
294 previous studies (Lumley et al., 2014), includes two groups: one made up of elongated
295 tools, where the maximum thickness is in the proximal third and the removals produced
296 by tangential gestures create acute-angled edges; and the other where the maximum
297 thickness is in the distal third, with re-entrant removals, creating a thick distal end with
298 more open angles. Finally, the heavy-duty tools from Terra Amata include a large
299 number of choppers, all made of limestone, with varying volumes. Lightweight tools
300 are rare and mainly made of silicified limestone or flint. The presence of allochthonous
301 materials, probably introduced as finished products, is noteworthy: flint from the Var,
302 quartzite from San Remo and rhyolite from the Estérel. Scrapers and notches dominate
303 the typological assemblage (Lumley et al., 2014). Lightweight tools therefore
304 complement the functional potential of heavy tools. Furthermore, at Terra Amata,
305 bifacial production is indistinguishable from unifacial production, since the same types
306 of functional structure and cutting edge conformation are found in both cleavers and
307 picks, and petro-technical choices are similar for both categories. *Here, bifacial and*
308 *unifacial shaping are used to produce heavy-duty tools with similar functional potential*
309 Ludian flint is the dominant petrographic component of the 70 bifaces unearthed in
310 levels 5 to 2 at Orgnac 3, whereas only eight of them are made of quartzite and one of
311 basalt. These raw materials are available in the immediate vicinity of the site (the
312 Barjac-Issirac Palaeogene basin), in limestone bars, and sometimes in local alluviums,
313 in the Cèze, for example. Flint occurs in the form of plates and, more rarely, rolled
314 plates (no. = 6; alluvial neocortex but the plate morphology is still visible). The use of
315 11 flake blanks is noteworthy, although this production is not systematically associated
316 with bifacial shaping. Shaping flakes are found on site, alongside a used biface point
317 fractured during re-sharpening, indicating the on-site production and use of some of
318 the bifaces. The importation of blanks in the form of flakes or finished products cannot
319 be ruled out but cannot be demonstrated on the basis of the available archaeological
320 data. Apart from the abovementioned point, there are no other indications of re-
321 sharpening or of the integration of bifaces into long cycles of use. Biface shaping
322 consists of extensive, invasive removals, mainly modifying the meso-proximal volumes
323 (Figure 4). The bases are mostly cortical, taking advantage of the natural prehensile
324 properties of the flint plates. Two main shaping patterns have been identified. The first
325 shapes the volume one face after the other and frequently uses a lateral tranchet blow
326 technique to create a distal end with a regular, straight and sharp cutting edge. The
327 second is based on alternating edge management, resulting in converging ends and
328 sinuous notched edges. In both cases, a marginal retouching phase may be applied

329 (although this is not systematic) to functionalise the cutting edges. The use of
330 tangential percussion is evidenced by thin and invasive removal scars. This could be
331 associated with the use of soft percussion tools (mineral or organic), but this cannot
332 be proven without a detailed re-examination of the shaping flakes.

333 Heavy-duty tools other than bifaces consist solely of chopper-type tools and a few
334 picks. In all levels, they are mainly made of limestone, followed by quartz, granite and
335 quartzite (Moncel, 1999), pointing to the selection of mainly hard rocks. Although the
336 volume of these tools is comparable to biface volumes, petrographic choices, the
337 blanks and the shapes of cutting edges suggest that they were designed to
338 complement the latter. Lightweight tools are mainly represented by 'scraper'-type
339 cutting edges with unifacial retouch, and to a lesser extent, by denticulates and notches
340 (Mathias, 2018; Mathias et al., 2020). They are almost always produced on flint flakes
341 and complement the production of heavy-duty tools.

342 The archaeological levels of La Terrasse site in Montmaurin contain 11 bifaces, all
343 made of quartzite from the alluvial deposits of the Save or Seygouade rivers (Figure
344 3). In seven cases, the blanks are pebbles, as shown by the relatively non-modified
345 proximal part of the bifaces, which preserves the initial pebble morphology. The other
346 four blanks are large flakes. There is no evidence of re-sharpening or of the
347 denaturation of these objects. A re-examination of all the flakes is required to determine
348 whether shaping took place on site or whether the bifaces were imported as finished
349 products. Shaping is always alternating, generally creating sinuous notched edges
350 associated with the convergent distal end. There is no functionalisation via a less
351 invasive shaping phase, but in two cases a latero-distal tranchet blow cuts into the
352 sinuous notched edge, creating a straight, biplanar edge. There is no evidence of
353 tangential percussion and, *a fortiori*, of soft mineral or organic percussion. The
354 associated heavy-duty tools are exclusively made of quartzite and are mainly chopper-
355 type tools. There are however three cleavers; two on flakes and one on a split pebble,
356 as well as a unifacial tool on a flake. The use of hard rock flakes as blanks is well
357 documented at La Terrasse, although this is not the most common technical choice.
358 Lightweight tools are mainly represented by scrapers *sensu lato* and notches,
359 produced on flint and lydian flakes. Two small lydian pebbles with alternating retouch
360 on one edge creating a sinuous notched cutting edge are also noteworthy. Bifaces,
361 choppers, cleavers and lightweight tools play a complementary role in the assemblage.

362 Eighteen bifaces were unearthed in ensemble 3 of Coupe-Gorge Cave (almost
363 exclusively from layer 3z), also located in the Montmaurin limestone massif. These
364 bifaces include three mixed flaking/shaping matrices; two in quartzite and one *a priori*
365 in highly altered basalt. One tool is unifacially shaped on the convex face of one edge
366 and on the flat face of the opposite edge, producing a convergent cutting edge on an
367 indeterminate quartzite blank. A single 'typological' quartzite biface, produced from a
368 pebble, is large enough to be classified as a heavy-duty tool. This tool was shaped by
369 few blows, including a latero-distal tranchet blow with a strongly hinged termination.
370 The latter does not appear to be intentional, as this technique is traditionally associated

371 with extensive, invasive removals. Most of the bifaces were produced from lydian
372 pebbles and are small, similar in size to lightweight tools (Figure 4). The aim of shaping
373 is to create a rather sinuous notched cutting edge with an asymmetrical section,
374 associated with a point, in oblique opposition to the cortical base. This description
375 broadly corresponds to seven pieces, in addition to a flint biface. Two bifacially shaped
376 meso-proximal elements in lydian stone can be added to the tough rock component.
377 We cannot infer the functional purpose of these artefacts due to the absence of a distal
378 end and the *a priori* unfinished cutting edges. Finally, three points complete the series:
379 one in quartzite, one in flint and one in lydian. The quartzite point is larger in terms of
380 volume. The other two display a flexural fracture (use?) at the distal end. The three
381 points probably result from accidental fractures during knapping. The dominant
382 shaping method is alternating shaping. There is no evidence of the use of soft
383 percussion. The gestures do not appear to be particularly tangential, with the exception
384 of the quartzite biface with a lateral tranchet blow.

385 Heavy-duty tools are represented by quartzite choppers and two convergent tools
386 shaped on a single face. Lightweight tools are dominated by straight lateral cutting
387 edges on flakes (scrapers *s.l.*), followed by denticulates and notches (Thiam, 2018).
388 The whole assemblage is mainly produced on flint and, to a lesser extent, on lydian,
389 showing a preference for tough materials. There are also lightweight tools made of
390 quartzite (Thiam, 2018). In terms of volume, the bifaces can be assimilated to
391 lightweight tools, and both categories display similar petrographic choices. However,
392 unlike the latter, the bifaces comprise sinuous notched latero-distal cutting edges, and
393 thus appear to be complementary to lightweight tools on flakes. They also complement
394 other heavy tools, with differences in weight and in the position and conformation of
395 the cutting edges.

396 Thirty-four bifaces were discovered in UA 26 of Lazaret Cave. The vast majority are
397 made of more or less marly limestone and, more rarely, silicified limestone, micro-
398 quartzite and, in one case, volcanic rock (Figure 4). These materials are available
399 locally as pebbles in the alluvial deposits of the Paillon or Var rivers. Pebbles are the
400 most frequently identified blanks, but large flakes were also used. The bifaces were
401 shaped by hard and soft hammer percussion, using tangential gestures. Soft
402 percussion is evidenced by the presence of typical shaping flakes. The functional
403 objectives of bifacial shaping are twofold: the production of elongated convergent tools
404 with biplanar cutting edges, sinuous notched or not; and the production of tools with
405 transverse cutting edges, produced by lateral tranchet blows. This technique is also
406 identified on points bearing a fractured surface. This means that some of the bifaces
407 were re-sharpened on site, with a change in functional purpose (from a convergent tool
408 to a transverse cutting edge). In addition to the numerous shaping flakes and
409 unintentionally fractured distal ends, this reveals that at least some of the bifacial
410 production took place in the cave. In addition, one biface has a double patina, indicating
411 the reuse of a former tool. Choppers made from large cortical flakes, subsequently
412 modified by abrupt bilateral retouch, are another component of the heavy-duty toolkit.

413 One of these choppers is in limestone and two are in volcanic rock (including green
414 andesite). The rest of the heavy-duty tools consists of a few uniaxially and unilaterally
415 shaped marly limestone pebbles (choppers) on smaller, often flat blanks, and a few
416 chopping tools. Lightweight tools consist mainly of scrapers and, to a lesser extent,
417 notched tools, as well as some retouched points, some of which show thinning
418 consistent with hafting. There are also a few end scrapers, burins, awls and limaces.
419 Fine-grained siliceous rocks were preferentially selected as blanks for lightweight tools;
420 mainly flint, but also chert, microcrystalline quartzite and, in very rare cases, jasper, as
421 well as two rhyolite tools, including a Quinson point. In UA 26 of Lazaret Cave, bifaces,
422 heavy-duty tools and lightweight tools constitute complementary components.

423 ***The biface series from the late middle Pleistocene in the northern Aquitaine***
424 ***basin and the question of the southern Acheulean***

425 In Aquitaine, sites attributed to the Acheulean, in particular the early Acheulean, are
426 rare. However, lithic assemblages with bifacial pieces (considered either as Late
427 Acheulean or Early Middle Palaeolithic) are more widespread, such as the MIS 6 series
428 from Barbas (Boëda et al., 1996).

429 F. Bordes defined the Southern Acheulean in the Dordogne, based on the lower levels
430 of Pech de l'Azé II and Combe-Grenal (Bordes, 1971), as opposed to the Northern
431 Acheulean of France. In the Middle Southern Acheulean (Pech-de-l'Azé II, layers 7c to
432 9), he notes 'amorphous' cores, few Levallois elements and modified pebbles
433 associated with a few coarse bifaces and cleavers. The Late Southern Acheulean
434 (Combe-Grenal, layers 58–61) is described as non-Levallois, with numerous bifacial
435 pieces, often fragmented or core-shaped (Bordes, 1971, 1992). A revision of these
436 series called into question the presence of cleavers (Mourre, 2003) and led to the
437 description of the Trifacial techno-complex (Boëda, 1989; Chevrier, 2006). However,
438 the validity of the latter as a genuine facies has also been questioned (Mathias &
439 Bourguignon, 2019; Turq et al., 2010).

440 La Micoque is one of the oldest sites in Dordogne. The lithics in layer L2/3 (excavations
441 by A. Debénath and J.-Ph. Rigaud) are well preserved compared to the other lithic
442 assemblages (some refits, presence of fine fraction). It contains a single biface made
443 from local flint, associated with 17 flint shaping flakes, with no refits. The biface shows
444 a mixed shaping phase, combining flake production followed by the functionalising
445 shaping of the cutting edge and the gripping area (Figure 5). There is no evidence of
446 soft percussion and no other associated heavy-duty tools. The lightweight tools, made
447 on flakes, are clearly dominated by scrapers *s.l.* Contrary to what has been suggested
448 in the literature, the Trifacial concept is absent from this level.

449 Level 2 of the Petit Bost site contains 13 whole bifaces, three of which are considered
450 to be roughouts (Bourguignon et al., 2006; Mathias et al., 2020). They are shaped on
451 pebbles or nodules with partially preserved cortical surfaces in the proximal part
452 (Senonian flint, Bergeracois) (Figure 5). There are no flake blanks. Shaping is followed
453 by a functionalising phase in nine out of ten cases. There is no evidence of the use of

454 soft percussion. Five biface fragments complete the corpus: two points and three
455 bases, showing unintentional fractures and no subsequent reworking. The heavy-duty
456 tools are supplemented by several trifaces (no. = 6 for the flaking/shaping method, no.
457 = 1 flaking/retouching; Mathias & Bourguignon, 2019) and a uniface on large Senonian
458 and Bergeracois flint flakes and chalcedony. The lightweight tools, also made of flint,
459 are dominated by scrapers, followed by convergent tools and denticulates. They
460 appear to complement the heavy-duty tools.

461 Layer 7 of Pech de l'Azé II yielded two flint bifaces and five shaping flakes (in local
462 Senonian flint). One biface was produced on a thick flake. There is no evidence of soft
463 percussion. Both bifaces are small in size with a thick base (Figure 5). They are
464 accompanied by two flint chopping tools (one of which can be considered to be a partial
465 biface), two quartz choppers and a basalt uniface. Compared to other series in
466 Dordogne, a wide variety of raw materials were used. Lightweight tools are almost
467 exclusively made of flint or chalcedony, dominated by scrapers, followed by notches
468 and denticulates. Bifaces, heavy-duty tools and lightweight tools are complementary
469 in the assemblage (blank size, types of cutting edges, raw materials).

470 Level VIIa at Combe Brune 2 yielded six bifaces in flint from the Bergerac region, two
471 of which are on flakes (Brenet, 2013; Mathias et al., 2020). Shaping is not always
472 accompanied by a functionalising phase, and no soft percussion tool has been
473 identified (Figure 5). A quartz chopper completes the heavy-duty tools. There are also
474 two trifaces, consisting of mixed flaking/shaping matrices, made of local flint.
475 Lightweight tools on flint flakes are dominated by scrapers, followed by notches and
476 denticulates. There is a complementary relationship between the tools from the
477 different production chains.

478 Although bifaces and other LCTs have been identified in all the series presented here,
479 flaking dominates the assemblages. Levallois is dominant in most series (Levallois
480 *stricto sensu*). In layer L2/3 of la Micoque, Levallois flaking in the broad sense of the
481 term is rare, but productions are nevertheless highly standardised (unipolar flaking,
482 backed flakes - Mathias et al., 2017). Thus, despite the presence of bifaces between
483 MIS 10 and 6, with the exception of Barbas, these series are attributed to the Early
484 Middle Palaeolithic (Mathias et al., 2020).

485 **Summary**

486 With regard to the choice of raw materials for tool production operational sequences,
487 the southern assemblages outline four scenarios. Tough and hard rocks were used for
488 bifacial shaping in the two ensembles with bifaces at la Caune de l'Arago, combined
489 with other heavy-duty tools preferentially made of hard rocks and lightweight tools
490 made of tough rocks. This scenario is not documented at other sites. In fact, at the
491 Terra Amata, La Terrasse and Lazaret sites, hominins chose hard rocks for all the
492 heavy-duty tools, including bifaces, whereas lightweight tools were made from tough
493 rocks. Conversely, at Orgnac 3 and Coupe Gorge, tough rocks were selected for the
494 bifaces and the lightweight tools, while the other heavy-duty tools are made of hard

495 rock. Furthermore, at Coupe Gorge, the bifacial tools are also similar in volume and
496 weight to the flake tools. In the south-western sites, all the tool production operational
497 sequences are in tough raw materials. These four differential raw material relationships
498 reflect variable technical choices.

499 The use of flake blanks for heavy-duty tools, including bifaces, is observed at each of
500 the sites in south-eastern France and the Pyrenees, but always only marginally, with
501 no systematic production of these blanks for shaping. The only counterexample could
502 be the series from La Terrasse, which, however, is quantitatively insignificant and also
503 included several tools shaped on pebbles. In the Dordogne series, flake blanks are
504 rare (one biface at Pech-de-l'Azé II, one uniface at Combe Brune 2). The use of lateral
505 or latero-distal tranchet blows to form apical edges is documented in all sites except la
506 Caune de l'Arago. This technique is common at Orgnac 3 and well represented at Terra
507 Amata and Lazaret. The use of tangential shaping and a soft percussive tool – mineral
508 or organic – is attested at la Caune de l'Arago in ensemble I. This percussion technique
509 is also documented at Orgnac 3 and Lazaret. It does not appear to have been used in
510 ensemble III at la Caune de l'Arago, Terra Amata, La Terrasse and Coupe Gorge.

511 Most often, bifacial shaping is used to create tools with a functional potential (illustrated
512 by differences in petrography, volume and cutting edge shape) that differs from the
513 operational sequences of other heavy-duty or lightweight tools. This is the case at la
514 Caune de l'Arago, La Terrasse, Orgnac 3, Lazaret and in the Dordogne series. At Terra
515 Amata, on the other hand, heavy-duty tools can be bifacially or unifacially shaped to
516 meet the same objectives. At Coupe Gorge, if we consider the volume and petrographic
517 choices made for biface production, bifaces are more similar to flake tools, but the
518 conformation of cutting edges (sinuous and notched in profile) can only be obtained by
519 bifacial shaping of the volume.

520 In the northern Aquitaine basin, in Dordogne, biface series show considerable
521 variability, both in terms of shaping and flaking (Brenet, 2013; Brenet et al., 2014;
522 Mathias et al., 2020; Ortega et al., 2022; Turq et al., 2010). Shaped pieces are often
523 found in small numbers or as isolated finds in Early Middle Palaeolithic assemblages,
524 or correspond to late occurrences of the Late Acheulean, as at Barbas C'3 base
525 (Boëda, 2001; Boëda et al., 1996). In many series, mixed flaking/shaping phases are
526 very clear, for both bifacial and trifacial tools. Differences are also noted between sites
527 where Senonian flint dominates and those in the Bergerac region (link to available raw
528 materials, modules?).

529 The assemblages from southern France therefore reflect diversified technical and
530 petrographic choices, associated with a variety of functional objectives. They represent
531 a mosaic of technical behaviours that must be considered in relation to environmental
532 and anthropological factors and then compared with data from neighbouring
533 geographical areas.

534 **Discussion**

535 ***Environmental context of the biface industries of southern France and***
536 ***subsistence behaviours***

537 Human occupations took place against a backdrop of global paleoenvironmental
538 upheaval known as the Early-Middle Pleistocene Transition (EMPT, e.g. Head &
539 Gibbard, 2005) or the Mid-Pleistocene Revolution (MPR, e.g. Magri & Palombo, 2013).
540 Governed by changes in orbital parameters, this transition had a profound impact on
541 landscapes and plant communities in the Palearctic zone, marked by increasing aridity
542 and seasonality (e.g. Kahlke et al., 2011; Zan et al., 2024), with repercussions on the
543 dynamics of animal community structuring through processes of extinction and specific
544 differentiation, as well as population dispersal and clustering (e.g. Magri & Palombo,
545 2013; Rodríguez et al., 2016).

546 The following discussion does not claim to cover all the major climatic fluctuations and
547 environmental diversity in southern France during the second half of the Middle
548 Pleistocene, but rather to outline the main trends. In this way, small vertebrate
549 associations provide us with insights into local environmental dynamics in parallel with
550 human occupation (SUP DAT 2).

551 Although most reconstructions refer to cold periods under a continental climate,
552 reconstructions of climatic parameters show that hominins evolved under very
553 diversified climatic conditions. Occupations took place during temperate phases
554 (Orgnac 3 level 7), or particularly cold periods (level E of Arago, Orgnac 3 level 3). For
555 the Lazaret and Coupe-Gorge sites, the local environment played an important role in
556 the reconstructed temperatures. At Lazaret, the proximity of the Mediterranean Sea
557 maintained a mild climate, unlike Coupe-Gorge, where the proximity of the Pyrenees
558 induced a strongly continental climate, with very low minimum temperatures (-8.7°C
559 and -9.9°C). The climate of southern France is influenced by three mountain ranges
560 (the Pyrenees, the Alps and the Massif Central), as well as by the Mediterranean Sea
561 and the Atlantic Ocean. These local influences create varied environmental responses
562 to global climate variations. In southern France, these global changes led to
563 contrasting ecosystems during glacial and interglacial phases. The relatively short
564 interglacial periods were always characterised by forest-type biomes, including
565 relatively sparse Mediterranean tree species. Ungulate associations were
566 characterised by the presence of adapted taxa such as *Palaeoloxodon*,
567 *Stephanorhinus*, *Bos*, *Cervus*, *Dama*, *Haploidoceros* and *Sus*. The significantly longer
568 glacial phases favoured the development of open landscapes and tundra-steppe
569 biomes originating from Asia, rich in grasses and with varying degrees of vegetation
570 depending on hygrometric conditions, relief and latitude. A typical associated fauna
571 then developed as far as the northern Mediterranean coast, including the genera
572 *Mammuthus*, *Equus*, *Bison*, *Rangifer* and *Praeovibos*. In rocky environments, these
573 communities were supplemented by the genera *Hemitragus*, *Ovis*, *Rupicapra* and, at
574 the end of the Middle Pleistocene, *Capra* (e.g. Brugal et al., 2020; Kahlke et al., 2011;
575 Magniez et al., 2013; Magri & Palombo, 2013; Moigne et al., 2006). The MPR can also
576 be observed through major changes in hominin subsistence behaviour, reflected by

577 the adaptable exploitation of varied ecosystems and the development of effective
578 hunting strategies for both large and small fauna during brief occupations (e.g. Terra
579 Amata, la Caune de l'Arago level L) or longer-term and seasonal occupations.
580 Depending on site functions, whole or partial carcasses could be exploited, at times
581 with the selection of prey (e.g. Lebreton et al., 2017; Lumley de, Echassoux, et al.,
582 2004; Lumley de, Grégoire, et al., 2004; Meier et al., 2025; Moncel et al., 2011; Valensi,
583 2000; Valensi et al., 2011, 2013). However, this period is also marked by the
584 transformation and use of hard animal materials (e.g. Daujeard et al., 2018; Moigne et
585 al., 2016) and the domestication of fire from the second half of the Middle Pleistocene
586 onwards (Lumley de, 2006).

587 As a result, Acheulean human groups demonstrate significant adaptive abilities in the
588 face of the complex paleoenvironmental dynamics of the Palearctic ecozone, and
589 these constraints undoubtedly contributed to the successful exploitation of a wide
590 variety of ecological niches. Given the variable climatic contexts of Middle Pleistocene
591 occupations with bifaces, it seems that hominins developed their technical traditions
592 without any discernible climatic influence.

593 ***Anthropological context of biface industries in southern France***

594 The description of abundant human fossils in the 2000s (Arsuaga et al., 2014,; Daura
595 et al., 2017; Lumley, 2022) and the revised dating of certain prehistoric sites (Arnold et
596 al., 2014; Manzi et al., 2010) have led to the definition of a rigorously argued, but still
597 debated European evolutionary framework (Bermúdez de Castro et al., 2016;
598 Bermúdez de Castro et al., 2019; Daura et al., 2017; Hublin, 1998; Rosas et al., 2019;
599 Tattersall, 2011). One of the leading hypotheses, known as the 'accretion of
600 Neanderthal traits', describes a gradual and mosaic-type emergence of Neanderthal
601 traits in Europe during the Middle Pleistocene (Dean et al., 1998; Hublin, 1998 ; 2019).
602 Thus, a Neanderthal lineage would have spread and gradually given rise to 'classical'
603 Neanderthals, of *Homo heidelbergensis* ancestry. Over the past decade, some
604 researchers have proposed the presence of two European human lineages (Arsuaga
605 et al., 2014; Tattersall, 2011), according to which, two different species of closely
606 related human groups coexisted. This hypothesis would not completely negate the
607 accretion hypothesis, which could still be valid for one of the two lineages. The other
608 lineage would consist of individuals with few or no Neanderthal traits (Martín-Francés
609 et al., 2022; Quam et al., 2024; Vialet et al., 2018). The human remains found at the
610 Caune de l'Arago would belong to this latter lineage with more archaic features
611 (Lumley, 2022). Indeed, the hypothesis of a single lineage seems incompatible with
612 the observed diversity (Daura et al., 2017; see also Bermúdez de Castro et al., 2016).
613 This diversity is thought to result from multiple factors, such as environmental changes,
614 population isolation, genetic drift and adaptation, but also hybridisation phenomena
615 (Bermúdez de Castro et al., 2019; Daura et al., 2017; Hublin, 2009). Genetic flows from
616 Southwest Asia (Bermúdez de Castro et al., 2019; Martín-Torres et al., 2007) and
617 Africa (Rightmire, 1998) are put forward to explain the origin of Middle Pleistocene

618 hominins in Europe. Continuous genetic flows could also account for the diversity of
619 human groups, leading to complex population dynamics.

620 Among the sites studied in this article, only la Caune de l'Arago, Montmaurin (Coupe-
621 Gorge), Orgnac 3 and Lazaret have yielded human remains. Remains from the former
622 site show few Neanderthal traits compared to contemporaneous remains from la Sima
623 de los Huesos (Atapuerca, Spain), which display many Neanderthal features, in
624 particular for dental remains (Arsuaga et al., 2014; Bermúdez de Castro et al., 2019;
625 Lumley, 2015, 2022). However, the more recent fossils from Montmaurin and Lazaret
626 do not appear to be as closely related to Neanderthals as might be expected, given
627 their chronological position (Becam et al., 2018; Lumley, 2018; Martínez de Pinillos
628 Gonzalez et al., 2020; Rosas, 2018; Vialet et al., 2018). The chronologically
629 intermediate remains from Orgnac 3 have not yet been published (Lumley, 1981; under
630 study).

631 Thus, recent studies of Middle Pleistocene human remain in southern France bring to
632 light the widespread persistence of primitive traits. Compared to other sites, such as la
633 Sima de los Huesos in Spain (430 ka) or Biache Saint-Vaast in northern France (250
634 ka), the hominins from southern France seem less overtly linked to the Neanderthal
635 lineage and cannot be considered as Neanderthal ancestors. This phenomenon could
636 be due to a lack of genetic mixing as a result of geographical isolation.

637 **Technological context: bifacial shaping in western Europe during the middle** 638 **Pleistocene**

639 The diversity of approaches to bifacial techno-complexes in Europe is not conducive
640 to in-depth bibliographic comparisons (García-Medrano et al., 2023). The results we
641 present concerning the complementarity or supplementarity of bifacial shaping chains
642 with other heavy or lightweight tool shaping chains cannot therefore be put into
643 perspective on a European scale. However, we can propose a targeted
644 contextualisation concerning raw material selection, biface mobility, the use of flakes
645 as blanks and biface associations with other heavy-duty tools. The geographical
646 location of the sites mentioned in the following paragraphs is illustrated in Figure 1.

647 **Raw material choices**

648 We identified four models of raw material use for tool production in southern France.
649 These represent technical choices made by hominins based on their objectives in
650 terms of volume, workability and, potentially, the functional efficiency of tools. The first
651 case, represented in the levels of la Caune de l'Arago, corresponds to the production
652 of heavy-duty tools on hard rocks, lightweight tools on tough rock and bifaces from
653 hard and tough rocks. These techno-economic choices recur, for example, in France
654 at Menez Dregan I (Monnier et al., 2016), in Italy at Castel de Guido, Notarchirico (A,
655 A1, B, D and F) and Torre in Pietra (m) (Anzidei et al., 2001; Nicoud, 2011; Santagata
656 et al., 2020) and in Spain at Galeria (GIIa and GIIb), Trinchera Dolina (10.1) and Santa
657 Ana Cave (García-Medrano et al., 2015; García-Vadillo et al., 2022). These techno-

658 economic choices are therefore mainly found in southern Western Europe, with the
659 exception of the Menez Dregan site in Brittany, and extend discontinuously from MIS
660 16 to 6. They do not therefore appear to be dependent on a particular environment or
661 techno-cultural affiliation. The second category of techno-economic choices
662 corresponds to the use of hard rocks for shaping heavy-duty tools, including bifaces,
663 and tough rocks for lightweight tools. This behaviour is observed at Terra Amata, La
664 Terrasse and Lazaret in southern France, as well as in the Massif Central at the end of
665 the Middle Pleistocene, at the Sainte-Anne 1 site, level J1 (Raynal et al., 2007). The
666 third scenario corresponds to the use of hard rocks for heavy-duty tools and tough
667 rocks for bifaces and lightweight tools. This behaviour has been identified at Orgnac 3
668 and Coupe Gorge and is found at the Aridos 1 site in Spain (Santonja & Villa, 2006).
669 The last scenario corresponds to the exclusive use of tough rocks for the production of
670 heavy-duty or lightweight tools. It should be noted that heavy tools other than bifaces
671 are rare or absent from sites displaying these techno-economic choices. In southern
672 France, the south-western sites presented in the article adhere to this scenario, in
673 addition to Barbas, layer C'3 (Boëda et al., 1996). The vast majority of sites in northern
674 Europe also form part of this category. Examples in England include Boxgrove (Q1A),
675 Barnham (I and IV), Beeches Pit, Elveden, Hoxne (Ashton & Davis, 2021; Davis &
676 Ashton, 2019; Moncel et al., 2015; Pope et al., 2022); and in northern France: Cagny-
677 la-Garennnes (I and II), Cagny-l'Épinette, Mont de l'Évangile (CO and CSI), Saint-
678 Pierre-les-Elbeufs (IV), La Celle, Soucy (1, 3P and 5), Etrécourt-Manancourt,
679 Gouzeaucourt (G), La Grande Vallée, La Noira and Londigny (Cliquet et al., 2009;
680 Connet et al., 2020; Hérison et al., 2016; Lamotte & Tuffreau, 2015; Lhomme, Connet,
681 et al., 2000a,b; Moncel et al., 2015; Moncel, Santagata, et al., 2020; Soriano, 2000).
682 Hominins at Guado San Nicola in Italy, dated to MIS 11/10, also display an exclusive
683 techno-economic preference for tough rocks (Peretto et al., 2016). This technical
684 choice is therefore mainly found in northern Europe and south-western France.
685 However, beyond its geographical distribution, it is observed in regions where flint is
686 abundant, which qualifies any behavioural interpretation. Chronologically, it
687 corresponds to the earliest biface assemblages in Europe: La Noira and Moulin
688 Quignon (MIS 16) and continues until the end of the Middle Pleistocene (MIS 6).

689 ***Spatio-temporal segmentation of bifacial shaping***

690 The anticipation of tool production by hominins is considered to be a marker of
691 cognitive complexity, including memory and abstraction abilities (Suddendorf et al.,
692 2009). When a tool production operational sequence is part of a prolonged cycle, it is
693 classified as a 'curated' tool (Binford, 1979; Shott, 1996; Shott & Seeman, 2015). The
694 arguments put forward for documenting this anticipation are the segmentation of
695 operational sequences in time and space and the identification of re-sharpening or
696 recycling cycles. The sites in southern France with large flake blanks, the importation
697 of finished bifaces to the site, and evidence of re- sharpening or recycling are: La
698 Caune de l'Arago, where the spatial and temporal segmentation of bifacial shaping is
699 well documented in ensemble 1 and ensemble 3 (Viallet, 2023), Orgnac 3, Petit Bost

700 and Lazaret. The spatio-temporal segmentation of bifacial shaping is also observed at
701 the sites of Boxgrove (Q1A), Gouzeaucourt (G), Sainte-Anne 1 (J1), Barbas (C'3),
702 Aridos 1 and Aroiera (Daura et al. 2018; Boëda et al., 1996; Leroyer, 2016; Raynal et
703 al., 2007; Soriano, 2000; Santonja & Villa, 2006), i.e. in northern Europe, on the Atlantic
704 coast and in the Iberian Peninsula. In other cases, technological analysis has identified
705 the importation of bifaces to the site and their re-sharpening/recycling. This is the case
706 at Coupe Gorge in the south of France and has been published in the Saint-Pierre-les-
707 Elboeufs (IV) and Soucy (3P) sites (Leroyer, 2016; Nicoud, 2011). Another case
708 concerns on-site bifacial shaping, associated with the integration of bifaces into re-
709 sharpening/recycling cycles. This has been identified at Pech de l'Azé (II) and Combe
710 Brune 2 in southern France and Soucy 5 and Grande Vallée further north (Hérisson et
711 al. 2016; Lhomme, Bémilli, et al., 2000). It should be noted that this review of sites
712 showing spatial and temporal segmentation of shaping sequences is by no means
713 exhaustive. A comprehensive assessment would require a systematic harmonisation
714 of published data at a European level, as well as better access to academic work.

715 The use of flake blanks for shaping bifaces is one of the distinguishing criteria for
716 defining a Lower Palaeolithic techno-complex: the Large Flake Acheulean; together
717 with the production of cleavers (Gossa & Hovers, 2024; Rubio-Jara et al., 2016;
718 Sharon, 2007, 2010). Flake blanks were used for shaping at some of the assemblages
719 from southern France, but this is always marginal, as is the presence of associated
720 cleavers. The only exception could be La Terrasse, but we do not have sufficient
721 technical evidence to demonstrate that the production of large flakes structures LCT
722 production. In the rest of Europe, a few sites are structured around the production of
723 large flakes, notably Porto Maior on the Iberian Peninsula (Méndez- Quintas et al.,
724 2018). Various other archaeological occurrences in the river networks of south-western
725 Europe display similar tendencies, but their stratigraphic contexts are problematic
726 (Méndez-Quintas et al., 2020; Mourre & Colonge, 2007; Santonja & Perez- Gonzalez,
727 2010).

728 **Conclusion: a mosaic of technical expressions**

729 The archaeological data from the southern half of France presented above point to a
730 wide variety of scales of analysis, in spite of the relatively well-defined chronological
731 contexts in which they were found. This observation applies not just to the geographical
732 area under consideration but to the majority of the available data on biface industries
733 in Europe (Nicoud, 2011, 2013). Due to the chronological margins of error associated
734 with lithic assemblages, many of which come from palimpsest-type accumulations that
735 cannot be systematically documented, as well as the variability of site functions,
736 caution is called for in determining the relationships between technical systems.

737 In the geographical area of southern France, environmental and anthropological data
738 tend to support the idea that Acheulean techno-complexes developed independently,
739 at least at the scale of analysis accessible here. It is clear that sites with bifaces are
740 found in a variety of environmental contexts: cold continental or mild Mediterranean.

741 They also occur in different petrographic contexts, and hominins made varied technical
742 choices for biface production, but also for the rest of the toolkit, which is rather specific
743 to each of the presented sites.

744 In fact, apart from the presence of bifaces, it is very difficult to discern any technical
745 consistency for the 'Acheulean' in southern France. Of course, the diachronic nature
746 of our comparisons may account for the observed diversity, but this is not necessarily
747 the only explanation. The lithic biface assemblages from northern Europe show much
748 greater homogeneity, even diachronically, making it possible to envisage a single
749 techno-cultural tradition (García-Medrano et al., 2023). At la Caune de l'Arago,
750 production techniques and petrographic choices appear to be relatively constant
751 between ensembles I and III, and most of the observed variability can be explained by
752 different functional objectives, perhaps linked to the function of the site (Viallet et al.,
753 2024). Conversely, for the bifacial productions of La Terrasse and Coupe Gorge in
754 Montmaurin, it is the petrographic choices, shaping methods and functional objectives
755 that vary. The same observation applies to the sites of Terra Amata and Lazaret
756 (Cauche, 2012). Therefore, based on these examples, it does not seem relevant to
757 make reference to a similar technical tradition. The different levels at Orgnac 3 reflect
758 consistent technical choices over time, but these are very different from other
759 observations from south-eastern France: the near-exclusive use of flint, soft
760 percussion, tranchet blow, and no blunt active zone.

761 The bifacial operational sequences from Orgnac 3 are reminiscent of the technical
762 traditions of northern Europe. However, they differ by the presence of other heavy-duty
763 tools, such as choppers and picks, made from hard rock. These tools are rare or absent
764 from the northern techno-complexes, where they are made from tough rock, like the
765 rest of the production. The near-exclusive use of flint characteristic of the assemblages
766 in northern Europe, and in the southwest, is not found in any Middle Pleistocene biface
767 sites in south-eastern France. However, the lithic assemblages contain a very limited
768 number of bifaces, and due to the importance of other production operational
769 sequences (notably Levallois), they are classified among Early Middle Palaeolithic
770 techno-cultural traditions, such as the upper levels of Orgnac 3 (Mathias et al., 2020),
771 with the exception of the special case of Barbas C'3, which is linked to the Late
772 Acheulean (Boëda, 2001; Boëda et al., 1996). On the margins of the geographical area
773 studied here, the Iberian and Italian peninsulas also display varied technological
774 characteristics and the same chronostratigraphic resolution issues. The LFA on the
775 Iberian Peninsula has no real counterpart in France during the Middle Pleistocene,
776 apart perhaps from La Terrasse. However, the production of large flakes does not
777 structure the entire heavy-duty tool operational sequence, and bifaces are rare. Other
778 open-air sites could correspond to the LFA definition, but they are either in a secondary
779 stratigraphic position or dated to the Upper Pleistocene (Mourre & Colonge, 2007;
780 Viallet et al., 2024).

781 These findings lead us towards a 'special case' archaeology, which should however
782 only be very cautiously interpreted as such. They are probably more a reflection of a

783 fragmentary record than of any prehistoric reality. Consequently, and given the current
784 state of our knowledge, it is perhaps more fitting to avoid seeking cultural links between
785 archaeological sites with significant spatial and temporal differences. The techno-
786 cultural mosaic of the Acheulean in southern France may well reflect technical
787 evolution, human mobility or even evolutionary convergence, but it must first and
788 foremost be construed as the result of archaeological gaps. As such, it is only fitting to
789 call for caution in interpretation and stress the need for further research. An analogy
790 can be drawn with the morphological diversity of human remains from sites in southern
791 France for this period, between isotopic stages 14 and 6. At each site, they display a
792 unique combination of features against a general background of primitive traits. This
793 can be interpreted as reflecting relatively isolated populations, due to the fragmentation
794 of the territory and the low density of groups, which reduces the possibility of genetic
795 mixing. However, the paucity of the fossil record must also be taken into consideration.

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817 **Data availability statement**

818 The authors confirm that the data supporting the findings of this study are available
819 within the article [and/or] its supplementary materials. For data not included in the
820 article or the supplementary data, please contact the first author.

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Site	Stratigraphical Unit	Chronology	Type of site	Faunal remains	Human remains	Handaxes quantity	Bibliography
Caune de l'Arago	P and Q	MIS 14 (or 12)	Cave	Yes	Yes	32	Falguères et al., 2015; Lebreton & López-García, 2023
Caune de l'Arago	E, F and G	MIS 12	Cave	Yes	Yes	16	Falguères et al., 2015
Terra Amata	C1a and b	MIS 11	Open air	Yes	Yes	13	Michel et al., 2022
La Terrasse	1 et 2	MIS 11 or 9	Cave	Yes	No	10	Vialet et al. 2021; 2022
La Micoque	L2/3	MIS 10	Open air	Yes	No	1	Texier, 2006b; Falguères et al. 1997
Orgnac 3	5 to 2	MIS 8 (or 10)	Cave	Yes	Yes	70	Bahain et al., 2022; Lewis et al., 2022
Petit Bost	2	MIS 9 or 8	Open air	No	No	13	Bourguignon et al., 2006
Coupe Gorge	3	MIS 7	Cave	Yes	No	18	Vialet et al. 2021; 2022
Pech-de-l'Azé II	7	MIS 6	Cave	Yes	No	2	Grün et al., 1991; Jacobs et al., 2016
Combe Brune 2	VIIa	MIS 7/6	Open air	No	No	6	Frouin et al., 2014
Le Lazaret	26	MIS 6	Cave	Yes	Yes	34	Michel et al., 2018 and 2022

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Tableau 1 - Summary of the various analysed sites, with general information on their geoarchaeological and chronological contexts.

Site	Stratigraphic unit	Chronology	Characteristics of bifaces										Other shaping tool			Cleave			Light tool			Flake production		
			Use of hard rock	Use of hard rock	Use of tough rock	Imported to the site	Shaped on site	Large flake as support	Re-sharpening		Other shaping tool		Cleave		Light tool		Flake production							
									Use of sandstone, limestone, Hornfels	Use of quartzite, sandstone, Hornfels	Use of flint, quartz	X	Flint, quartz	X	Few cases	X	Hard	Present	Raw material	Yes	Tough and hard	Unipolar	Core reduction	Raw material
Goupe de l'Arago	P and Q	MIS 14 (or 12)	Quartzite, sandstone, Hornfels	Quartzite, Hornfels	Flint, quartz	X	X	Few cases	X	X	No	No	-	Yes	Tough and hard	Unipolar	Tough and hard	Unipolar; S.S.D.A.; Discoidal	Tough and Hard					
Goupe de l'Arago	E, F and G	MIS 12	Quartzite, sandstone, Hornfels	Quartzite, Hornfels	Flint, quartz	X	X	Few cases	X	X	No	No	-	Yes	Tough and hard	Unipolar	Tough and hard	Unipolar; S.S.D.A.; Discoidal	Tough and Hard					
Terra Amata	C1a and b	MIS 11	Limestone	Limestone	No	-	X	One case	No	X	Yes	Yes	Limestone	Yes	Tough and hard	Unipolar	Tough and hard	Unipolar; Discoidal sensu lato	Hard					
La Terrasse	1 et 2	MIS 11 or 9	Quartzite	Quartzite	No	-	X	No	No	X	Yes	Yes	Quartzite	Yes	Tough	Discoidal	Tough	Discoidal; S.S.D.A.	Hard and tough					
La Micoque	L2/3	MIS 10	No	No	Flint	-	-	No	No	-	No	No	-	Yes	Tough	Unipolar (backed flakes)	Tough	Unipolar	Tough					
Cognac 3	5 to 2	MIS 8 (or 10)	Few case	Few case	Flint	X	X	Few cases	X	X	No	No	-	Yes	Tough	Unipolar, Levallois	Tough	Unipolar, Levallois	Tough					
Petit Bost	2	MIS 9 or 8	No	No	Flint	X	X	Few cases	X	X	No	No	-	Yes	Tough	Levallois	Tough	Levallois; Cores-on-flakes	Tough					
Goupe George	3	MIS 7	Few case	Few case	Lydian, flint	X	-	No	X	X	No	No	-	Yes	Tough and hard	S.S.D.A.; Discoid lato	Tough and Hard	S.S.D.A.; Discoid lato sensu lato	Tough and Hard					
Pech-de-l'Azé II	7	MIS 6	No	No	Flint	-	-	One case	X	X	No	No	-	Yes	Tough	Levallois	Tough	Levallois; Discoid sensu lato, cores-on-flakes	Tough					
Combe Brun 2	VIIa	MIS 7/6	No	No	Flint	-	X	Few cases	X	X	No	No	-	Yes	Tough	Levallois	Tough	Levallois; Cores-on-flakes	Tough					
Le Lazaret	26	MIS 6	Limestone	Limestone	No	X	X	X	X	X	No	No	-	Yes	Tough	Unipolar, Discoidal, S.S.D.A., Levallois	Tough and Hard	Unipolar, Discoidal, S.S.D.A., Levallois	Tough and Hard					

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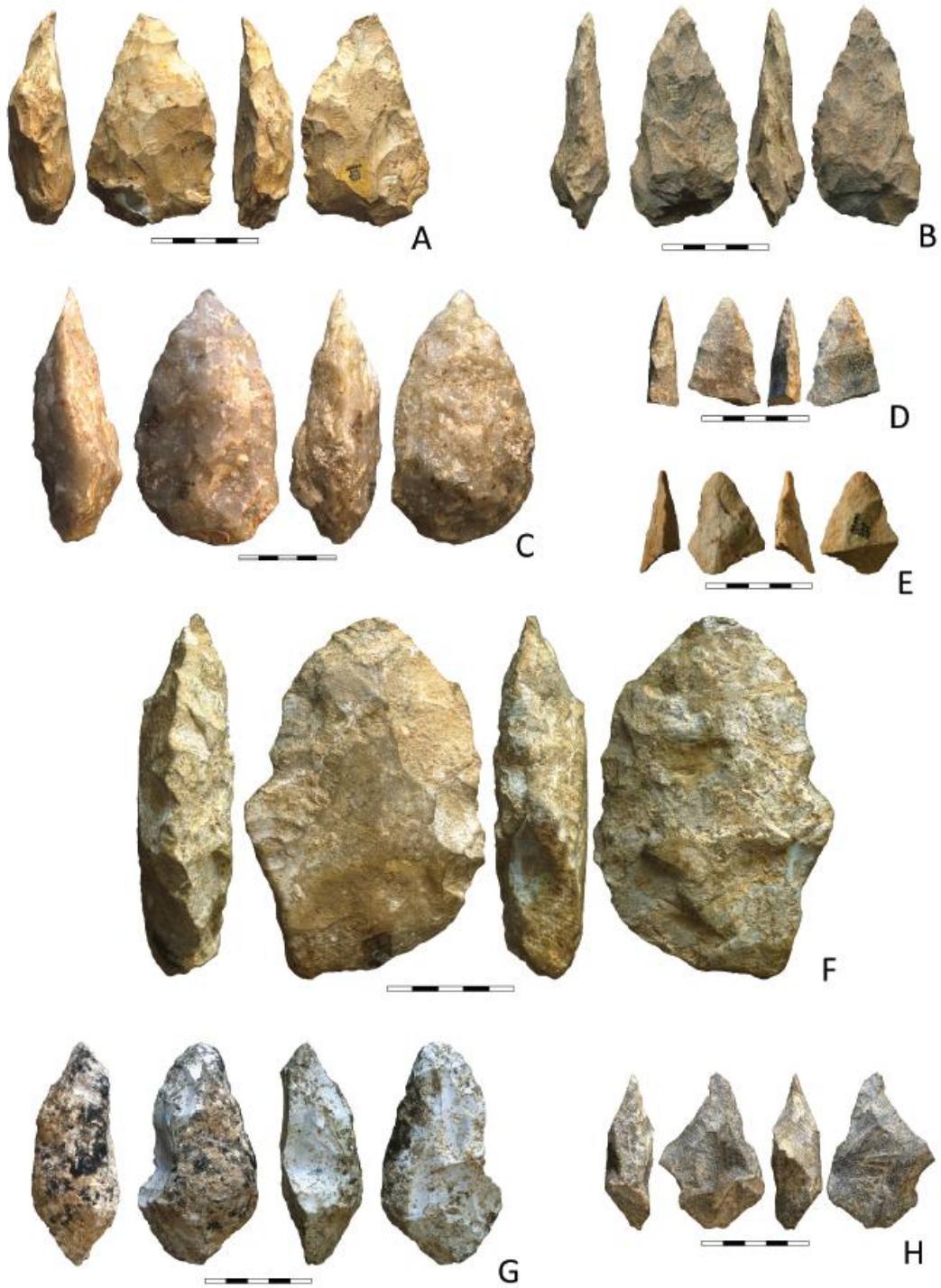
Tableau 2 - Main descriptive elements of the lithic toolkits according to the sites and petrographic choices.



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Figure 1 - Main lithic assemblages with bifaces attributed to the Middle Pleistocene in Western Europe. Black dots, studied sites and sites used for comparison; white dots, other sites with bifaces. 1: Beeches Pit, 2: Elveden, 3: Hoxne, 4: Swanscombe, 5: Barnham I, IV, 6: Boxgrove, 7: Kent's Cavern, 8: Moulin Quignon, 9: Étricourt-Manancourt, 10: Gouzeaucourt, 11: Mont-de-l'Évangile, 12: Cagny-la-Garenne I & II, Cagny-l'Épinette, 13: Revelles, 14: Saint-Pierre-lès-Elbeufs, 15: La Celle, 16: Soucy 1, 3P & 5, 17: Menez-Dregan I, 18: La Noira, 19: La Grande Vallée, 20: Londigny, 21: Petit-Bost, 22: Combe Brune 2 & 3, 23: Barbas I, 24: La Micoque, 25: Pech-de-l'Azé II, 26: Sainte-Anne 1, 27: Ornac 3, 28: Aldène, 29: Caune de l'Arago, 30: La Terrasse & Coupe-Gorge, 31: Baume-Bonne, 32: Terra Amata, 33: Le Lazaret, 34: L'Observatoire, 35: Torre in Pietra m, 36: Castel di Guido, 37: Fontana Ranuccio, 38: Valle Giumentina, 39: Guado san Nicola, 40: Notarchirico, 41: Grotta Paglicci, 42: Galeria & Trinchera Dolina, 43: Porto Maior, 44: Ambrona, 45: Aridos I, 46: Santa Ana, 47: Gruta da Aroeira, 48: Cueva de Bolomor, 49: Cueva del Ángel (map made using QGIS 3.40, basemap data ESRI Satellite, WGS 84 C. Mathias).



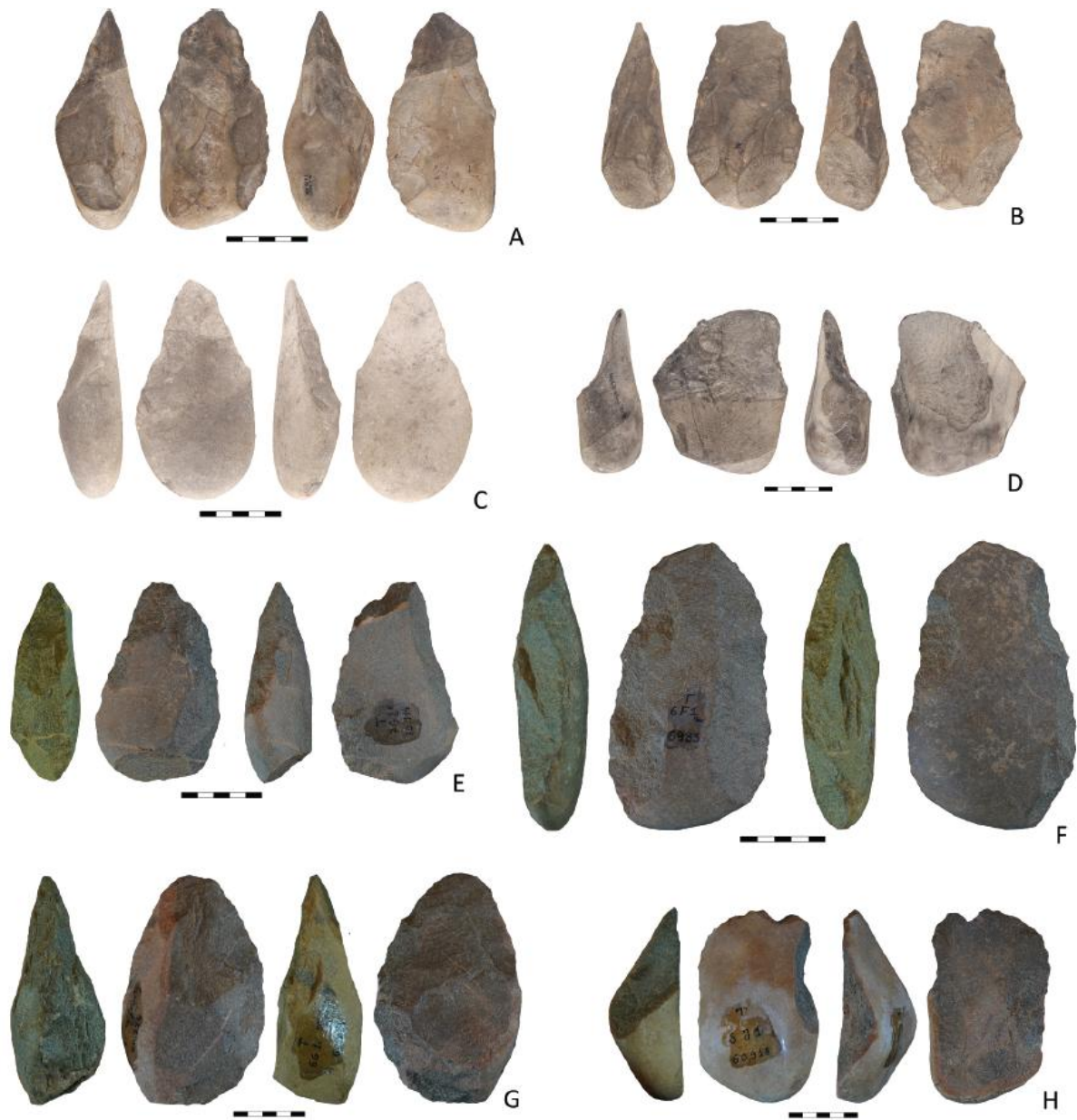
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Figure 2 - Photographic representation of various bifaces from ensembles I (A to E) and III (F to H) of the Caune de l'Arago. D and F correspond to accidentally fractured biface points, while H is a waste piece from the tranchet blow (photographs D. Dainat, CERP Tautavel).

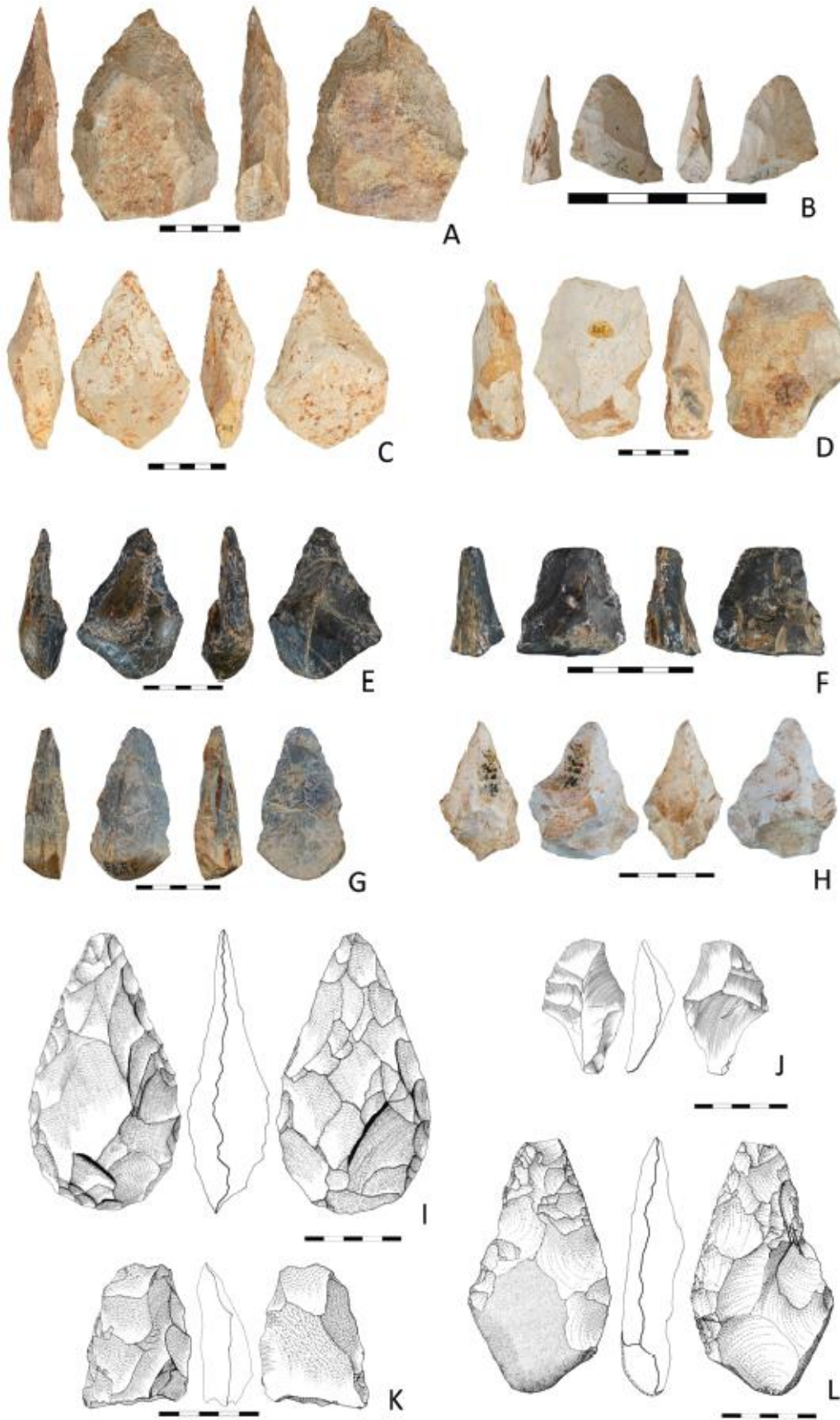


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Figure 3 - Photographic representation of various bifaces from Terra Amata (A and B) and La Terrasse (E to G). Photographs C correspond to a pick and those of D and H to cleavers (C. Viallet).



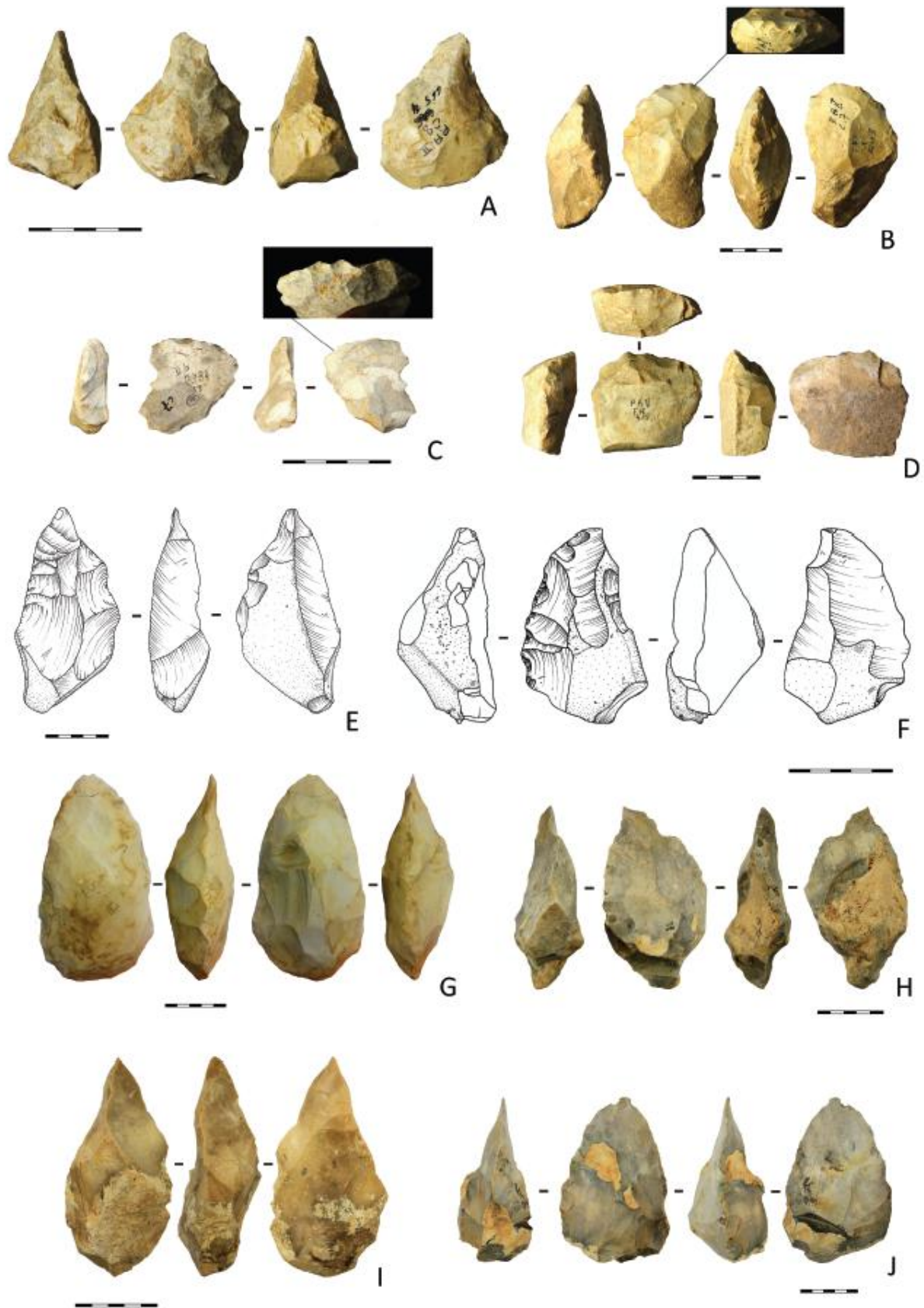
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Figure 4 - Photographic representation of various bifaces from Orgnac 3 (A to D) and Coupe-Gorge (E to H). Scientific drawing of the bifaces from UA 26 at Lazaret (I to J, D. Cauche). The points of bifaces B and F correspond to accidental fractures, while J and K are the result of a tranchet blow.



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Figure 5 - Photographic representation of bifaces, bifacially shaped tools (e.g. chopping-tools) and trifaces from lithic assemblages in Dordogne, Southwest France. A is a biface from Pech-de-l'azé II, as well as two bifacial shaped tools (B,D) and a waste piece from the tranchet blow (C). E is a triface and G a biface from Combe Brune 2 made of Bergeracois flint. F is a bifacial piece of La Micoque. H and J are bifaces and I a triface from Petit-Bost (photographs and drawings C. Mathias).