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FROM FLAKES TO GROOVES: A TECHNICAL SHIFT IN ANTLERWORKING DURING THE LAST GLACIAL MAXIMUM IN SOUTHWEST FRANCE

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Abstract

The evolution of antlerworking technology in Paleolithic and Mesolithic Europe – especially the production of splinters – is usually described as a cumulative process: a progressive increase in blank standardization and productivity was prompted by the application of a key technical process, the groove and splinter technique (GST). The Badegoulian, however, appears as an interruption in this continuum: according to the original definition of this post-Solutrean, pre-Magdalenian archeological culture, one of its distinctive features is the absence of the GST and the manufacture of antler blanks by knapping only. However, this conception has been recently questioned, leading to an alternative hypothesis suggesting that both GST and knapping were used during the Badegoulian. In this article we present a renewed set of evidence from several sites in southwest France, which shed a new light on the issue of Badegoulian antlerworking and the transition with the subsequent Lower Magdalenian. Our study is based on two complementary methods: the technological analysis of antler assemblages well-dated to the Badegoulian (Le Cuzoul de Vers) or to the Lower Magdalenian (La Grotte des Scilles, Saint-Germain-la-Rivière); and the direct ¹⁴C-dating of specific antler artifacts from mixed or problematic contexts (Cap-Blanc, Reverdit and Lassac). The results firmly establish that, in southwest France, knapping is the only method used for the production of antler splinters during the Badegoulian, before ca. 20500 cal BP; and that it is rapidly replaced by the GST at the beginning of the Lower Magdalenian, after ca. 20500 cal BP. This technical shift is not linked to an influx of new human populations, to environmental change or to the supposed economic advantages of the GST. Instead, it must be understood as one of the expressions of a broader reconfiguration of the technical world that starts to take shape in the middle of the Last Glacial Maximum.

Keywords

Badegoulian; Lower Magdalenian; reindeer antler; osseous technology; antler knapping; groove and splinter technique

Antlerworking appears in Europe as early as the beginning of the Upper Paleolithic (Knecht, 1993; Liolios, 2003; Tejero, 2010) and, in the southwest of the continent – i.e., France, Spain and Portugal – it remains an integral part of the technical system until the end of the Mesolithic and beyond. Thus, contrary to northern Europe, which was depopulated during the Last Glacial Maximum (LGM), or to southeast Europe, which saw only a marginal use of antler material during a large part of the Upper Paleolithic, southwest Europe offers an uninterrupted record of antler technology used by hunter-gatherers for some 30 millennia. This makes it undoubtedly the longest and best documented technological sequence for this

material in the world, and an exemplary case to study long-term technical evolutions in hunter-gatherer societies.

Reconstructions of long-term trends in antler technology among European Paleolithic-Mesolithic groups emphasize the key role of the groove and splinter technique (GST). This technique – or rather, this combination of technical actions – involves scoring two parallel, longitudinal grooves through the outer tissue of the antler, and then prying off the intervening portion (Clark, 1953; Clark and Thompson, 1953; Rigaud, 1972, 1984; Semenov, 1973; Averbouh, 2000; Goutas, 2009; etc). The pieces extracted in this manner are elongated strips of compact antler that can then be used as blanks for the shaping of objects such as projectile points and wedges (although several names have been given to these blanks – including the French *baguette* –, in this article these blanks will be called “splinters” in order to be consistent with the previous English-language literature). In Europe, the GST is formally attested from the Early Gravettian (ca. 28 kyr BP) onwards (Goutas, 2004). Compared to the earlier Aurignacian technology, where antler splinters were produced by splitting and cleavage (Knecht, 1993; Liolios, 2003, 2006; Tejero, 2010), the GST allows for a better predetermination and standardization of the dimensions of the blanks (Goutas, 2009; Tejero et al., 2012). And indeed, once introduced, the GST quickly becomes the exclusive technique for the manufacture of the dominant object in the antler kit, and much-needed piece of hunting equipment: the projectile points. Later archeological cultures such as the Middle and Upper Magdalenian (ca. 18-14 kyr cal BP) or the Early Mesolithic (ca. 11-10.5 kyr cal BP) will improve the use of the GST to its full productivity potential by extracting multiple parallel blanks from the same segment of antler (Clark and Thompson, 1953; Averbouh, 2000; Elliott and Milner, 2010). Thus the technological history of the production of antler splinters in Paleolithic-Mesolithic Europe appears, in broad outline, as a cumulative process: a progressive increase in blank standardization and productivity was made possible by the application of the GST.

The Badegoulian archeological culture, however, appears as an interruption in this continuum. Formally defined in the years 1960-1980 by J. Allain (1989) after the pioneering work of A. Cheynier (1930, 1939), R. Delarue, E. Vignard and G. Vacher (Delarue and Vignard, 1958, 1960, 1963; Vignard and Vacher, 1965), the Badegoulian was identified mainly in France (Fig. 1), although similar assemblages might exist in Spain (Aura Tortosa, 2007) and in central Europe (Street and Terberger, 1999). It spans the gap between the end of the Solutrean ca. 23.5 kyr cal BP and the beginning of the Magdalenian ca. 20.5 kyr cal BP, thus taking place during the first half of the LGM (GS-2c: Ducasse, 2010:391; Banks et al., 2011) according to the definition of this climatic event by Lowe et al. (2008) or MARGO Project Members (2009).

According to its original definition, one of the distinctive features of the Badegoulian is the absence of the GST. Indeed, the results of Allain’s excavations in Fritsch shelter showed that, in the Badegoulian levels, antler blanks were manufactured only by knapping (i.e., direct diffuse percussion: Allain et al., 1974). This technique was used to produce the same type of blanks that were made by GST in the earlier Gravettian and in the following Magdalenian: antler splinters mainly intended to be shaped by scraping into projectile points (Rigaud, 2004). In this perspective, the Badegoulian would represent a very peculiar event in the evolution of Paleolithic techniques: the disappearance of a key technical element – the GST – prior to its reintroduction several millennia later. Thus the Badegoulian technology would undermine a strictly cumulative scenario for the evolution of antlerworking.

However, this conception of the Badegoulian antlerworking has been questioned in recent years (Averbouh, 2006a). While some scholars maintained Allain's original views (Rigaud, 2004, 2007:279-280), others emphasized the discovery of antler artifacts with traces of GST in Badegoulian levels (Séronie-Vivien, 1995:254; Sacchi, 2003a). This led to an alternative hypothesis suggesting that both methods, GST and knapping, were used in parallel for the production of antler blanks during the Badegoulian (Castel and Chauvière, 2007); according to this hypothesis, the GST would have persisted in the early LGM.

In this article we present a renewed set of evidence from several sites in southwest France, which shed a new light on the issue of Badegoulian antlerworking and the transition with the Lower Magdalenian. Our study is based on two complementary methods: the technological analysis of well-dated antler assemblages, and the direct ¹⁴C-dating of specific antler artifacts from mixed or problematic contexts.

Historiography and analytical framework

From its very first identification, the archeological culture that would later be called the Badegoulian had been clearly separated from the preceding Solutrean (Capitan and Breuil, 1902). However, whereas its lithic industry was described by Breuil in depreciative terms (Breuil, 1937[1913]), the quality of its osseous equipment seemed to justify its characterization as the “very ancient step” of the subsequent Magdalenian culture (Peyrony, 1912:525; Breuil, 1937[1913]). In the following years, while the differences with the Solutrean were rarely questioned, the relationship with the “classical” Magdalenian was challenged by other scholars based on several new discoveries and analyses (e.g., Cheynier, 1939; Vignard and Vacher, 1965). A controversy took place between the supporters of cultural continuity, who considered these assemblages as “ancient Magdalenian” (Bordes, 1958), and those advocating the existence of a specific archeological culture called “Badegoulian” (after the Badegoule rockshelter excavated by Peyrony, then by Cheynier). After years of debate, J. Allain's arguments stemming from his comparison between the assemblages of the Fritsch shelter and the Middle Magdalenian of La Garenne (Allain, 1961; Allain and Fritsch, 1967) were finally given a broader value and were accepted by most: the absence of backed bladelets at Fritsch and the obvious difference in antlerworking between the two sites (see above) seemed consistent with a real cultural shift (Allain, 1989).

At the dawn of the 1990s, a two-step partition of the Badegoulian was generally accepted (e.g., Bordes, 1958; Allain and Fritsch, 1967): an Early Badegoulian mainly characterized by transverse burins is followed by a Recent Badegoulian marked by the appearance of *raclettes* (small “scrapers” made by abrupt retouch on thin flakes: Cheynier, 1930). Some scholars, however, also suggested the possible existence of a third step, the Final Badegoulian, showing typological and technological links with the Magdalenian (re-appearance and increase of backed bladelets, use of the GST: Séronie-Vivien et al., 1981; Séronie-Vivien, 1995). Today this two- (or three-) step model is being questioned by several studies, notably through the reappraisal of the chronological, technological and economical status of *raclettes*, transverse burins and backed bladelets (Bodu et al., 2007; Chehmana et al., 2007; Ducasse and Langlais, 2007; Ducasse, 2010). At the same time, recent studies led to the definition of a previously unrecognized phase of the Magdalenian in France: earlier than the Middle Magdalenian, younger than the Badegoulian but deprived of *raclettes*, the Lower Magdalenian (Langlais, 2010) can be related to the *Magdalenien inferior* known in northern Spain (Utrilla Miranda, 1981; Cazals, 2000). Its flint industry shows several elements of technological continuity with

the Badegoulian, notably the implementation of flake production on local raw materials and certain bladelet and micro-bladelet productions involving specific reduction sequences on flake cores (Ducasse and Langlais, 2007; Ducasse, 2010; Langlais, 2010).

These studies allow to reconsider the Badegoulian-to-Magdalenian transition on a new basis. Indeed, according to this updated cultural chronology, both the Badegoulian and the Lower Magdalenian take place during the LGM (GS-2c to GS-2b, i.e., from 23.5 to 18 kyr cal. BP), under cold and humid conditions that remain mostly constant until the cold and dry Heinrich event 1 (e.g.: Elenga et al., 2000; Kageyama et al., 2005; Beaudouin et al., 2007). During this period, landscapes and faunas experience no significant changes in southwest France (e.g.: Costamagno, 1998; Castel, 1999; Delpech, 1999). At that time, southwest Europe was quite isolated, most of northern Europe being rendered uninhabitable by the extension of the ice sheets and a different cultural development – the Early Epigravettian – occurring in the southeast of the continent. Furthermore, between the Badegoulian and the Lower Magdalenian, no settlement hiatus exists (as evidenced by the stratigraphic sequences and the radiocarbon data), and no evidence of demographic growth – such as an increase in the density of sites – that could hint at the arrival of new human groups could be identified. These arguments, added to the similarities in lithic technology, all speak against the idea of a population replacement and suggest a local cultural evolution. This study addresses the question of the Badegoulian and Lower Magdalenian antlerworking by inserting it both in its long historiographical heritage and in this renewed cultural framework resulting from recent works in lithic technology.

Technological analysis of well-dated antler assemblages

Archeological context

The controversy surrounding Badegoulian antlerworking has been based on a small body of published evidence: the assemblage of knapped antler from the Fritsch shelter (Allain et al., 1974; Allain, 1983:136-137; Rigaud, 2004) and a few artifacts with traces of GST recovered in a Badegoulian context at two sites, Lassac and Pégourié (Séronie-Vivien, 1995:254; Sacchi, 2003a). In order to better document antlerworking techniques in the Badegoulian, and to clarify its distinction with the Lower Magdalenian, we selected a number of sites which (1) yielded evidence of antler industry, and (2) had been the subject of recent, multi-disciplinary analyses allowing to assure their attribution to either the Badegoulian or the Lower Magdalenian.

For the Badegoulian, the main focus of our work was the assemblage of Le Cuzoul de Vers (Lot, France: Fig. 1). This small rockshelter – about 30 m² – was excavated from 1982 to 1986 by J. Clottes and J.-P. Giraud (1985, 1989a, 1989b). The stratigraphy is between 2.5 and 3 meters thick, and 31 levels were identified during the excavation. Levels 31 to 29 are attributed to the Upper Solutrean and the attribution of level 28 is considered uncertain (Ducasse and Renard, in press), but the overlying levels 27 to 1 all yielded exclusively Badegoulian material. The Badegoulian sequence was divided into Early Badegoulian (levels 27 to 22) and Recent Badegoulian (levels 21 to 1) on the basis of lithic analysis – especially the presence of *raclettes* in the upper levels only. A first series of six non-AMS ¹⁴C dates on bone placed the Early Badegoulian ca. 22.5-21 kyr cal BP and the Recent Badegoulian ca. 21-17 kyr cal BP, but these results were contradicted by a second series of 11 ¹⁴C dates on bone by AMS, the majority of which placed the same phases respectively ca. 24.5-22.5 and 23.5-

21.5 kyr cal BP. Additionally, for the purpose of this article, two pieces of knapped antler from Recent Badegoulian levels were subject to direct ^{14}C dating by AMS (one antler flake from level 15, and one antler base with negatives of flake removals from level 6). This complementary analysis was undertaken in order to enlarge the database of direct ^{14}C dates on knapped antler (see below), and gave dates of 18660 ± 100 BP (22530-21990 cal BP, OxA-24963, layer 6) and 19180 ± 110 BP (23350-22450 cal BP, OxA-24964, layer 15; all ^{14}C dates in this article were calibrated with the OxCal 4.1. program [Bronk Ramsey, 2009] using the IntCal09 atmospheric data [Reimer et al., 2009]). The AMS dates rely on a more controlled sampling strategy and are in good agreement with recent data from other sites (Primault et al., 2007; Chauvière et al., 2008); they will thus be retained in this article.

A comprehensive study of the Badegoulian levels was carried out within a monograph project (Clottes et al., in press), including, among others, zooarcheology (Castel, 1999, 2003) and lithic technology (Lelouvier, 1996; Ducasse, 2010). Zooarchaeological data indicates that the Badegoulian groups occupied the shelter in late summer and/or early fall and targeted mostly reindeer, whose carcasses were brought back complete and processed on the site (Castel, 1999, 2003).

For the Lower Magdalenian, two assemblages were considered: La Grotte des Scilles (Haute-Garonne, France: Fig. 1), layer B, and Saint-Germain-La-Rivière (Gironde, France: Fig. 1), layers C3-C4.

La Grotte des Scilles is a shallow cave – actually more of a rockshelter – in the gorge of the river Save near Lespugue; it was excavated by R. de Saint-Périer in 1923-1924 (Saint-Périer, 1926). Saint-Périer identified two archeological layers; the upper layer, A, yielded only a few artifacts, and most of the archeological material is concentrated in layer B, which was 35-40 cm thick and was excavated over approximately 20 to 30 m². On the basis of Saint-Périer's publication, layer B has been attributed to the beginning of the Middle Magdalenian ("Magdalénien III": Simonnet, 1973:43, 1976:118) then to the classic Middle Magdalenian of the French Pyrenees (Clottes, 1989:284); but a recent, exhaustive study of the material concluded that it was of Lower Magdalenian age, and thus represented one of the rare occurrences of human occupation in the Pyrenean region during this period (Pétillon et al., 2008; Langlais et al., 2010). The only existing ^{14}C date is coherent with this attribution (TO-13555, AMS date on antler artifact: 16180 ± 140 BP or 19570-18890 cal BP). Study of the faunal remains indicates a varied range of game species, with reindeer as the most abundant, followed by bovines and chamois; however, the season of occupation of the site and the detail of the butchering practices remain undetermined due to the selective recovery of the faunal remains during the excavation (Letourneux and David in Langlais et al., 2010).

The Saint-Germain-La-Rivière rockshelter was discovered and excavated by H. Mirande and R. Lépront in 1929. R. Blanchard resumed excavations in the shelter terrace in 1933-1935 and discovered a rich archeological sequence, rock sculptures and a female burial, all dated to the Middle Magdalenian (Blanchard et al., 1972; Bouvier and Trécolle, 1984; Gambier et al., 2000; Henry-Gambier et al., 2002; Vanhaeren and d'Errico, 2005). In 1963-1968, G. Trécolle excavated a 8 m² trench on the slope below the Blanchard excavations and found a different, 2-meters-deep stratigraphy: three layers dated to the Middle Magdalenian (C, C1, C2) overlaying two older layers (C3, C4) attributed to the Lower Magdalenian (Lenoir et al., 1991, 1994; Costamagno, 1999, 2001; Langlais, 2010). Layer C4 yielded two ^{14}C dates: Gif-5479, non-AMS date on bone, 16200 ± 600 BP or 20570-18420 cal BP; and OxA-7260/Lyon-617, AMS date on bone, 16890 ± 130 BP or 20370-19580 cal BP. Hunting during the Lower

Magdalenian in Saint-Germain-La-Rivière was primarily centered on saiga antelope – followed by reindeer, horse and bovines – whose carcasses were brought back complete and intensively processed at the site (Costamagno, 1999, 2001).

Material and methods

The antler industries from Le Cuzoul de Vers layers 1-27, La Grotte des Scilles layer B and Saint-Germain-La-Rivière layers C3-C4 were studied in order to identify the antler reduction sequences and, specifically, the techniques used to manufacture splinter-like blanks. This work was carried out by J.-M. P. – in collaboration with A. Averbouh for Le Cuzoul de Vers (Averbouh and Pétilion, 2011; Pétilion and Averbouh, in press). The analysis was not done on samples but on the complete assemblages: all manufacturing waste, blanks, finished and unfinished objects were observed, measured, recorded on a database and studied.

In Le Cuzoul de Vers, no differences in antlerworking techniques were observed between the different layers, and the whole antler industry from layers 1 to 27 will be considered here as a single assemblage for the purpose of the technological analysis. Similarly, no difference in antler technology was found between the material from layers C3 and C4 in Saint-Germain-la-Rivière. Thus the antler artifacts from layers C3, C4 and the interface between the two (labeled “C3/C4” by G. Trécolle) will be grouped together in this study.

In Le Cuzoul de Vers, systematic sieving with a 1.2 mm mesh allowed to recover the smaller antler fragments (Clottes and Giraud, in press). Sieving was apparently also in general use during the Trécolle excavations in Saint-Germain-la-Rivière, although the mesh size is not specified (Costamagno, 1999:134). In La Grotte des Scilles, the sediment was not sieved, resulting in an underrepresentation of the smaller elements (e.g., in the lithic industry, the population of bladelets and micro-bladelets is skewed towards specimens longer than 20 mm: Langlais et al., 2010:13-14).

The technological analysis was often hampered by the state of preservation of the artifacts. In all three sites, the antler collection was subject to intensive post-depositional breakage and most of the artifacts are fragmentary (although refittings of post-depositional breaks were systematically searched). Additionally, in La Grotte des Scilles and Le Cuzoul de Vers, the surface of most artifacts is altered to a more or less pronounced degree, sometimes up to the point of obliterating the technical traces. The spongy tissue is especially degraded. This situation is obviously due to deposit conditions (shallow rockshelters, exposed slopes) that, contrary to cave sites, did not provide an optimal protection against weathering agents.

Results of the Badegoulian assemblage

The antler assemblage In Le Cuzoul de Vers, layers 27 to 1 yielded altogether 1119 antler elements (Table 1). 367 of them are unworked fragments showing only breaks on “dry” antler (i.e., their fracture surfaces appear irregular, rough, but not fibrous, and form a wide angle with the outer surface of the antler, often close to 90°: Averbouh and Pétilion, 2011; Pétilion and Averbouh, in press). Since these fragments show no sign of use as raw material, they were considered as being exclusively the result of post-depositional breakage, and were excluded from the technological study.

Of the 752 remaining elements, 110 show traces of shaping by scraping and were classified as partially worked blanks, rough-outs, shaping debris or finished objects (see below).

This second selection left 642 antler fragments whose technological status was not immediately obvious (Fig. 2). All of them show at least one fracture on “green” antler (i.e., a fracture plane showing the fibrous structure of the material and forming a narrow angle with the outer surface of the antler, often less than 45°: “tongued” fracture). These fractures are obviously of anthropic origin: in Le Cuzoul de Vers, the impact of carnivores on the faunal stock in general is negligible and traces of their intervention are almost absent on the bone remains (Castel, 1999, 2003); moreover, in 77 cases (12%), the “green” antler fractures are associated with notches indicating the use of direct percussion with a stone hammer (Fig. 4-8, passim).

Contrary to bone fracturing, antler fracturing cannot be linked to marrow extraction or to the use of osseous material as fuel (only two of the 1119 antler elements show traces of burning). These 642 fragments were therefore interpreted as evidence of manufacturing, produced through the reduction of the antler raw material by knapping.

Most of these elements are small (average length and width: 47.1 x 14.1 mm) but the large majority of them come from reindeer antlers of medium to large dimensions (mean thickness of compact tissue: 5.7 mm; *compacta* thickness lies between 4 and 7 mm for 76.8% of the sample). Both shed antlers (two specimens) and unshed antlers (one specimen and a second possible one) are present. Despite the systematic collecting of all antler fragments during the excavation, several antler parts are underrepresented in the collection, especially the extremities (base, palm and the smaller tines); this suggests that the antlers were not always brought to the shelter in a complete state and that the removal of the peripheral parts might often have been made outside of the excavated area, leaving only the beam and the larger tines.

Knapping is the only technique identified for the primary reduction of reindeer antler. Only a single, fragmentary artifact from layer 22 shows on one side a series of longitudinal striations that might be interpreted as the edge of a groove, evoking the use of the GST (Fig. 3). However, the delineation of this edge is more irregular than on GST manufacturing waste; the striations might also be seen as the result of a very firm longitudinal scraping action. The presence of a single, uncertain edge of groove on one artifact is not sufficient to document the use of the GST that implies the scoring of two parallel grooves.

Primary reduction The reconstitution of the primary reduction sequence was mostly based on the few knapped elements that yielded precise technological information – i.e., those which could be refitted and/or attributed to a specific portion of the antler (base, beam or tines). These elements are: five antler portions with traces of flake removals (3 from the base of the antler and 2 from the second tine); and two flake refittings, each of which allowed to describe a sequence of flake removals from the same segment of antler beam.

The first piece is the base of a large, right shed antler (Fig. 4:1). Fracture traces indicate that the two basal tines were detached from the beam, and the negative of a large flake on the posterior face – with at least one percussion notch – shows that this side of the beam was removed by flaking. Another percussion notch on the lateral side indicates that, after the removal of the posterior side, the anterior side of the beam was detached from the base by striking at the junction with the second tine. In this case, the objective of the reduction sequence was apparently to obtain an elongated “strip” of compact antler with an

approximately semicircular cross-section, corresponding to the anterior face of the beam above the second tine.

Fragments of two more antler bases can be attributed to the same type of reduction sequence. A fragment of the base of a right, unshed antler of medium to large dimensions (Fig. 4:2) shows very similar traces: a fracture surface indicating the detachment of the first tine; two partial negatives of flake removals from the posterior side of the beam; and traces of the detachment of the remaining part of the beam – i.e., the anterior side – from the base by striking ca. 40-50 mm above its junction with the tine. A long flake from the posterior side of a large, right shed antler (Fig. 4:3) also indicates the removal of this side of the beam by knapping (in this case, the flake took off part of the burr).

Two other pieces attest that the beam was not the only part of the antler to be exploited. The second tine of a large antler (Fig. 5:1) shows several negatives of flake removals on the medial side, along with 5 or 6 percussion notches. The detachment of these flakes leaves a 220 mm long, 25 mm wide “strip” mostly made of compact tissue, with a semicircular cross-section, corresponding to the lateral side of the tine. Another fragment of the second tine of a large antler (Fig. 5:2) shows two negatives of flake removals: a large flake on the medial side, with a very pronounced percussion notch, and a thinner flake on the lateral side that was removed using the negative of the former flake as a striking platform. Here again, the objective of these operations is apparently to carve out a 25 mm wide strip of compact antler from the lateral face of the tine; in this case however, the knapping sequence was interrupted, perhaps because of a failed attempt at removing a third flake from the medial side (as indicated by an insistent percussion trace, without associated flake negative, ca. 35 mm further up the tine shaft).

Two flake refittings also document the objectives of the primary reduction sequence. The first refitting includes three flakes (and the negative of a fourth one) illustrating the removal of the two-thirds of the circumference of the beam, thus leaving a 30 mm wide strip of compact antler that corresponds to the missing portion of the refitting (Fig. 6). The second refitting includes four flakes (and the negative of a fifth one) from the lateral or posterior side of the beam of a large antler, showing the removal of more than one third of the circumference of the beam on a 300 mm long antler segment. Measure of the *compacta* thickness and examination of the percussion notches show that the flaking starts on the upper part of the antler and goes down to the base, and that the strokes were given from alternate sides (Fig. 7). Although they could not be refitted, many other antler flakes in the assemblage show comparable dimensions and a similar “tile” shape, characteristic of the knapping of the beam by successive flake removals (each flake bearing the partial negative of the preceding one: Fig. 8).

All these knapped antler elements, found from layer 6 to layer 25, allow to reconstruct the primary reduction sequence (Fig. 9). The early stages of this sequence are poorly documented but likely include the (offsite?) removal of the peripheral parts of the antler (smaller tines, palm, upper part of the beam?). Then, after the detachment of the second tine, several flakes are successively removed from the beam, eliminating approximately one half or the two-thirds of its circumference – thus leaving only a straight strip of compact tissue corresponding to the anterior side of the beam. This strip is then detached from the base of the antler. The same operation is carried out on the shaft of the second tine, the strip being carved out of the lateral face.

According to this reconstruction, the intention of the Badegoulian antlerknappers at Le Cuzoul de Vers was to produce actual splinters: elongated elements with an approximately straight outline, a 20-30 mm width, a more or less semicircular cross-section and a thick compact tissue (6-8 mm after the measurements made on the antler fragments in Fig. 4-7). The length of these splinters is difficult to estimate but can reach 200-300 mm (Fig. 5:1 and Fig. 7).

Secondary reduction After having been carved out of the beam or tine, the splinters were often further reduced by flaking. This is indicated by several small flakes showing percussion traces on the spongy side (Fig. 10), and therefore having been detached from an antler part on which a primary knapping exposed the inner spongy tissue (i.e., probably a splinter). It is suggested that the aim of this secondary reduction was to correct the outline and profile of the splinter, in order to bring it closer to the shape of the intended artifact. This interpretation is illustrated by two refittings. The first one includes three elements that, together, reconstitute a portion of antler splinter with a slightly curved outline and profile (Fig. 11). Two percussion points indicate that this splinter was struck on the upper face and on one side in order to section it: we thus consider these three elements as waste products resulting from the elimination of the curved, twisted extremity of the splinter, in order to use only the straighter part (i.e., the part missing from the refitting) as a blank. A second refitting groups four elongated flakes knapped off the side of a splinter with a length of at least 240 mm (Fig. 12). By comparing the outline of the splinter's side before and after the removal of the flakes (Fig. 12), it can be suggested that this knapping operation was intended to straighten the splinter by suppressing a bulge on its side.

Although manufacturing debris and finished objects are the large majority of the antler assemblage at Le Cuzoul de Vers, a few artifacts were identified as splinters having undergone secondary reduction by knapping (Fig. 13). These objects are 120 to 240 mm long (the length of some of them is incomplete) and 20-30 mm wide; they have a 6-8 mm thick compact tissue, a straight outline and profile and a semicircular or quadrangular cross-section.

Shaping techniques and finished objects Apart from six wedges made on complete or half-complete antler segments (*supports en volume* and *supports intermédiaires* after Averbouh, 2000), all other rough-outs, shaping debris and finished objects whose type of blank could be determined were made on splinters (Table 2). As indicated by the longitudinal striations on these 96 artifacts, their final shaping was done by scraping. Scraping traces are usually present on all sides of the objects and on their entire length; this extensive shaping erased all traces of the techniques used in blank production. Most of the objects are fragmentary (only 13 – i.e., 13.5% – are complete) and the majority of them (61, i.e., 63.5%) show an oval cross-section. Typologically, the assemblage includes 19 projectile points (Fig. 14:4-6) and 31 wedges (Fig 14:1-3). Ten short, pointed artifacts whose opposite extremity shows signs of sectioning by bilateral scraping (*pointes à base raccourcie*: Fig. 14:7-8) were interpreted as shaping debris resulting from the calibration of a projectile point (removal of an exceeding length or of an irregular portion: Le Dosseur, 2003; Chauvière and Rigaud, 2005, 2008; Rigaud, 2006). Most projectile points and all *pointes à base raccourcie* are ca. 5-10 mm wide and 4-6 mm thick, with a 4-6 mm thick compact tissue; the only complete point is 90 mm long, but two slightly longer point fragments (92 and 95 mm) attest the existence of larger specimens. Wedges have larger overall dimensions, with width usually between 12 and 20 mm, maximum thickness between 8 and 12 mm, thickness of compact tissue between 5 and 10 mm, and a 130-150 mm length for the three complete specimens (but three fragments reach 135 to 182 mm).

The dimensions of the splinters made by knapping (a 20-30 mm width, a 6-8 mm thick compact tissue and a length up to 300 mm) are compatible with those of the finished objects: splinters of this type are large enough to have been used as blanks for even the largest types of tools in the antler assemblage (e.g., the wedges shown on [Fig. 14](#)), and a fortiori for the smaller ones. Furthermore, as noted by Allain and colleagues (Allain et al., 1974:70), splinters made by knapping tend to be significantly wider than thick, thus their shaping into finished objects “naturally” produces artifacts with an oval cross-section: adequately, this type of cross-section is by far the most common among the antler tools in Le Cuzoul de Vers. In other words, although the extensive shaping work made by scraping erased all traces of blank production techniques on the finished objects, these objects are technologically compatible with the rest of the antler reduction sequence evidenced in the same site: they can be considered as the final objective of this sequence.

Results of the Lower Magdalenian assemblages

La Grotte des Scilles The assemblage of reindeer antler from layer B in La Grotte des Scilles numbers 79 elements ([Table 3](#); Pétilion et al., 2008 ; Langlais et al., 2010). Six of them are unworked fragments, likely resulting from post-depositional breakage. The remaining 73 artifacts include only five pieces of manufacturing waste; two of them attest to the transversal sectioning of antler segments by chopping, and the three others attest to the use of the GST. The most informative of these three elements are two bases of large antlers (one shed and one probably unshed) showing the beginning of a longitudinal groove on the beam, at the junction with the second tine ([Fig. 15](#)). These traces indicate the use of the grooving technique along the length of the beam, most probably for the removal of a splinter. The poor preservation of these artifacts precludes a more detailed technological analysis. Four fragments of blanks confirm the use of the GST: three fragments of antler splinters, not modified after their removal from the beam, show grooving traces on both sides ([Fig. 16](#)); and a fourth fragment of antler splinter, although already partly shaped by scraping, still shows the beginning of a groove on one side and a longitudinal incision on the upper face left by the slipping of the grooving tool ([Fig. 16](#)). These four blanks are quite wide (12-23 mm) and made on antlers of large dimensions (thickness of compact tissue: 6-8 mm).

The remainder of the antler assemblage is made of 64 finished or half-finished products, most of which are projectile points (n = 29), wedges (n = 7), spatulate tools (n = 3) or fragments of partially worked blanks (n = 23). All these artifacts are made on splinters and have had their sides shaped by scraping, which destroyed the traces of blank removal. The morphology and dimensions of these artifacts are, however, compatible with a production of the blanks by the GST on medium to large antlers (artifacts width: 11-17 mm; thickness: 7-12 mm; thickness of compact tissue: 5-11 mm). No evidence of antler knapping was found in the assemblage.

Saint-Germain-la-Rivière In Saint-Germain-la-Rivière, layers C3 and C4 yielded together 124 antler elements ([Table 4](#)). The 19 pieces of manufacturing waste show the exploitation of reindeer antlers of large dimensions, both shed (two specimens) and unshed (one possible specimen). Eight of these 19 elements show longitudinal edges of grooves, or extremities of grooves, all of which attest to the use of the GST for the removal of splinters from the main beam and from the second tine ([Fig. 17](#)). From the four waste pieces on which the number of removals could be determined, three show the removal of a single splinter per antler; the removal of two parallel splinters from the same segment of antler beam is documented in only

one case. In all cases, the splinters removed are 12-15 mm wide and have a 6-8 mm thick compact tissue.

Blank splinters and half-finished products are comparatively few in C3 and C4, numbering only seven elements. Several of them still show edges of grooves on both sides (Fig. 18). As in La Grotte des Scilles, the majority of the assemblage (n = 80) is made of finished objects shaped from splinter blanks: the types identified are projectile points (n = 69), wedges (n = 4) and antler needles (n = 3). Traces of splinter removal are no longer visible on these objects that were fully shaped by scraping; but their dimensions are compatible with the type of blanks produced by the GST at the site (projectile points: 6-11 mm width by 5-10 mm thickness; wedges: 12-14 mm width by 8-10 mm thickness; needles: 4-5 mm width by 4-5 mm thickness; thickness of compact tissue on all categories: 4-8 mm). The use of the grooving technique – although not for blank production – is also evidenced by the fact that ca. 20% of the projectile points (n = 14) bear one or two longitudinal grooves on the upper and/or lower faces – a feature commonly interpreted as a mount for lithic inserts (e.g., Pétilion et al., 2011).

However, one part of the antler industry from layers C3 and C4 is not linked to antler reduction by the GST. Seven pieces of manufacturing waste show only traces of transversal sectioning of the beam or tines – this sectioning being made by chopping, cutting, or opposite bilateral grooving. These elements might relate either to the preparation of the antler before further processing by the GST (e.g., “pruning” of unnecessary parts such as the base and the smaller tines), or to the manufacture of some specific tools. Indeed, layers C3 and C4 yielded 17 finished objects made on complete antler segments: one fragment of perforated staff (“*bâton percé*”) from an antler base, and 16 fragments of blunt tools apparently shaped from large tines.

Finally, antler knapping is also attested in Saint-Germain-la-Rivière, but the evidence is restricted to two artifacts from layer C3: one fragment of flake, and one fragment from the basal part of the antler (including the proximal portion of the second tine), which was detached from the beam by percussion (Fig. 19). However, these artifacts remain technologically isolated and do not allow to characterize a specific reduction sequence.

Summary

The technological analysis of three antler assemblages from southwest France – one dated to the Badegoulian and two dated to the Lower Magdalenian – unequivocally evidenced the use of two distinct methods for the production of splinters. In Le Cuzoul de Vers, splinters were manufactured by direct percussion, and evidence of this method spans the entire Badegoulian sequence dated ca. 24.5-21.5 kyr cal BP. In Saint-Germain-la-Rivière, layers C3-C4, and La Grotte des Scilles, layer B – respectively dated ca. 20.4-19.6 kyr cal BP and 19.6-18.9 kyr cal BP – antler splinters were manufactured by the GST (Fig. 20).

In all three sites, the manufacturing waste, blank splinters, half-finished and finished tools are technologically compatible and build a coherent, consistent assemblage. The only evidence that might seem contradictory are one artifact with a possible edge of groove in Le Cuzoul de Vers, layer 22, and two antler flakes in Saint-Germain-la-Rivière, layer C3. However, one of these artifacts – Le Cuzoul de Vers layer 22 – is dubious. Furthermore, all three artifacts remain technologically isolated in their respective assemblages and are not specifically linked to splinter production: their mere presence does not allow to describe a splinter manufacturing

sequence that would be based on the GST in Vers, or on reduction by knapping in Saint-Germain-la-Rivière. Thus these three artifacts do not invalidate our analyses.

According to our results, the transition from the Badegoulian to the Lower Magdalenian is marked by a clear change in antlerworking techniques: splinters intended for the manufacture of similar objects (mostly projectile points and wedges) were produced through entirely different methods.

Direct dating of antler artifacts from assemblages with both GST and knapping

Archeological context

The antler industries from the Cap-Blanc and Reverdit rockshelters (Dordogne, France: Fig. 1) were recently studied by J.-M. P. within a collective work centered on the archeological contextualization of the Magdalenian rock sculptures (Bourdier, 2008, 2009-2010, 2010; Bourdier et al., in press), and the collection from the Lassac open-air site (Aude, France: Fig. 1) was analyzed as a part of a monograph project (Sacchi et al., in press). Each of these three collections yielded evidence of antler reduction both by knapping and by the GST, which seems to contradict the results presented in the previous section of this article. However, in all cases, the respective chronological position of the knapping products and the GST elements – and hence the question of the possible contemporaneity of the two methods – is undecidable.

Indeed, at Cap-Blanc, the excavations that yielded most of the antler industry, directed by G. Lalanne, were conducted in 1909 within four months, without sieving and without stratigraphic control (these excavations led to the uncovering of the rock sculpture: Lalanne and Breuil, 1911; Roussot, 1984). After the discovery of a Paleolithic burial (Capitan and Peyrony, 1912), and most of the shelter having been emptied from its archeological filling, later excavations centered on small preserved areas that yielded little or no antler industry (Peyrony, 1950; Roussot, 1984) and on the backdirt of the Lalanne excavations (Castel and Chadelle, 2000). Analysis of the archeological material was mostly centered on the lithic industry and showed evidence of the occupation of the site during the Solutrean, Magdalenian and Azilian (Sonneville-Bordes, 1960:403-405; Roussot, 1984; Castel and Chadelle, 2000; Chehmana in Bourdier, 2010:69). The antler industry of the Lalanne collection includes 37 pieces of manufacturing waste; 23 show traces of splinter production by the GST, while eight are antler flakes (two of which could be refitted) attesting to antler reduction by knapping.

The situation is quite similar at Reverdit. The site was discovered in 1878 but little is known of the early excavations inside the shelter and most of the material has been lost. Most of the available antler industry comes from the excavations made by F. Delage in 1911-1914 (Delage, 1935). He excavated two trenches on the slope before the shelter and found two archaeological layers; but he attributed both of them to the Middle Magdalenian (“Magdalénien III”) and, for this reason, did not separate the material from each layer. In 1985-1987, D. Robin and A. Roussot excavated a 10 m² area in the southern part of the shelter (Robin, 1986), but this operation yielded very few remains of antler industry. A recent reevaluation of the archeological material from the Delage collection showed evidence of human occupation at Reverdit during the Badegoulian and the Magdalenian (Bourdier et al., in press). Among the 340 remains of antler industry in the Delage collection, 32 artifacts show traces of splinter production by the GST (11 pieces of manufacturing waste, and 21

elements that could be either fragments of blanks or fragments of manufacturing debris). They are associated with five artifacts attesting to antler reduction by knapping: three flakes, one antler base with possible traces of flake removals, and one semi-cylindrical segment of antler beam with traces of several flake removals.

At Lassac, the association of the GST and the knapping debris is problematic because the artifacts come from different sectors of this extensive open-air site. The first field intervention at Lassac occurred in 1973 when D. Sacchi conducted the excavation of a 6 m² sector termed “locus 1” (Sacchi, 1986; although this excavation was made in the conditions of a rescue operation, 3D coordinates and sieving with a 1.2 mm mesh were systematically used). The single archeological layer yielded a rich lithic assemblage attributed to the Badegoulian (Sacchi, 2003a, 2003b; Ducasse, 2010) despite a rather recent ¹⁴C date (Gif-2981, non-AMS date on bone, 16750±250 BP or 20440-19420 cal BP). Later on, in 1994, P. Barthès excavated 30 test pits and trenches at Lassac in the context of an archeological diagnosis prior to a rescue excavation (Barthès, 1994). Eight test pits yielded Paleolithic material, both osseous and lithic; and one of them (test pit 1, layer 4) was dated to 20040-19450 cal BP (GrA-18788/Lyon-1548, AMS date on bone, 16580±80 BP). Meanwhile, regular field surveys of the site since the years 1960 allowed A. Bennes to collect a large amount of Paleolithic material from the surface. The antler industry from the Sacchi excavation, from the Barthès test pits and from the Bennes surveys were recently reexamined within a monograph project (Pétillon and Sacchi, in press). Three fragments of antler beam with traces of splinter production by the GST were identified: two from test pit 1, layer 4; and one from surface finds. Locus 1, on the contrary, yielded an assemblage of 53 antler flakes but no evidence of the GST.

Material and methods

In order to establish the relative chronological position of the two antlerworking methods at each site, specific artifacts were chosen for direct ¹⁴C dating by AMS. From Cap-Blanc (Lalanne collection), we selected two artifacts: one flake knapped off the beam of a reindeer antler (Fig. 21:2), and one piece of reindeer antler manufacturing waste with traces of GST (Fig. 21:1; this artifact is from the median part of the beam – “*perche B*” after Averbouh, 2000 – and shows the extremities of six parallel grooves evidencing the removal of three splinters from the anterior, medial and lateral sides of the lower part of the beam or “*perche A*”). Similarly, from Reverdit (Delage collection), two objects were chosen: one semi-cylindrical fragment of antler splinter obtained by knapping (as evidenced by the traces of several flake removals: Fig. 21:4), and one fragment of splinter from the main beam of a reindeer antler that shows two parallel edges of grooves attesting to extraction by the GST (Fig. 21:3). Two antler flakes from Lassac (locus 1) were also dated (Fig. 21:7-8), as well as two of the three artifacts with traces of GST (Fig. 21:5-6; one fragmented artifact from test pit 1, layer 4, and the artifact from the Bennes surface finds: both come from the main beam of a reindeer antler and show two parallel edges of grooves attesting to the removal of one splinter from the anterior side of the beam).

These eight dates were undertaken in the context of several distinct research programs detailed in the “acknowledgements” section. As a result, the sampling techniques were not entirely homogeneous. For the two Cap-Blanc dates and one of the Reverdit dates (GifA-10115 / SacA-19771), sampling was done at Gif-sur-Yvette by cutting off a 2 g fragment with a diamond-tipped saw. For the five other dates (Lassac and Reverdit OxA-24940), sampling was done by the authors using the micro-coring process designed by Laurent Brou (2006): on

each artifact, after selection of a proper spot for sampling (with the thickest possible compact tissue), the surface of the spot was abraded in order to remove the outer layer, most exposed to outside contaminants; then a hollow bit with a jagged end and a 7 mm diameter, mounted on a micro-drill, was used to take several adjacent core samples. This process allows to take “solid” samples – thus avoiding the handling problems sometimes caused by powder samples – without altering the outline and overall dimensions of the artifacts. The total weight extracted from each artifact with this process was between 250 and 1,040 mg of compact antler.

Results

All samples yielded enough collagen to allow the ^{14}C date to be performed; the results are given in [Fig. 22](#) and [Table 5](#). In each of the three sites, the dates of the knapped antler are older than the dates made on the GST manufacturing waste. This result contradicts the hypothesis of a contemporaneous use of the two methods in these sites, and supports the idea of a replacement of antler knapping by the GST. In Reverdit and Cap-Blanc, the presence of the two methods in the same assemblage appears as a result of stratigraphic mixing. In Lassac, the four dates shows that the occupation of locus 1 (with the antler knapping debris) is older than the GST waste from test pit 1, layer 4 and from the surface finds. Incidentally, the date made on the artifact from test pit 1, layer 4 fully confirms the previous AMS ^{14}C from the same layer (see above); while the two new dates from locus 1 are mutually consistent but older than the non-AMS date from this locus. In our opinion, this invalidates the non-AMS date, whose younger age likely results from contamination of the bulk sample.

When the three sites are taken together, the consistency of the results remains: taken as a whole, the series of four dates made on knapped antler is older than the series of four dates made on GST waste products ([Fig. 22a](#)). The boundary between the two series lies ca. 20500 cal BP. The two dates made on knapped antler from Le Cuzoul de Vers are older than 22000 cal BP and therefore do not contradict the younger limit of the distribution of the knapping method ([Fig. 22b](#)).

These eight dates were compared with AMS ^{14}C dates currently available for Recent Badegoulian and Lower Magdalenian assemblages in southwest France ([Fig. 1](#)). To ensure a reliable comparability with our data, the comparison sample includes only dates made on osseous material (6 on bone, 1 on antler, 1 on tooth). The AMS ^{14}C dates of the Lower Magdalenian levels at Gandil were excluded from the sample because of their problematic results (two internally consistent but mutually conflicting series of AMS ^{14}C dates: Langlais et al., 2007). Finally, as shown on the graph ([Fig. 22b](#)), the transition between the two archeological cultures is also located ca. 20500 cal BP and thus coincides with the boundary between the direct dates on knapped antler and those on GST waste. This data is therefore fully consistent with the hypothesis stemming from our technological analyses: the technical change from antler knapping to the GST occurs at the transition from the Badegoulian to the Lower Magdalenian, at the time when *raclettes* disappear from lithic toolkits.

Discussion

Assessment and comparisons

Badegoulian The exclusive use of knapping and the absence of the GST in the Badegoulian antler assemblage of Le Cuzoul de Vers is in accordance with what was described in the Badegoulian levels of the Fritsch shelter. The antler reduction sequence described in Fritsch is very similar to that of Le Cuzoul de Vers (Allain et al., 1974; Rigaud, 2004, 2007:279-280). Antler knapping is also mentioned in the Badegoulian levels of Le Petit Cloup Barrat (Castel et al., 2006:272). The radiocarbon dates obtained on three antler flakes and one knapped portion of antler beam in Cap-Blanc, Reverdit and Lassac are also compatible with a Badegoulian age.

Before this study, the only two cases of GST in a Badegoulian context were the artifacts of Lassac (Sacchi, 2003a) and Pégourié (Séronie-Vivien, 1995). We have demonstrated that, in Lassac, the artifacts bearing traces of GST were not contemporaneous with the Badegoulian knapped antler from the same site, and that their dates were closer to those of the Lower Magdalenian. We have also shown that the Badegoulian levels of Le Cuzoul de Vers yielded only a single, dubious and fragmentary object with an uncertain trace of groove, insufficient to document the use of the GST. Thus the single remaining case of GST in the Badegoulian is one artifact from Pégourié: a splinter from layer 8B that, according to Séronie-Vivien, shows edges of grooves on both sides (Séronie-Vivien, 1995:254). This artifact is not illustrated in the site monograph, and was not analyzed or dated within our study. It must be noted, however, that the interpretation of the Pégourié stratigraphy has been debated (possible presence of Lower Magdalenian? Ducasse, 2010:355-361; Langlais and Ducasse, in press) and a non-Badegoulian age for this splinter cannot be ruled out. Thus this artifact does not invalidate our conclusions.

In Abri Casserole (Dordogne), Detrain and colleagues excavated four layers that yielded material attributed to the Badegoulian (which they term “Magdalenian 0” and “Lower Magdalenian with *raclettes*”: Detrain et al., 1991:87). The uppermost level, NA3, yielded one fragment of antler splinter with a possible edge of groove on one side (Bidart, 1992:65; the artifact is not illustrated). However, this artifact cannot be considered reliable proof of the use of the GST in the Badegoulian, for several reasons: (1) it does not show the use of two parallel grooves; (2) its technological status remains dubious, since the side opposite the groove is said to bear percussion notches; (3) the stratigraphic integrity of the site is not beyond question (NA3 is overlaid by two levels probably dated to the Middle Magdalenian, and the stratigraphy is described as “reworked” and “seriously disturbed with probable cryoturbation, leaching and bioturbation”: Detrain et al., 1991:87).

Allain and colleagues write that, in the Périgord, contrary to the central and northern parts of France, layers with *raclettes* “generally” yield some evidence of the GST, “or, when it is not mentioned, at least its absence is not underlined” (Allain et al., 1974:69). Two assemblages are listed to support this assertion: “Badegoule I” (lowermost Badegoulian level of the Cheynier excavations in Badegoule; re-labeled “level VI” in Cheynier, 1949) and “Lachaud, layer C” (actually “Badegoulian c, layers 2 and 2-3” in Cheynier, 1965). However, Cheynier describes no clear evidence of the GST in the lowest Badegoulian level of Badegoule (Cheynier, 1939:375-377, 1949:223); and even if he indeed does not mention the absence of the GST in this level, this omission alone is not a conclusive argument. In the antler industry of the “Badegoulian c” in Lachaud, Cheynier mentions both GST manufacturing waste and a

number of antler flakes (Cheynier 1965:63-72). However, given the early date of the excavations (1941 to 1944), the complexity of the stratigraphy and the fact that the “Badegoulian c” is overlaid by an “Ancient Magdalenian” level that also yielded evidence of the GST (Cheynier, 1965:83; Cretin, 2000; Ducasse et al., 2011:144), we consider that, in the present state of the data, this is not solid evidence for the contemporaneous use of the two methods in the Badegoulian, and that direct ^{14}C dating of the antler elements by AMS should be considered in this case also.

A specific point must be made regarding one artifact from the Lascaux cave. At Lascaux, 51 pieces of osseous industry were found, including mostly finished objects (chiefly projectile points) and a single artifact with traces of blank production. This last artifact is an antler splinter that shows edges of grooves on both sides and was thus made with the GST (Allain, 1979:108-109). However, contradicting the weighed means of 17070 ± 130 BP (20560 - 19840 cal BP) given for the three non-AMS ^{14}C dates made on charcoals from Lascaux (Leroi-Gourhan and Évin, 1979), a recent AMS date yielded the result of 18600 ± 190 BP (GifA-95582, 22580 - 21510 cal BP: Aujoulat et al., 1998:320), suggesting a Badegoulian age. And when she restudied the osseous industry in the early 2000s, C. Leroy-Prost could not find the GST splinter again and suggests that it probably corresponds to the artifact that was chosen as a sample for this ^{14}C date (Leroy-Prost, 2008:123). Given that: (1) this artifact would thus be the only antler object with traces of the GST directly dated to the Badegoulian; (2) it was entirely destroyed by the dating process (Leroy-Prost, 2008:123) and is thus no longer available for confirmation of its identification, for further technological study or for redating; (3) the characters of both the lithic and the osseous industry of Lascaux support an attribution to the Lower Magdalenian (Allain, 1979; Glory et al., 2008; Langlais 2010:275); we cannot draw definite conclusions from this information. In our opinion, a new series of AMS dates on diagnostic bone and antler tools from Lascaux are necessary to further the discussion.

Lower Magdalenian The use of the GST during the Lower Magdalenian for the production of antler splinters is attested in La Grotte des Scilles, layer B, and Saint-Germain-la-Rivière, layers C3-C4. The ^{14}C ages of four GST waste products from Cap-Blanc, Reverdit and Lassac (test pit 1, layer 4, and surface find) are also consistent with an attribution to the Lower Magdalenian. This statement is further supported by mentions of the GST in other antler assemblages from Lower Magdalenian sites in southwest France: Gandil, layers 20 and 23-25 (Langlais et al., 2007:359) and Le Petit Cloup Barrat, layer 4 (Castel et al., 2006:272; Chauvière in Ducasse et al., 2011).

The lack of evidence of antler knapping in the Lower Magdalenian of La Grotte des Scilles must be considered with caution. Indeed, given the early date of the excavations and the field methods used by R. de Saint-Périer, it is likely that, if “simple” antler flakes were present, they would have been disregarded by the excavators – characteristic is the fact that the faunal assemblage from La Grotte des Scilles is heavily dominated by easily identifiable remains, such as teeth and epiphysis, while most fragments of diaphysis have obviously been discarded during the excavation (Letourneux and David in Langlais et al., 2010). However, the fact that several unworked antler fragments are present in the assemblage qualifies this objection by indicating that the collecting of antler elements was apparently quite careful nevertheless. Furthermore, this objection does not apply to Saint-Germain-la-Rivière: although G. Trécolle’s collecting strategy was much more careful, remains of antler knapping are still very underrepresented in layers C3-C4. From the two artifacts found in layer C3, we can say that the technique of antler percussion does exist in the Lower Magdalenian, but that it seems restricted to marginal technical operations. Splinter production by knapping – as evidenced in

the Badegoulian – is not attested in the Lower Magdalenian and, in our material, this situation cannot be considered as a mere sampling bias.

The same restriction applies to Le Petit Cloup Barrat. In this recently excavated site, layer 4 was attributed to the Lower Magdalenian on the basis of lithic technology, osseous typology and radiocarbon dates (Castel et al., 2006; Chauvière et al., 2008; Ducasse et al., 2011). The antler assemblage of this layer yielded evidence of both splinter production by the GST and antler reduction by knapping; however, the small sample of knapped antler currently known from layer 4 does not allow the identification of a specific reduction sequence, and it cannot be ascertained that the remains of knapped antler are linked to splinter production (Chauvière in Ducasse et al., 2011).

Finally, even if this study was centered on antlerworking, the little evidence currently available from Badegoulian and Lower Magdalenian bone working is not contradictory with our conclusions. The production of bone splinters by the GST is not attested in Le Cuzoul de Vers (Le Guillou, in press), while it is clearly evidenced in La Grotte des Scilles, layer B (Chauvière in Langlais et al., 2010), and in Saint-Germain-la-Rivière, layers C3-C4 (J.-M. P., personal observation).

To sum up, this study established that, in southwest France, knapping is the only method used for the production of antler splinters during the Badegoulian, i.e., before ca. 20500 cal BP; and that it is replaced by the GST at the beginning the Lower Magdalenian, i.e., after ca. 20500 cal BP (Fig. 23). The few counterexamples are marginal discordances that could be explained by various biases still to be analyzed.

Interpretation and implications

As mentioned at the beginning of this article, the technological history of the production of antler splinters in Paleolithic-Mesolithic Europe is generally considered overall as a cumulative process, prompted by the introduction and progressive improvement of the GST. Our results are in clear contradiction with this perspective and support a more cyclic view of technological evolution. In the European Upper Paleolithic, antler splinters were first manufactured by splitting and cleavage (Aurignacian); then the GST was introduced (Gravettian); then it fell out of use and was replaced with splinter production by knapping (Badegoulian); and finally, the GST appeared again and became the key method for the production of antler splinters (Magdalenian and subsequent cultures).

Of course, this general pattern still needs to be tested on other material in order to be validated, characterized and interpreted. For instance, in the present state of our knowledge, it is not possible to exactly determine when and how the GST disappeared after the Gravettian. Indeed, the approach developed in this article for the Badegoulian and the Lower Magdalenian (technological analysis of well-dated assemblages with no risk of stratigraphic mixing, and direct dating of diagnostic technological pieces) has not yet been implemented for the Solutrean. All we can say is that, according to the evidence of Le Cuzoul de Vers, the giving up of the GST and the development of antler knapping was already effective in the Early Badegoulian. A. Rigaud mentions the absence of the GST and the presence of antler knapping in the Solutrean levels of the Fritsch shelter, and the probable presence of splinters made by knapping in the Solutrean levels of the Badegoule site (Rigaud, 2004); in Le Cuzoul de Vers, the intermediary level between the Upper Solutrean and the Early Badegoulian (layer 28) yielded both antler knapping waste and Solutrean shouldered points (Pétillon and

Averbouh, in press; Ducasse and Renard, in press). However, this preliminary evidence and the reality of this association must be considered with caution and need to be supported by future studies (at Le Cuzoul de Vers, a taphonomical study of layer 28 is still wanting). Thus, in the absence of a renewed set of data for the Solutrean-to-Badegoulian transition, we will concentrate in the next steps of this discussion on the interpretation of one particular moment in the technological cycle: the change between the Recent Badegoulian and the Lower Magdalenian, that is, the reintroduction of the GST.

This change appears as an abrupt one. Indeed, splinter production by knapping and splinter production by the GST are, in many ways, technologically and conceptually opposite: the knapping method actually involves *the carving of the antler block into a splinter*, while the use of the GST involves *the extraction of the splinter from the antler block*. This difference is very similar to the distinction made in lithic technology between *façonnage direct* (direct shaping of an artifact from a block) and *débitage* (production of blades, bladelets or flakes removed from a core: Tixier et al., 1980; Averbouh, 2000). It is thus impossible to imagine a third “mixed” or “intermediary” method that could combine the two others and represent a transition between them. Furthermore, the evolution described in this article follows a similar pattern throughout the whole study area (Fig. 1), from central France (Fritsch shelter) through Dordogne, Gironde and Lot down to the central and eastern Pyrenees (La Grotte des Scilles, Lassac), without detectable chronological delay between regions. This indicates that the spread of the new method was rapid – by Upper Paleolithic standards – and disregarded possible cultural or ecological boundaries (Banks et al., 2011). The term “technical shift” fully applies in this case.

Given that one part of the lithic toolkit is intended for the working of osseous materials, this change in antler technology has direct implications in the stone industry. Actually, it might provide a possible explanation to several differences between the Recent Badegoulian and the Lower Magdalenian lithic assemblages (Fig. 24). Indeed, whereas the importance of burins in the Lower Magdalenian toolkit (generally between 20% and 50% in Les Scilles, Saint-Germain-La-Rivière and Gandil c.23/25) is consistent with the importance of this tool in the implementation of the GST (both for splinter production by grooving and for the shaping of splinters by scraping: Clark and Thompson, 1953; Bordes, 1965; Rigaud, 1972; Semenov, 1973; etc), the knapping method used during the Badegoulian implies the use of a wider range of tools: the primary and secondary reduction sequences require at least stone hammers for knapping, and the shaping phase requires the use of scraping tools. According to the experiments of A. Rigaud (1990), the detachment of the antler flakes could also have involved the use of splintered pieces as lithic wedges (Allain et al., 1974:67-69; Rigaud, 2004:75). This type of tool, present but unobtrusive in Lower Magdalenian assemblages (generally less than 10%), often represents an important part of the Badegoulian equipment: except in Le Cuzoul de Vers layer 6, splintered pieces amount to 15-25% of the tools (see also Bodu and Senée, 2001:31; Bodu et al., 2007). *Raclettes*, which are as abundant as splintered pieces in Recent Badegoulian assemblages, were probably involved in the scraping process (Allain et al., 1974; Rigaud, 2004) although this should be tested by further experimental work and traceological analyses.

We can thus underline the morphological compatibility of the Badegoulian lithic toolkit with the techniques and methods identified in antlerworking, even if, in the current state of our knowledge, these hypotheses must be considered as a plausible scenario only. It is nonetheless likely that such a noticeable change in the technology of antler will be correlated

with corresponding transformations in the lithic tools used to work this material. The factors that prompted this technological shift remain to be discussed.

The arrival of new populations? A first possibility would be to try to explain this shift by an influx of new human populations: “Badegoulian” groups would have been replaced or rejoined in southwest France by “Magdalenian” populations carrying different technical traditions. We have seen, however, that the idea of a population change between the Recent Badegoulian and the Lower Magdalenian was not supported by any archeological evidence (see above). With the Badegoulian-to-Magdalenian transition in southwest France, we most likely have to deal with a local evolution of the same, essentially stable populations.

An environnemental stress? A second type of explanation would be to view technical evolutions as adaptive responses to environmental changes. Here, however, there is simply no ground for such a theory. Indeed, the Badegoulian and the Lower Magdalenian respectively occupy the first and second half of the LGM, and thus develop in the same environment and under similar climatic conditions (see above). So, in the present case, the incitement to technical change must therefore be sought elsewhere than in environmental fluctuations.

An economic improvement? A further hypothesis would be to consider that the GST was reintroduced and became widespread in the Lower Magdalenian because it presented economic advantages over the Badegoulian method. Indeed, splinters made by knapping have an irregular outline and require an extensive shaping phase to be transformed into finished objects; while splinters produced with the GST are more regular and can be precisely calibrated to the dimensions of the desired artifact, thus reducing the time and effort devoted to shaping (Goutas, 2009:444). Additionally, the Badegoulian method implies that the majority of the raw material will be wasted by the knapping process, and only one splinter can be produced from each segment of antler (Allain et al., 1974:67); while the GST allows to remove several parallel splinters from the same antler (up to six on the beam of very large reindeer antlers: Averbouh, 2000:226), thus maximizing the productivity of the raw material.

However, several objections can be made to this hypothesis. First, while the use of the GST indeed makes the shaping of splinters faster and easier, it requires that a very long time is spent on the production of the splinter itself. Replication experiments showed that the removal of a splinter from an antler beam with the GST takes overall an average 2.5 hours (75 minutes per groove: Pétillon, 2006:126). No timed experimental data has been published for antler knapping, but it is obvious that the removal of flakes from an antler beam by direct percussion will take less time (it is described as a “rather quick” process in Allain et al., 1974:67). In other words, with the adoption of the GST in the Lower Magdalenian, the time and effort “spared” from the shaping phase is “reinvested” in the production of the blank (Goutas, 2009:444; Tejero et al., 2012). All in all, when considering the manufacturing process from blank production to the finishing of the artifact, it is not obvious that the total time balance will be in favor of the GST.

Second, while it is true that the GST allows a higher productivity of the raw material, this potential does not seem to have been immediately or systematically exploited by the Magdalenian groups. In the Lower Magdalenian assemblage of Saint-Germain-la-Rivière, the most frequent case is that only one splinter was removed from each antler segment (three of the four identifiable artifacts; the single exception shows two parallel removals: see above). The same is true for the Lower Magdalenian manufacturing debris with traces of GST in Lassac (Pétillon and Sacchi, in press) and in Reverdit (Bourdier et al., in press), while the

manufacturing debris of the Lower Magdalenian assemblage of La Grotte des Scilles are too badly preserved to be informative (see above). In Saint-Germain-la-Rivière and Lassac, the Lower Magdalenian is dated ca. 20.4-19.1 kyr cal BP (see above). Although the available evidence is still scarce, it seems that the removal of multiple parallel splinters from the same antler could appear only in the second half of the Lower Magdalenian, beginning slightly before 19000 cal BP. This is suggested by the date of 16050 ± 130 BP or 19440-18890 cal BP on the Cap-Blanc manufacturing waste, and by the presence of one antler element attesting to several parallel splinter removals in the uppermost Lower Magdalenian layer at Gandil (layer 20; J.-M. P., personal observation). The practice of multiple parallel splinter removals then becomes widespread after ca. 18 kyr cal BP, in the Middle and Upper Magdalenian (Averbouh, 2000). Thus the increase in splinter productivity after the beginning of the Lower Magdalenian seems to have been a slow process, maybe not equally effective in all regions (for the contrasting case of the Upper Magdalenian in the Paris Basin, where the removal of a single splinter per antler seems to be the rule, see Averbouh, 2006b, 2010; Leroi-Gourhan and Brézillon, 1972:203-204). Consequently, it cannot be considered as the initial incentive for the adoption of the GST.

A wider techno-economic process One last, more fruitful perspective is to consider the differences in skill and know-how implied by the two methods. Basically, the Badegoulian method involves the use of two techniques: knapping and scraping. The first technique is not specific to antlerworking, as it is also involved in the making of flint tools. It might be mundane to say that knapping is a knapper's work, but we believe it to be a key point in the present discussion: with the Badegoulian method, most of the technical knowledge and know-how of a flintknapper (posture, body movements, adequate choice of the hammer, control of the impact point and angle of the blow, etc.) can be transferred to antlerworking with little adaptation. As far as techniques are concerned, the only true specificity of antlerworking is the final scraping phase (we are aware that even the scraping technique was probably not used only for antler- or boneworking, but was likely also involved in the manufacture of wooden implements, given its perfect adaptation to the working of hard fibrous materials; but since we have of course no direct evidence of Badegoulian wooden objects or their manufacturing techniques, this discussion will be limited to the comparison of stone and antler). Thus the Badegoulian technology involves a rather lightweight but very flexible technical repertoire, that can be applied by the same person to the working of different raw materials – with antlerworking “borrowing” techniques from stone- (and maybe wood-) working.

In Lower Magdalenian antlerworking, the knapping technique seems still used for marginal operations (as evidenced by the two artifacts from Saint-Germain-la-Rivière C3), but the main techniques employed are grooving and scraping. None of these techniques can be applied to flint. Thus the development of the GST in the Lower Magdalenian has two meanings:

- An enrichment of the technical repertoire of antlerworking, with the introduction of a new technique playing a key role in splinter production, and the necessary construction of the related know-how (knacks and gestures, etc.).
- A stronger separation between the technical fields of flintworking and antlerworking. While in the Recent Badegoulian both fields overlapped clearly, here, the main techniques used in each case are markedly different. This evolution appears more exactly as an autonomization of antlerworking from flintworking, with the implementation of more specific techniques (Fig. 25).

A similar phenomenon is perceptible within the lithic technical system. The structure and organization of the Recent Badegoulian flint reduction sequences is built around a high

flexibility (a term that must not be understood in a depreciative way: Cretin, 2000; Ducasse, 2010). Indeed, next to tools made on blades, a large part of the equipment is made on flakes that require a low or moderate degree of standardization. These objectives are linked to adaptable flintknapping methods which can be applied to very variable types and qualities of raw materials, thus allowing the manufacture of a stable stone equipment over large areas. A key point is that the lithic sub-system is characterized by a ramification of the *chaînes opératoires* that often link up the domestic and cynegetic intentions (i.e., manufacture of both “domestic” tools and weapon elements). Although the Lower Magdalenian lithic technical system has much in common with the Recent Badegoulian (Ducasse, 2010), it witnesses several modifications leading to a progressive disjunction of these economical intentions (Langlais, 2010). In general terms, whereas the blades take an increasing role in domestic toolkits (generating a higher demand in good quality flint, and thus new strategies of raw material procurement), bladelet production shows a techno-economic evolution: while in the Badegoulian one dominant method (“edge blank debitage” family: the so-called “notched burin cores”) allows to obtain a large range of blanks (bladelets and micro-bladelets, lamellar flakes) used for the manufacture of both domestic tools and hunting equipment, in the Lower Magdalenian, a larger variety of production methods is used solely to obtain (micro-)bladelets used as hunting weapons (Ducasse and Langlais, 2007; Ducasse, 2010; Pétilion et al., 2011).

In parallel to the disappearance of *raclettes*, the Recent Badegoulian-to-Lower Magdalenian transition is characterized by a progressive reconfiguration of the lithic technical system. The techno-economical “overlapping” of the domestic and the cynegetic fields perceptible in the Badegoulian gives way to a more “disconnected” organization of these fields during the Lower Magdalenian.

All in all, many of the evolutions that define the transition between the Recent Badegoulian and the Lower Magdalenian amount to a “disinterweaving” of the different technical domains – or rather, a stronger compartmentalization of the technical world. This can also be viewed as a change in the perception of the different raw materials: Lower Magdalenian groups seem to have a more hierarchical conception of their range of lithic and osseous raw materials, since specific production schemes and techniques are associated with the specific properties of each material (lower-quality flint, higher-quality flint, bone or antler). The rapid adoption of the GST can thus be explained by the fact that this innovation was not an isolated phenomenon but rather a part of a broader, ongoing reconfiguration of the conception of technical categories.

This compartmentalization logically appears as one of the necessary conditions for the subsequent autonomous development of each technical field and their increase in complexity. This hypothesis is supported by the fact that, in the present state of our knowledge, the development of the GST in the Lower Magdalenian accompanies an enlargement and diversification of antler tool types, even those that are not made on splinters. Indeed, several of them are, so far, not clearly attested in the Badegoulian (see above): spatulate tools, antler needles, blunt tools made on tines, *bâtons percés* (the single published case of a *bâton percé* found in a clearly Badegoulian context is the diminutive and atypical fragment from Cassegros, layer 9 [Le Tensorer, 1981:328]; Rigaud already noted the “disappearance” of *bâtons percés* in the Badegoulian: Rigaud, 2001:101-102), etc. This evolution will culminate in the following Middle and Upper Magdalenian (ca. 18-14 kyr cal BP): these periods witness and increased development of bone and antler technology, unprecedented in the European Upper Paleolithic; one of the most striking manifestations of this development being the refinement and much more frequent occurrence of osseous art items (e.g., Clottes ed., 1987,

passim; Fritz, 1999; Sacchi, 2003c:67-77). Furthermore, as indicated above, it is during the Middle and Upper Magdalenian that the concept of serial production of standardized splinters from the same segment of bone or antler becomes widespread (Averbouh, 2000; Goutas, 2009). Meanwhile, blade production also reaches its technological peak (at the level of the European Upper Paleolithic) with a particular emphasis on the acquisition of the best raw materials for the making of very large blades – and, here again, the development of elaborated reduction sequences allowing the serial production of long blades and bladelets (e.g., Pigeot, 1987; Bodu, 1993; Valentin, 1995; Lacombe, 1998; Cazals, 2000; Langlais, 2007). In many ways, these Late Glacial developments can be considered as the continuation and progressive unfolding of technical trends that started to take shape in the middle of the LGM.

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	Number
Not worked by scraping	
with fractures on "dry" antler only	367
with fractures on "green" antler	642
Worked by scraping	110
TOTAL	1119

Table 1 - Number of antler elements in the Badegoulian levels (1-27) of Le Cuzoul de Vers.

Type of blank	Typology and technology					TOTAL
	Projectile points	Wedges	Pointed tools	Shaping debris	Rough-outs and unidentified	
Complete antler segment (<i>support en volume</i>)	0	3	0	0	0	3
Half-complete antler segment (<i>support intermédiaire</i>)	0	0	0	0	3	3
Splinter	19	31	4	10	32	96
Unidentified	0	5	0	0	3	8
TOTAL	19	39	4	10	38	110

Table 2 - Typology and technology vs. type of blank for the 110 antler rough-outs, shaping debris and finished objects in the Badegoulian levels of Le Cuzoul de Vers.

	Number
Unworked fragments	6
Manufacturing waste	
transversal sectioning groove and splinter technique	2
	3
Splinters	
blank splinters	4
partially worked splinters	1
splinter sectioning debris	22
Finished objects on splinters	
projectile points	29
wedges	7
spatulate tools	3
undetermined	2
TOTAL	79

Table 3 - Typology and technology of the antler assemblage in layer B of La Grotte des Scilles.

	Number
Manufacturing waste	
transversal sectioning	7
groove and splinter technique	8
knapping	2
other	2
Splinters	
blank splinters	6
partially worked splinters	1
Finished objects on splinters	
projectile points	69
wedges	4
needles	3
undetermined	4
Finished objects on complete antler segments	
blunt tools	16
<i>bâton percé</i>	1
Undetermined	1
TOTAL	124

Table 4 - Typology and technology of the antler assemblage in layers C3-C4 of Saint-Germain-la-Rivière.

Site	Excavators	Sector/Layer	Material	Description	Method	Laboratory code	14C BP	Cal. BP
Direct datings of antler manufacturing waste								
Lassac (Aude)	A.F.A.N	Surface	Antler	GST manufacturing waste	AMS	Lyon 6420 (SacA 17497)	16230 ± 100	19580-18930
Lassac (Aude)	A.F.A.N	Test trench 1 layer 4	Antler	GST manufacturing waste	AMS	Lyon 6421 (SacA 17498)	16650 ± 100	20140-19480
Lassac (Aude)	D. Sacchi	Locus 1	Antler	Flake	AMS	Lyon 6417 (SacA 17494)	17400 ± 110	21220-20330
Lassac (Aude)	D. Sacchi	Locus 1	Antler	Flake	AMS	Lyon 6418 (SacA 17495)	17530 ± 100	21330-20440
Reverdit (Dordogne)	F. Delage	Unknown	Antler	GST splinter	AMS	GifA 10115 (SacA 19771)	17180 ± 110	21050-20090
Reverdit (Dordogne)	F. Delage	Unknown	Antler	Knapped splinter	AMS	OxA 24940	17770 ± 90	21517-20569
Cap-Blanc (Dordogne)	G. Lalanne	Unknown	Antler	GST manufacturing waste	AMS	GifA 10084 (SacA 19715)	16050 ± 130	19440-18890
Cap-Blanc (Dordogne)	G. Lalanne	Unknown	Antler	Flake	AMS	GifA 10083 (SacA 19714)	17640 ± 160	21450-20480
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	Layer 6	Antler	Flaked antler	AMS	OxA 24963	18660 ± 100	22534-21860
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	Layer 15	Antler	Flake	AMS	OxA 24964	19180 ± 110	23350-22450
Badegoulian dates								
Cuzoul de Vers (Lot) [1]	J. Clottes/J.-P. Giraud	Layer 11	Bone	Diaphysis/Reindeer or Ibex	AMS	Lyon 1963 (Poz 1595)	18480 ± 180	22423-21519
Le Blot (Haute Loire) [2]	H. Delporte	Layer 9	Tooth	Unknown	AMS	Lyon 1336	17850 ± 80	21560-20965
Le Taillis des Coteaux (Vienne) [3]	J. Primault	AG-Vd	Bone	Unknown	AMS	Lyon 2639	18140 ± 145	22170-21310
Lower Magdalenian dates								
Le Taillis des Coteaux (Vienne) [4]	J. Primault	AG-IIIa	Bone	Unknown	AMS	Lyon 2264	16920 ± 170	20467-19565

Le Taillis des Coteaux (Vienne) [5]	J. Primault	AG-IIIa	Bone	Unknown	AMS	Lyon 2107 (OxA 12180)	17130 ± 65	20910-20092
Fontgrasse (Gard) [6]	F. Bazile	Layer 1a	Burnt bone	Unknown	AMS	Erl-8928	16338 ± 153	19911-18939
Saint-Germain-la-Rivière (Gironde) [7]	F. Trécolle	Layer C4	Bone	Unknown	AMS	Lyon 617 (OxA 7260)	16890 ± 130	20373-19580
Les Scilles (Haute-Garonne) [8]	R. de Saint-Périer	Layer B	Antler	Splinter fragment	AMS	TO 13555	16180 ± 140	19574-18889

Table 5 - Summary of direct dates of antler manufacturing waste and comparison sample of AMS dates made on osseous material from Badegoulian and Lower Magdalenian contexts (numbers in brackets refer to Fig. 20b). After Bazile, 2006; Bourdier et al., in press; Clottes et al. eds., in press; Lenoir et al., 1991; Pétilion et al., 2008; Primault et al., 2007; Sacchi et al. eds., in press; <http://www.archeometrie.mom.fr/banadora/>.

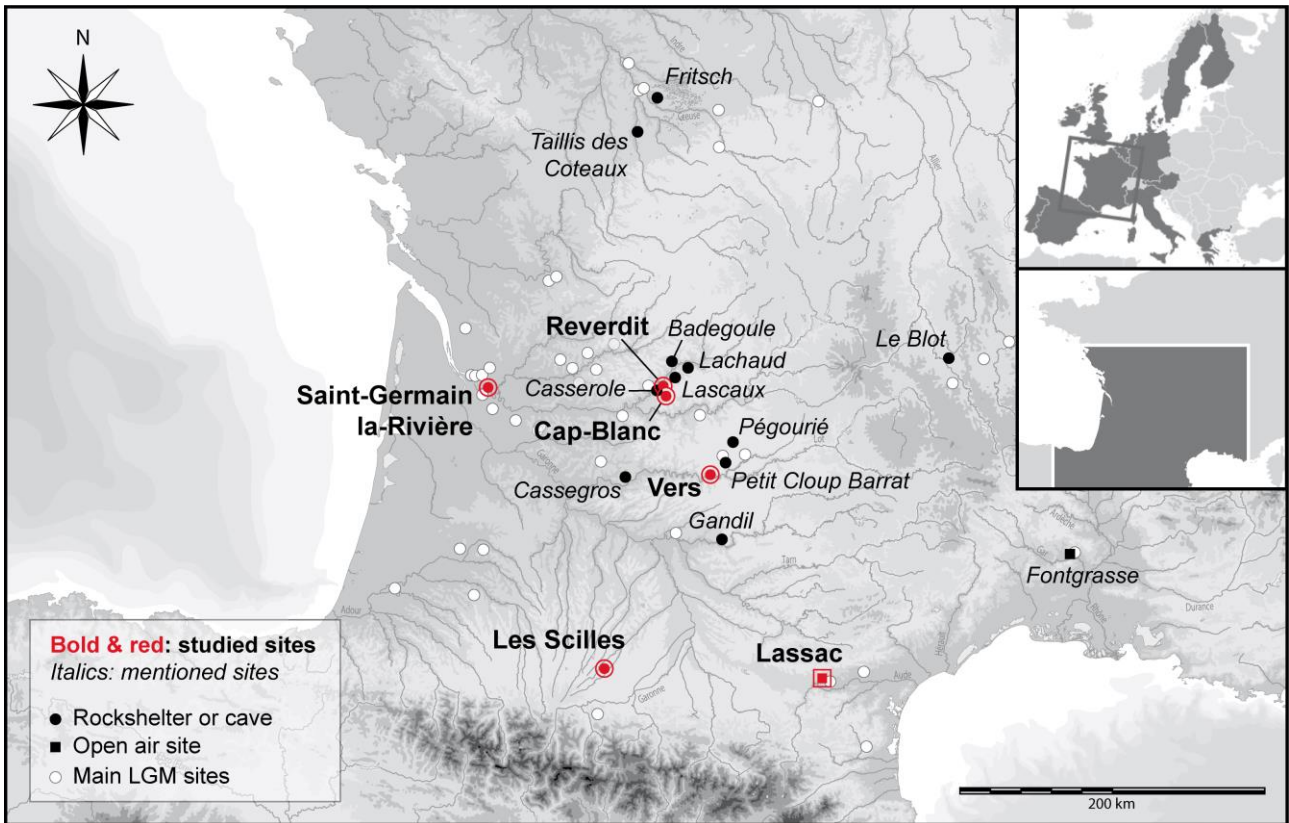


Figure 1 - Distribution of the main LGM sites in southwest France, and location of the sites mentioned in the text (all pictures and illustrations in the article are from the authors unless otherwise stated).



Figure 2 - Le Cuzoul de Vers, layer 13: examples of antler flakes from the Badegoulian layers.

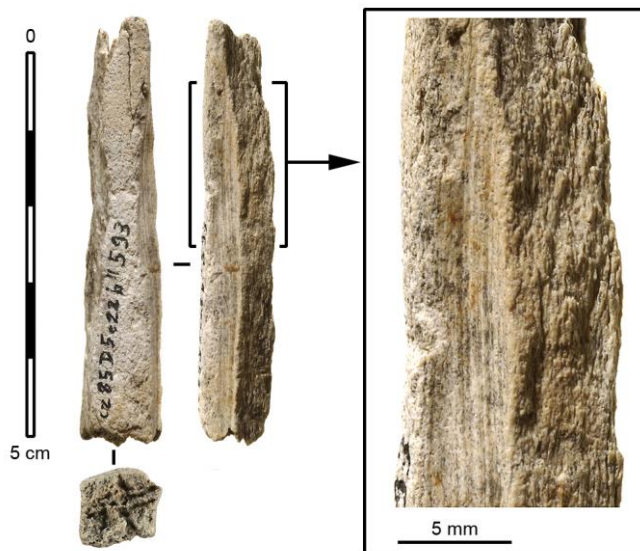


Figure 3 - Le Cuzoul de Vers, layer 22: antler artifact with a possible edge of groove on one side; detail view of the striations (picture by J.-F. Peiré, DRAC Midi-Pyrénées).

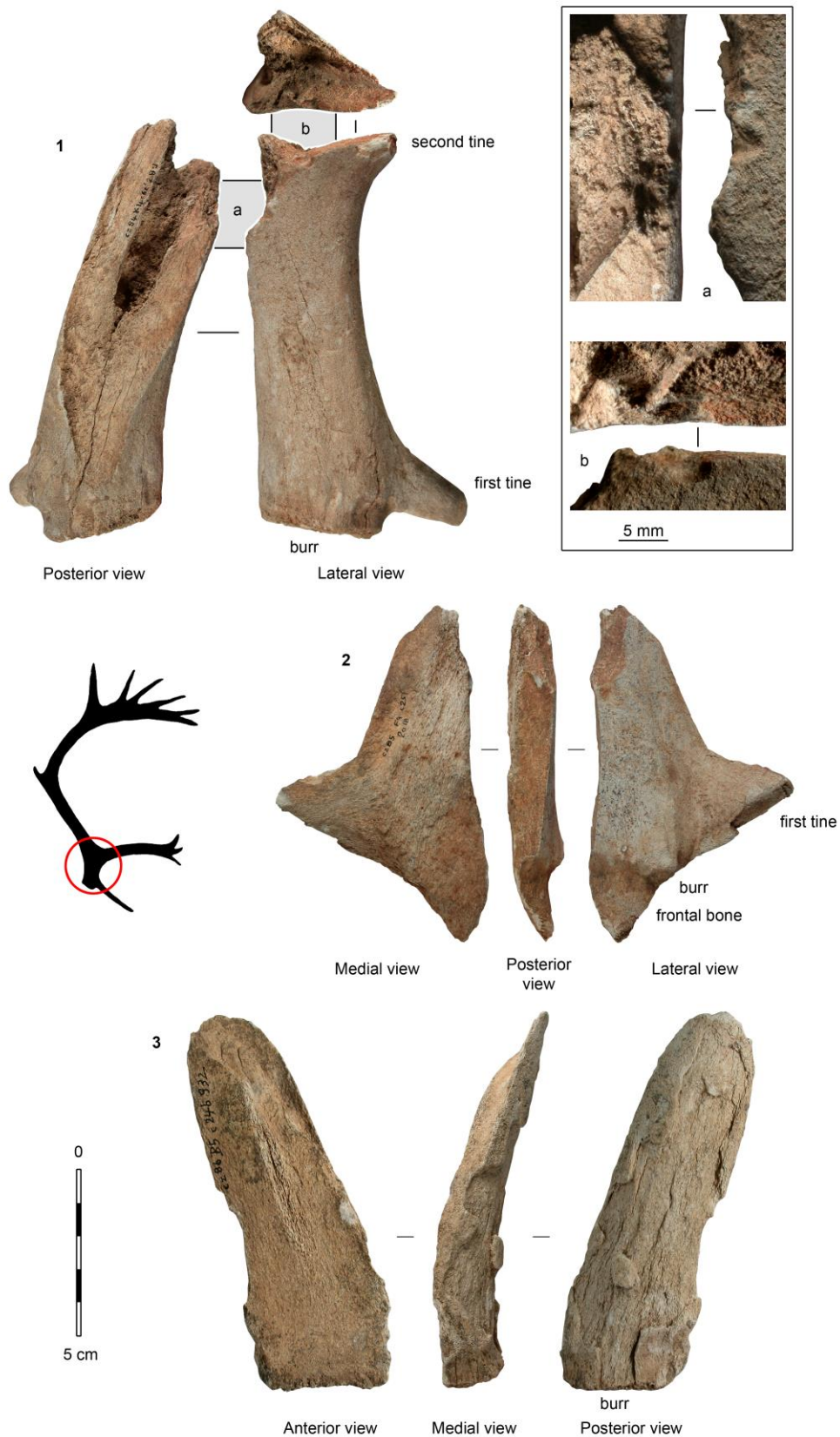


Figure 4 - Le Cuzoul de Vers: antler bases with knapping traces. 1: layer 6, base of a right shed antler with a large flake negative on the posterior face; a and b: detail views of the percussion notches on the lateral side. 2: layer 25, base of a right unshed antler with partial flake negatives on the posterior face. 3: layer 24, flake from the posterior side of a right shed antler.

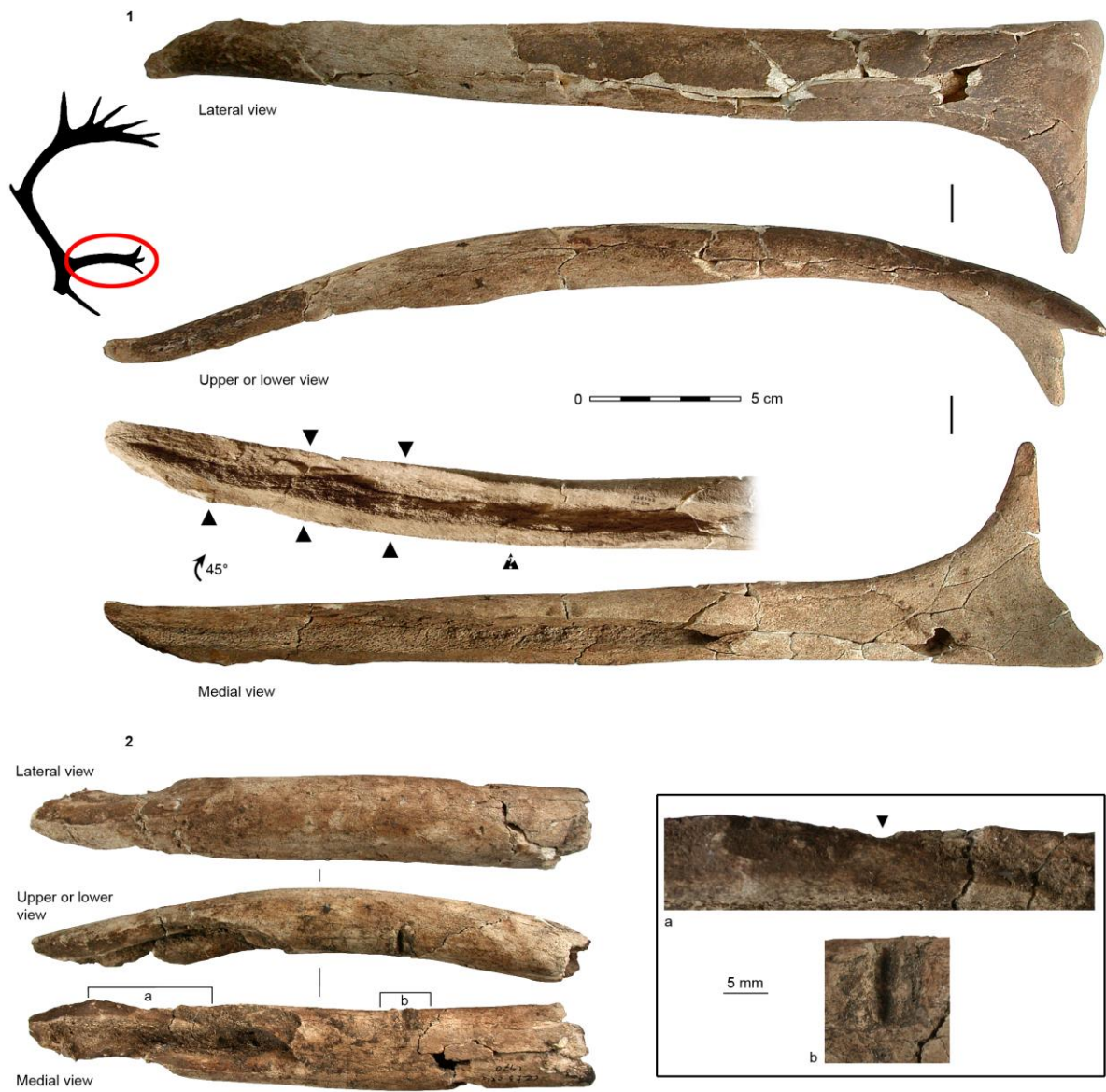


Figure 5 - Le Cuzoul de Vers: antler second tines with knapping traces. 1: layer 15, tine with flake removals on the medial side; detail view of the knapped portion (detail picture by J.-F. Peiré, DRAC Midi-Pyrénées). 2: layer 21, tine with flake removals on the medial and lateral sides; a and b: detail views of the percussion notches (b: failed flake removal).

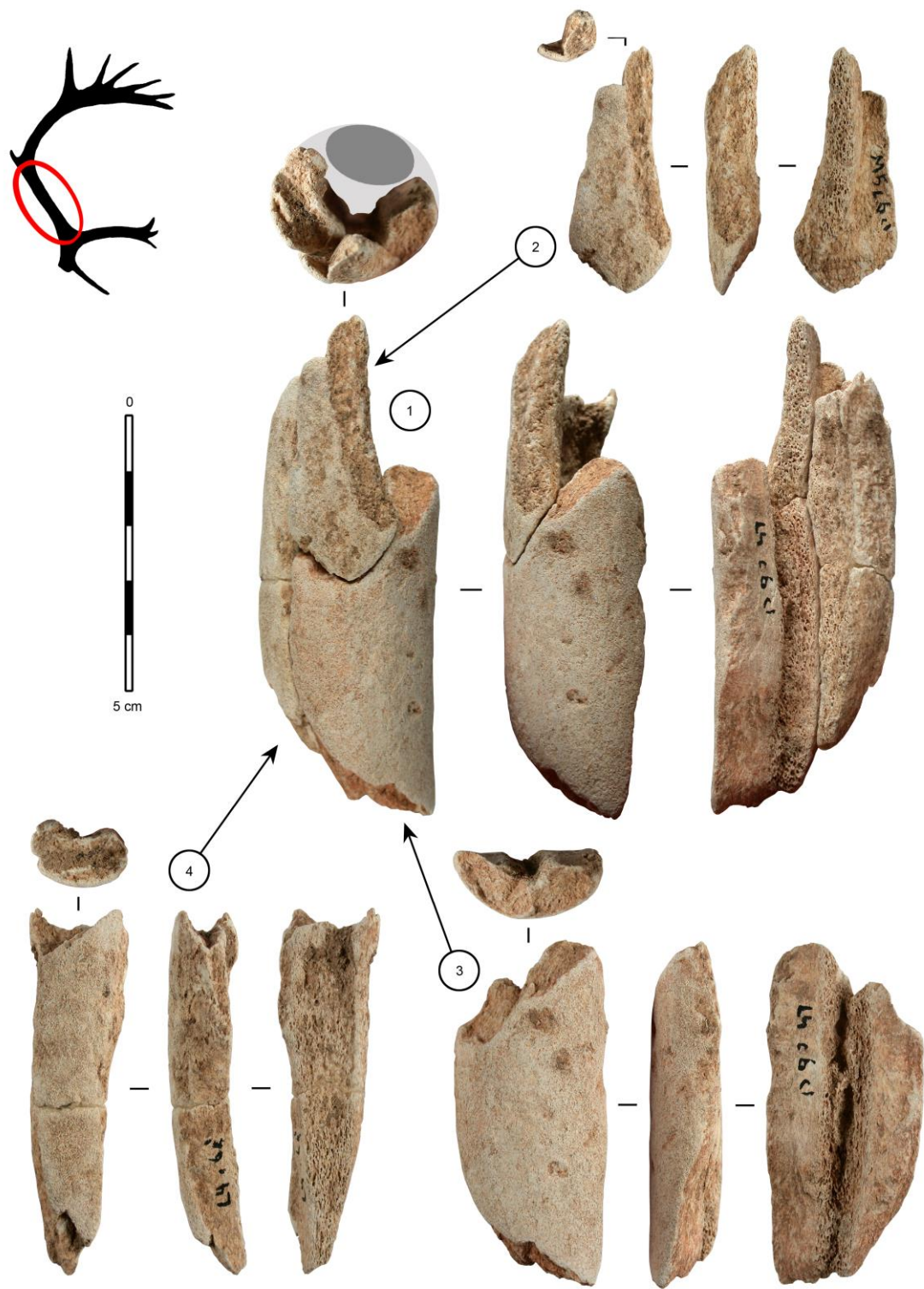


Figure 6 - Le Cuzoul de Vers, layer 6: refitting of three flakes representing the two thirds of the circumference of an antler beam. Numbers from 1 to 4 indicate the order of removal of the flakes (1: negative of a first, missing flake). On the cross-section view, the light shading indicates the missing part of the antler, and the dark shading outlines the part sought by the knapper.

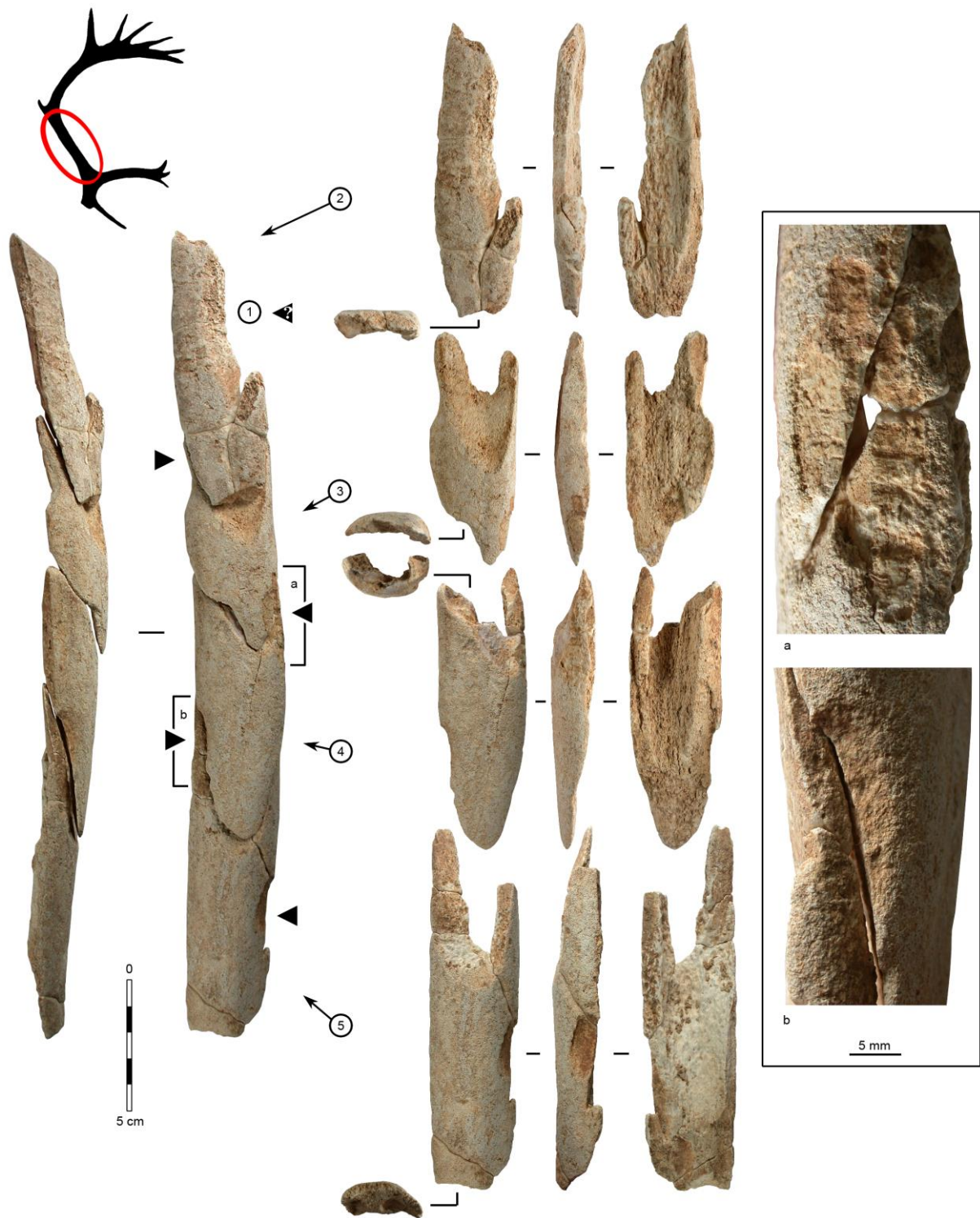


Figure 7 - Le Cuzoul de Vers, layer 6: refitting of four flakes from the lateral or posterior side of an antler beam. Numbers from 1 to 5 indicate the order of removal of the flakes (1: negative of a first, missing flake). Black stemless arrows show the location of the percussion notches; a and b: detail views of two percussion notches).



Figure 8 - *Le Cuzoul de Vers*: examples of antler flakes with a characteristic “tile” shape. 1: layer 13; 2: layer 6; 3: layer 11; 4: layer 16.

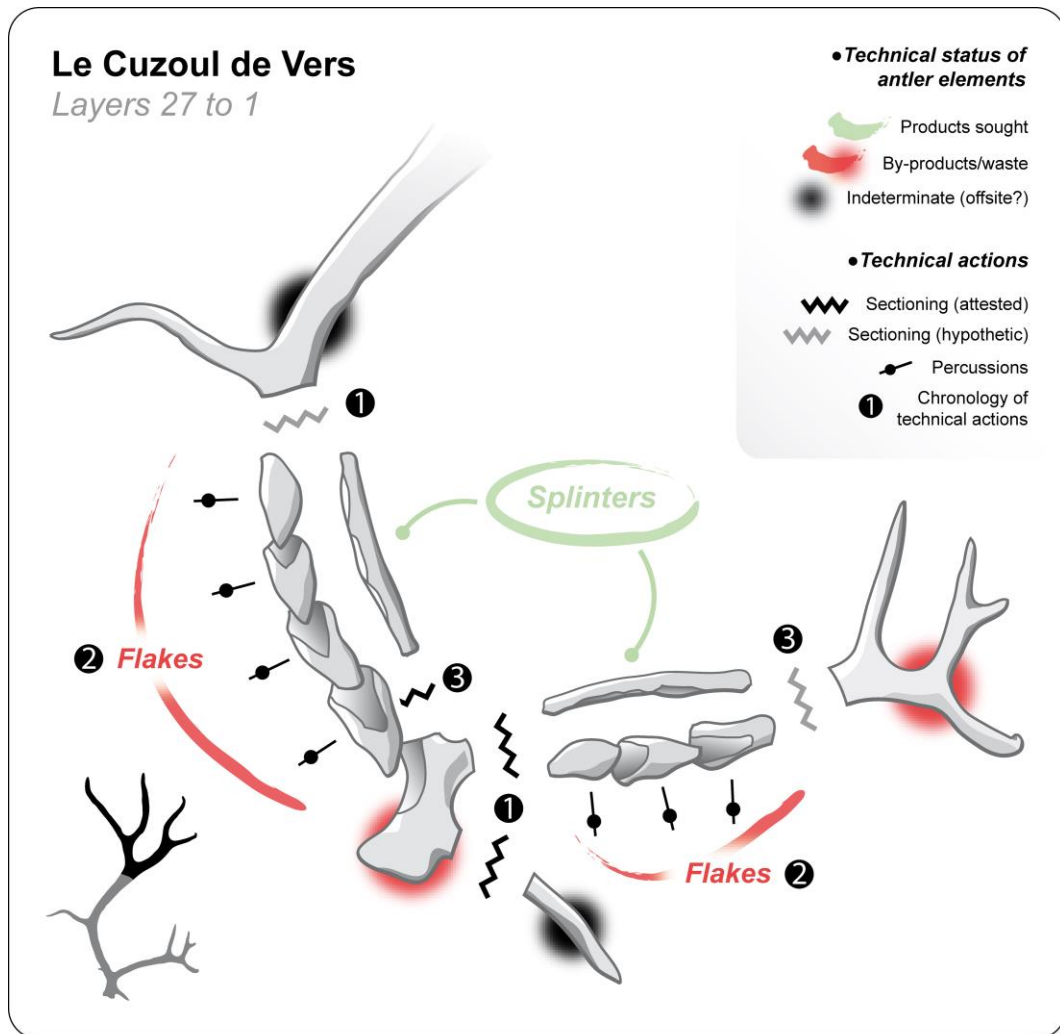


Figure 9 - Le Cuzoul de Vers: reconstruction of the antler primary reduction sequence in the Badegoulian levels.

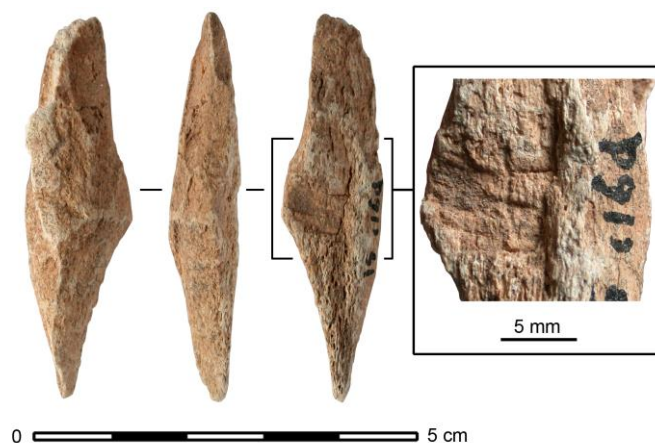


Figure 10 - Le Cuzoul de Vers, layer 16: antler flakes with percussion traces on the spongy side; detail view of the traces.

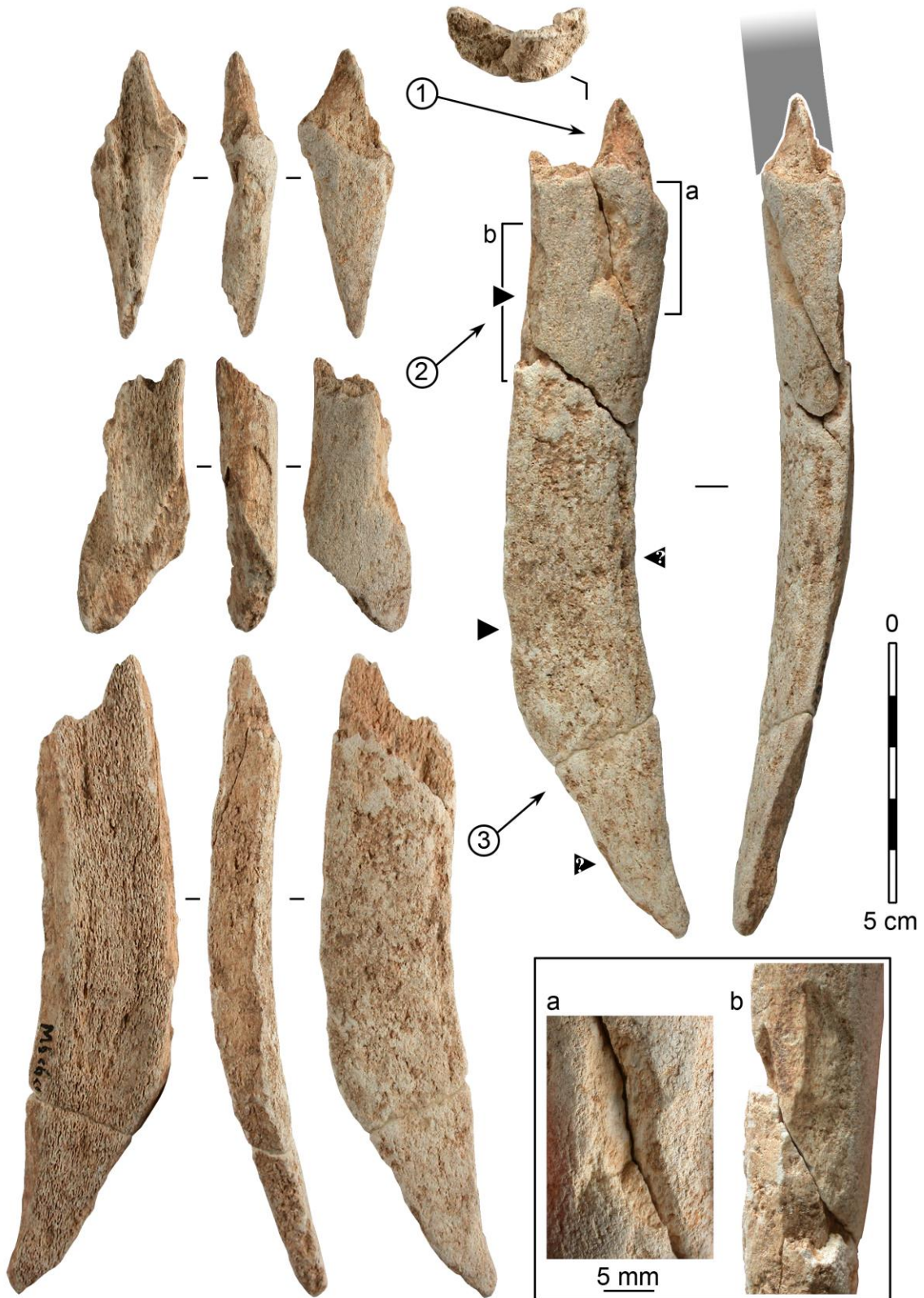


Figure 11 - Le Cuzoul de Vers, layer 6: refitting of three elements reconstituting a portion of antler splinter with a curved outline and profile. Numbers from 1 to 3 indicate the order of removal of the fragments. Black stemless arrows show the location of the percussion notches; a and b: detail views of two percussion notches on the upper and right sides. The shading outlines the part sought by the knapper.

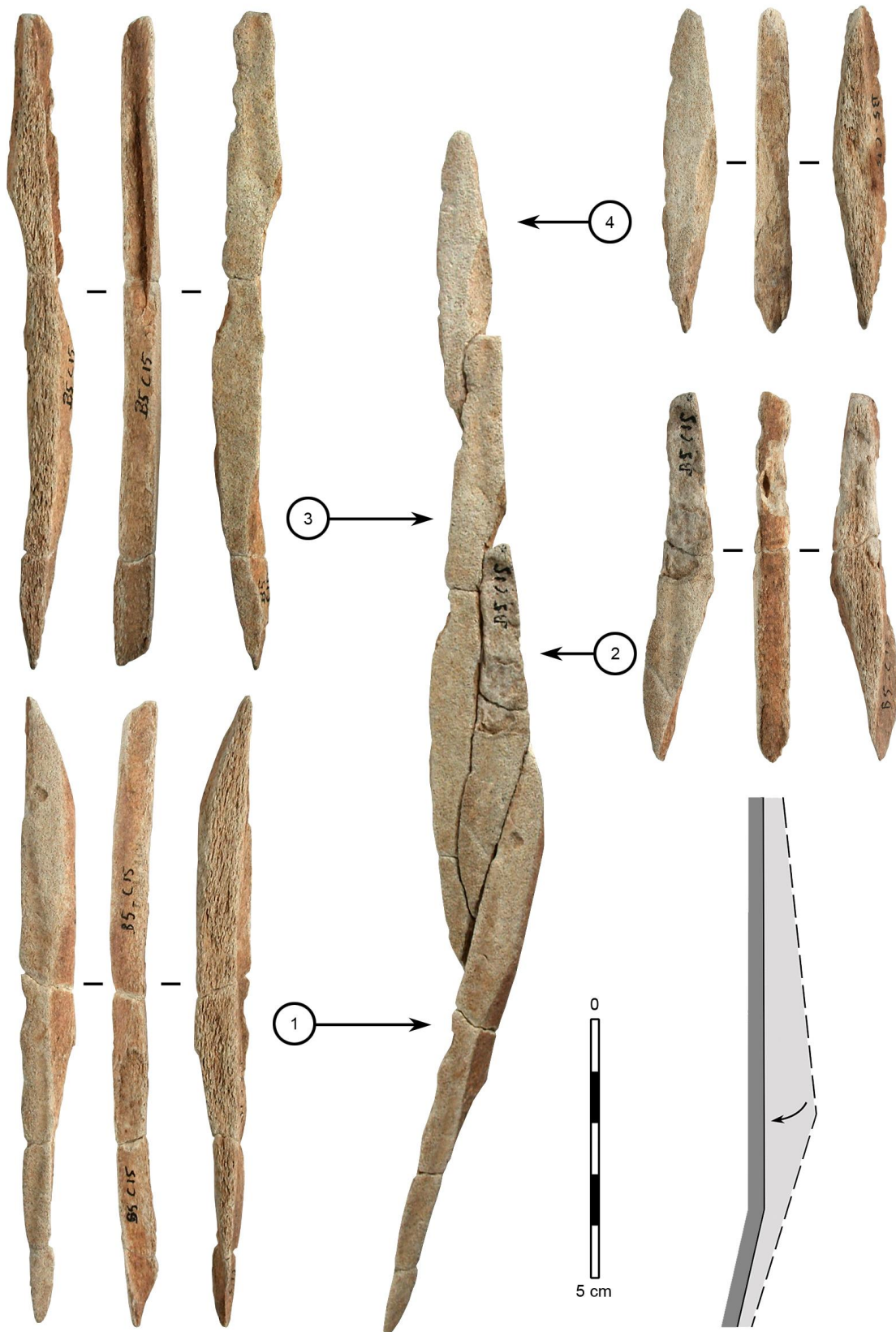


Figure 12 - Le Cuzoul de Vers, layer 15: refitting of four flakes knapped off the side of an antler splinter. Numbers from 1 to 4 indicate the order of removal of the flakes. Bottom right: comparison of the outline of the splinter's side before (light shading) and after (dark shading) the removal of the flakes.

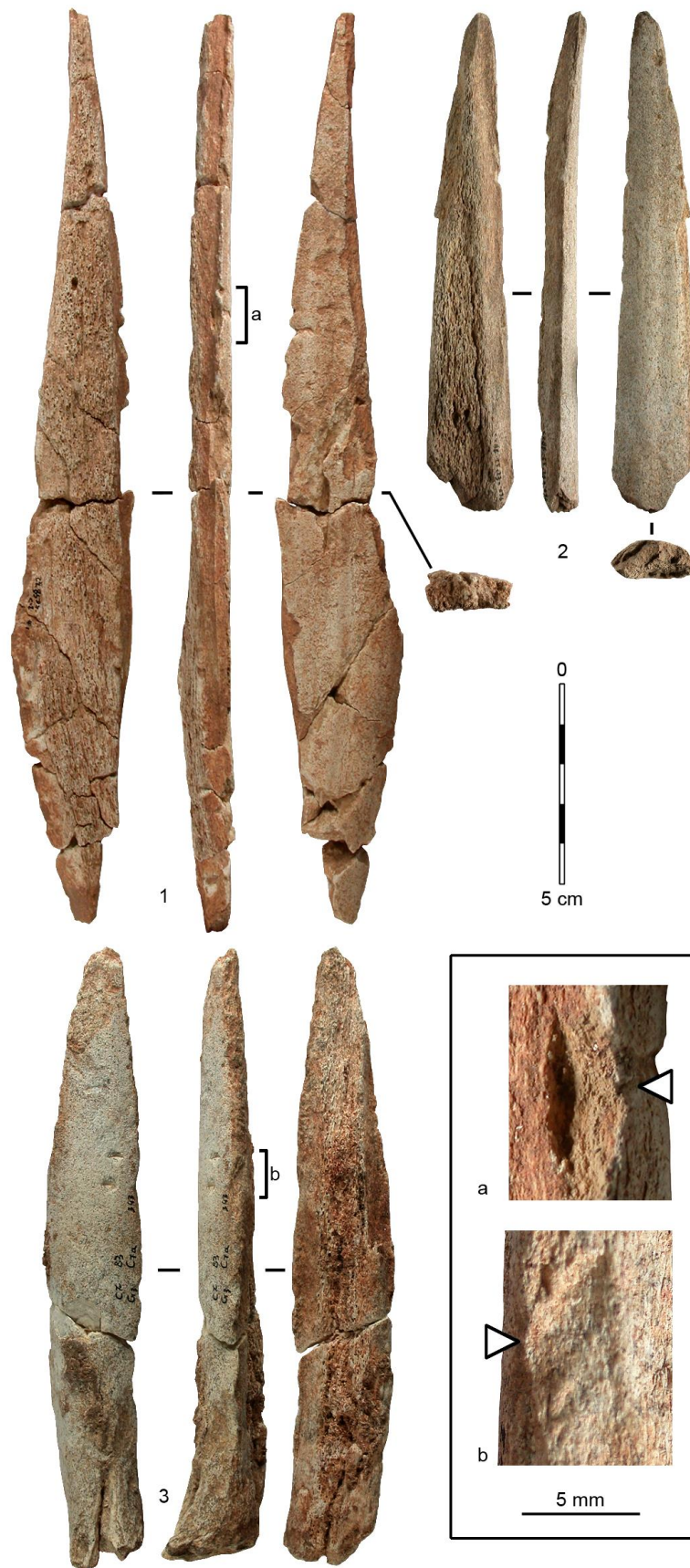


Figure 13 - Le Cuzoul de Vers: examples of splinters having undergone secondary reduction by knapping. 1: layer 12; 2: layer 23; 3: layer 7; a and b: detail views of two percussion notches (white arrows show the location of the percussion points).



Figure 14 - Le Cuzoul de Vers: finished objects on antler splinters. 1 to 3: wedges (layers 13, 16 and 11); 4 and 6: fragments of projectile points (layers 10 and 12); 5: complete self-barbed projectile point with its probable hafting mode (layer 9; drawing after Pokines and Krupa, 1997); 7 and 8: shaping debris or pointes à base raccourcie (layers 13 and 12).

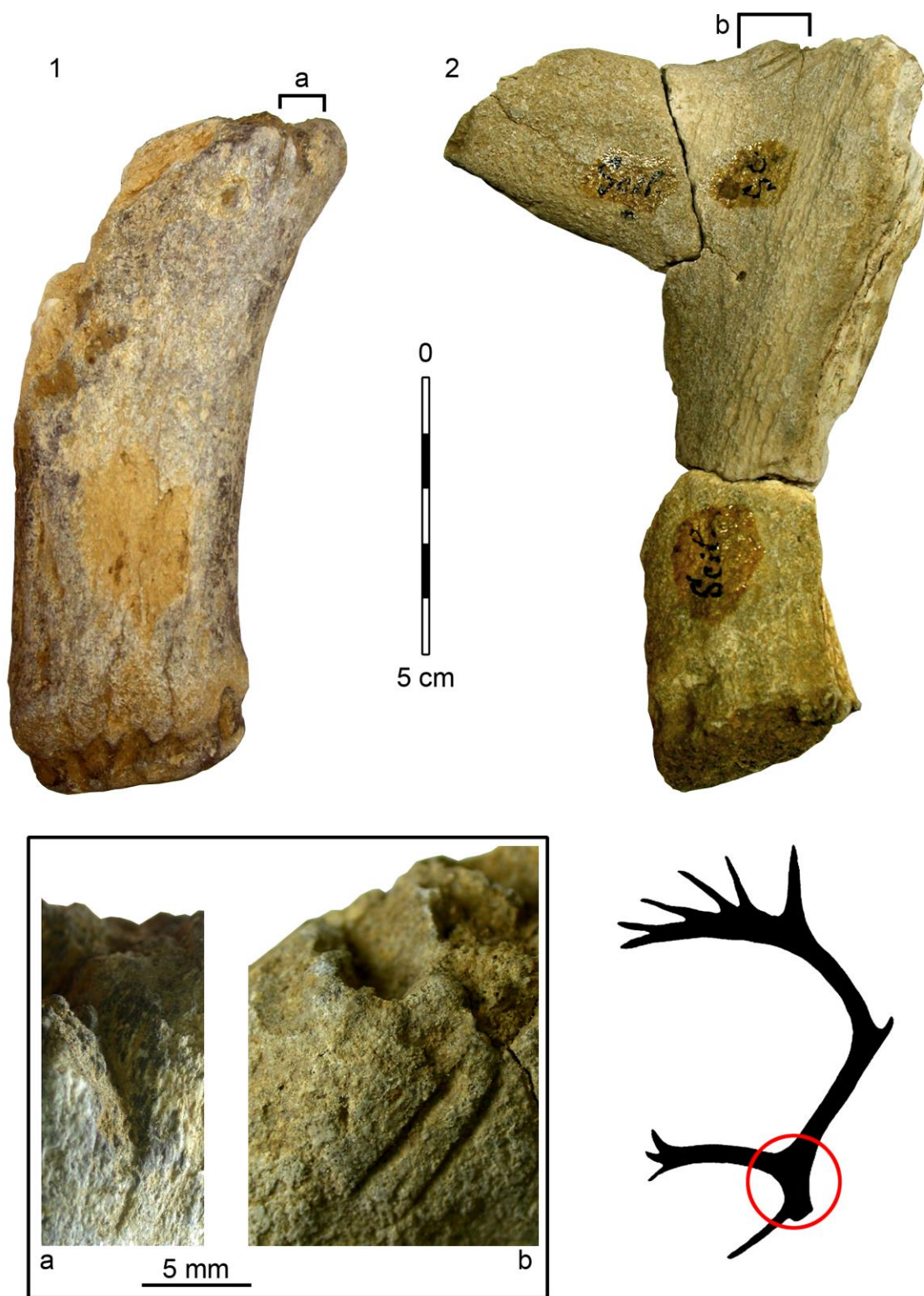


Figure 15 - La Grotte des Scilles, layer B: antler bases with traces of longitudinal grooving on the beam. 1: right shed antler; 2: left antler, probably unshed; a and b: detail views of the beginning of the grooves.

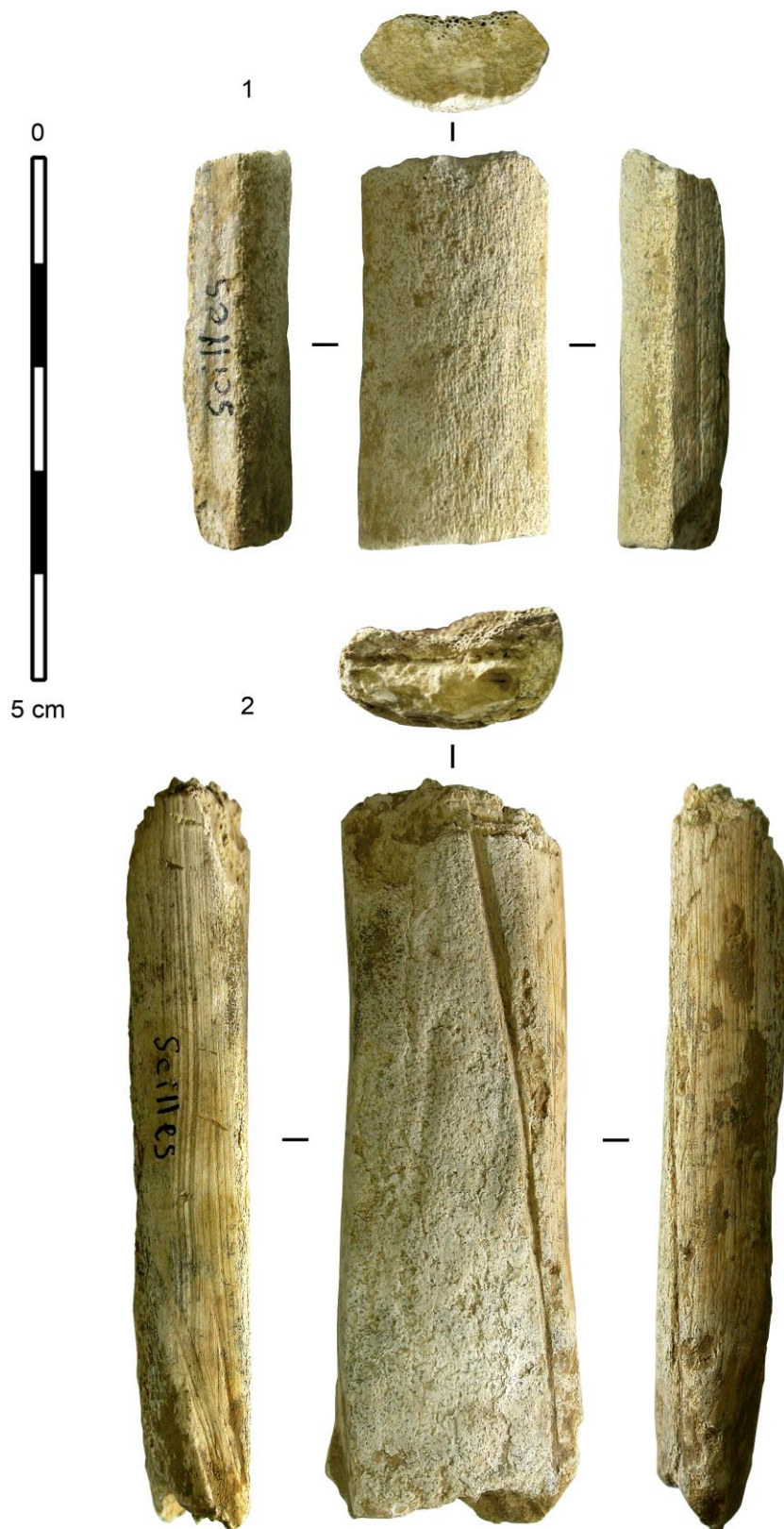


Figure 16 - La Grotte des Scilles, layer B: fragments of antler splinters. 1: fragment with edges of grooves on both sides; 2: fragment with sides already shaped by scraping, still showing the beginning of a groove on one side and an incision on the upper side left by a grooving tool.

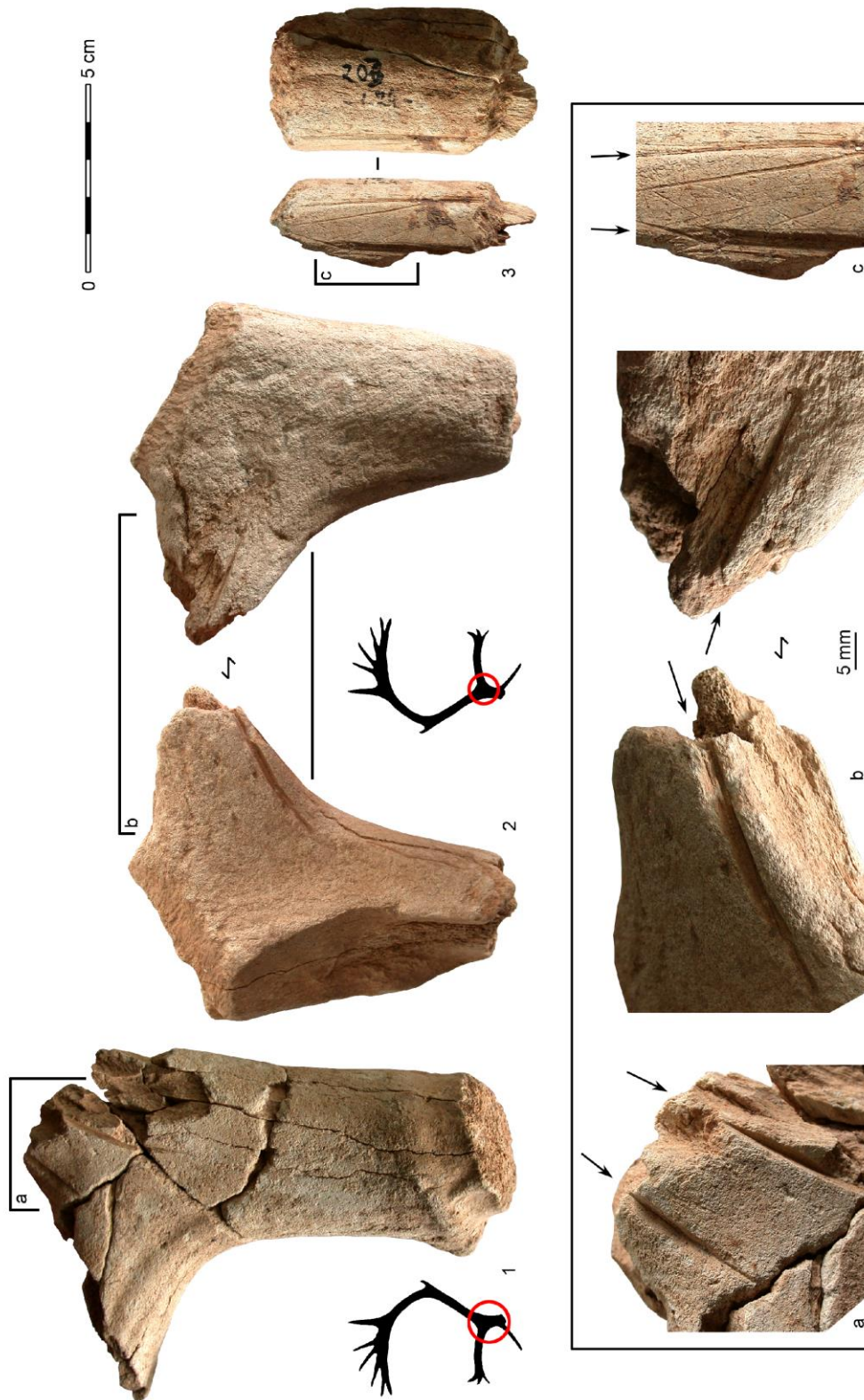


Figure 17 - Saint-Germain-la-Rivière, layer C3: antler manufacturing waste with traces of splinter removal by the GST. 1: base of a left shed antler with extremities of two longitudinal grooves along the beam on the lateral side; 2: base of a right, probably unshed antler, with extremities of grooves indicating the removal of a splinter on the lower side of the second tine (the antler was presumably detached from the skull by chopping and flexion – which broke part of the posterior face – and the beam was sectioned by chopping above the second tine); 3: fragment of beam with traces of an unfinished splinter extraction by the GST; a, b and c: detail views of the grooves (indicated by black stemmed arrows).



Figure 18 - Saint-Germain-la-Rivière, layer C3: fragment of antler splinter (probably a blank for a needle) showing edges of grooves on both sides.

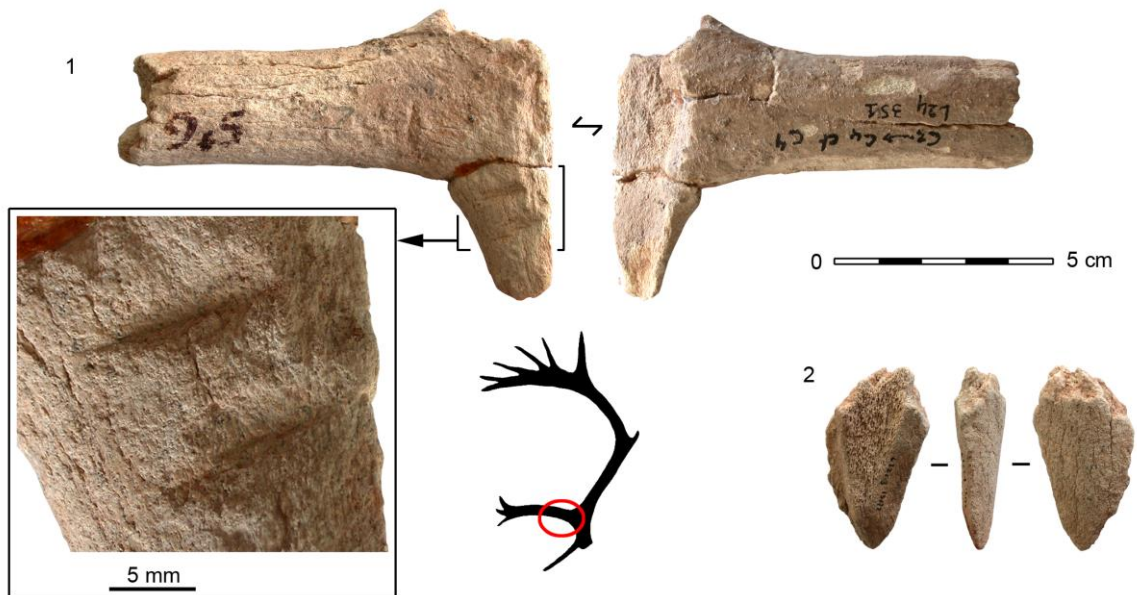


Figure 19 - Saint-Germain-la-Rivière: antler elements with traces of knapping. 1: fragment of antler base (with the beginning of the second tine) detached by percussion, with detail view of two percussion traces (layers C3/C4 and C4); 2: fragment of antler flake (layer C3).

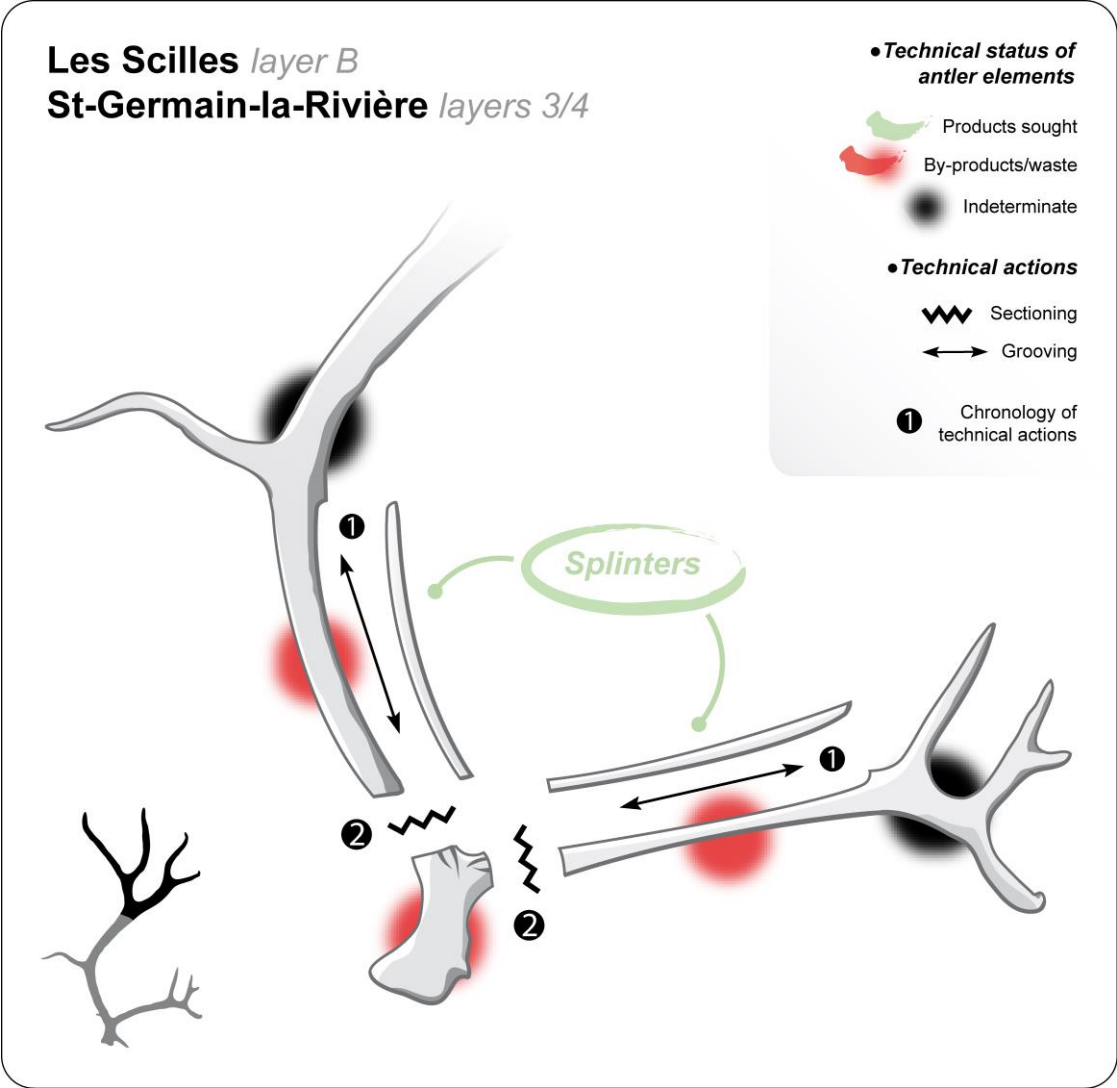


Figure 20 - La Grotte des Scilles, layer B, and Saint-Germain-la-Rivière, layers C3-C4: simplified reconstruction of splinter production on antler using the GST.

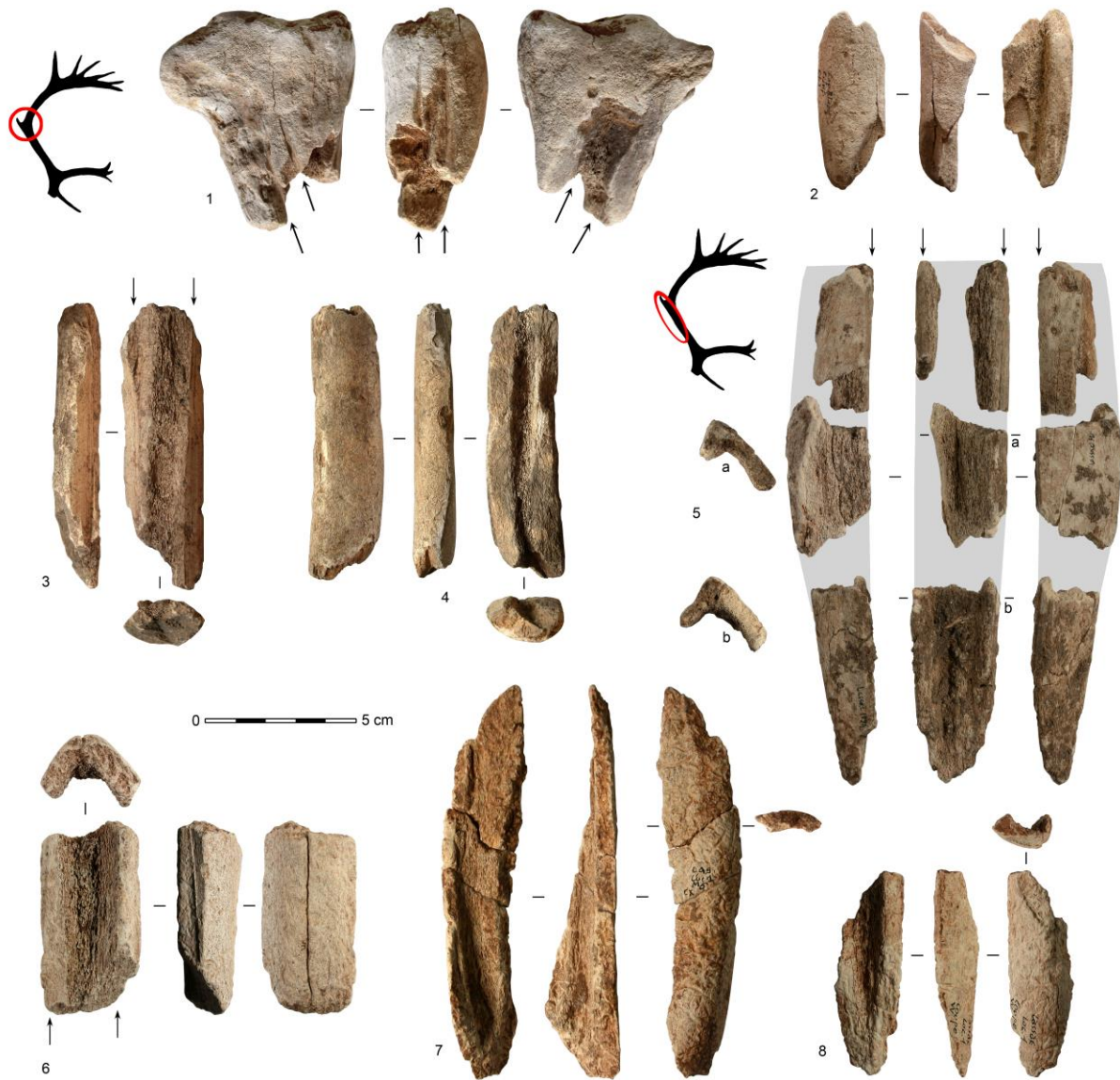


Figure 21 - Antler artifacts chosen for direct ^{14}C dating by AMS; grooves are indicated by black stemmed arrows. 1: Cap-Blanc, piece of manufacturing waste with six extremities of grooves, showing multiple splinter removals by the GST; 2: Cap-Blanc, antler flake; 3: Reverdit, splinter fragment with two parallel edges of grooves indicating the use of the GST; 4: Reverdit, splinter fragment with traces of several flake removals; 5: Lassac (test pit 1, layer 4), piece of manufacturing waste with two parallel edges of grooves indicating the removal of a splinter from the anterior side of the beam; 6: Lassac (surface finds), piece of manufacturing waste with two parallel edges of grooves indicating the use of the GST; 7 and 8: Lassac (locus 1), antler flakes.

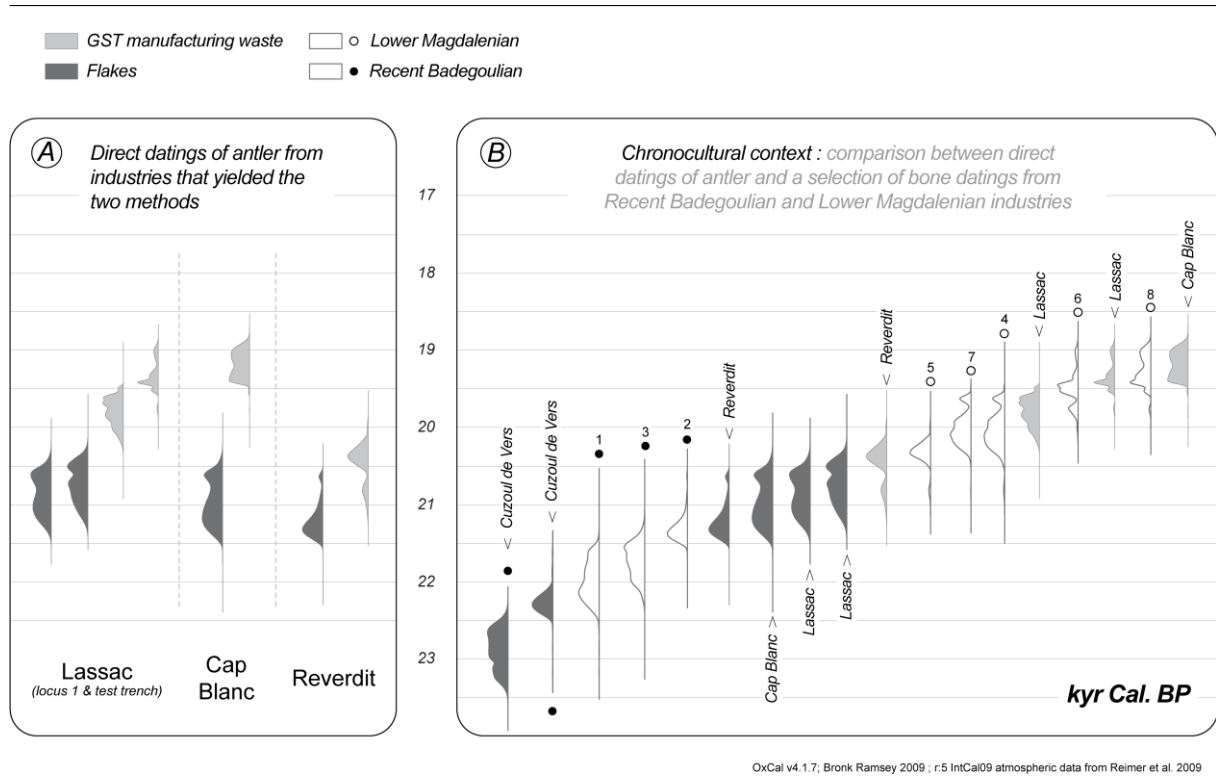


Figure 22 - a: calibrated results of the ^{14}C dates by AMS; b: and comparison with other ^{14}C AMS dates on osseous material from Badegoulian and Lower Magdalenian sites.

	Knapping	GST	¹⁴C Data (AMS)	
Questioned sites	Lassac locus 1		successive	This article Sacchi, 2003a and 2003b Pétillon and Sacchi, in press
	Lassac test trench			
	Reverdit			This article; Bourdier et al., in press
	Cap Blanc			This article
Badegoulian	Vers		23.5 to 21.5 kyr cal. BP	This article Pétillon and Averbouh, in press
	Fritsch		none	Allain et al., 1974; Rigaud 2004
Lower Magdalenian	St-Germain La Rivière		20.4 to 19.6 kyr cal. BP	This article
	Les Scilles		19.6 to 18.9 kyr cal. BP	This article; Langlais et al., 2010 Pétillon et al., 2008
	Gandil		20.5 to 18 kyr cal. BP	Ladier in Langlais et al., 2007
	Lascaux		22.6 to 21.5 ?* kyr cal. BP	Allain, 1979; Leroy-Prost, 2008 Aujoulat et al., 1998

*see the discussion in the text

Figure 23 - Summary of the antlerworking methods identified in Badegoulian and Lower Magdalenian sites in southwest France.

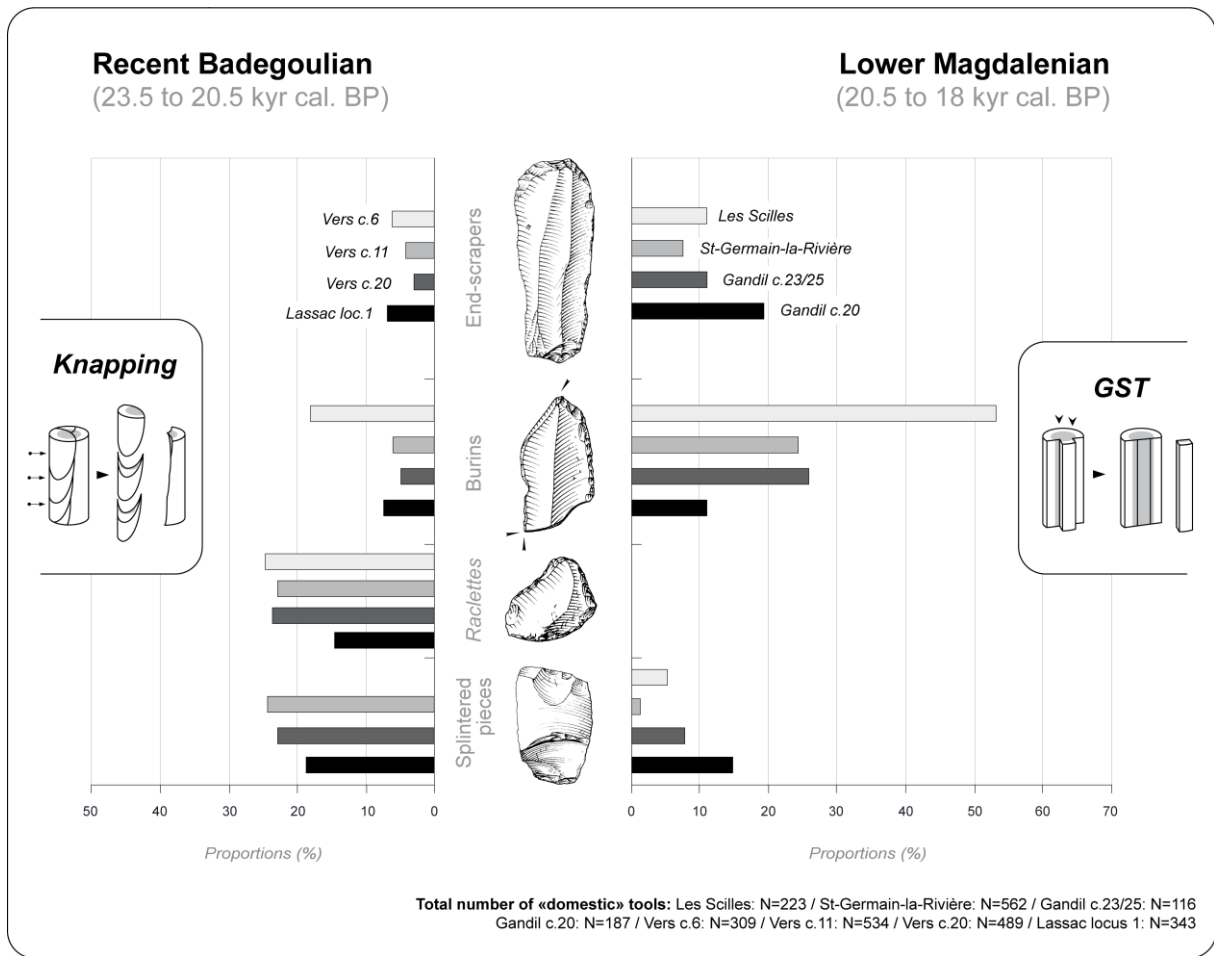


Figure 24 - Comparison of the proportions of the main lithic domestic tools (end-scrapers, burins, raclettes and splintered pieces) in assemblages from the Recent Badegoulian and the Lower Magdalenian with identified antlerworking methods. Data after Ducasse, 2010; Langlais, 2010; Langlais et al., 2010. Drawings by M. Jarry.

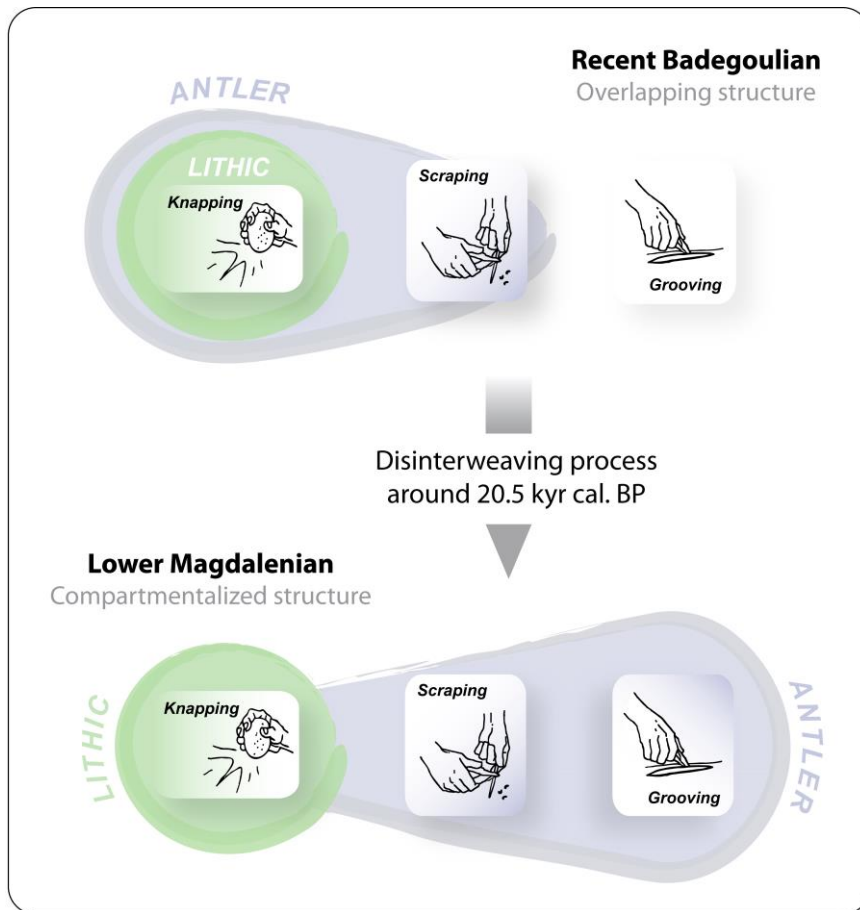


Figure 25 - Summary of the evolution of antlerworking techniques, and their relation to lithic technology, between the Recent Badegoulian and the Lower Magdalenian (“knapping”, “scraping” and “grooving” drawings adapted from S. Souvenir in Bellier et al., 1990, 1997).