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IDEAS NO LONGER WRITTEN IN ANTLER

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ABSTRACT

In the course of the Upper Paleolithic, antler debitage techniques seem to have followed a linear evolution. The earliest one, fracturing by cleaving, appeared during the Aurignacian and is considered by some specialists to be ineffective. According to them, it was not until the invention of the groove and splinter technique during the Gravettian that antler debitage became efficient. Nonetheless, during the Solutrean, fracturing once again became the most common technique, but by splitting. Based on a study of 102 Solutrean pressure tools and experimentations, we reach the conclusion that splitting is a very effective technique that can produce blanks with the same qualities as those made by the groove and splinter technique. The splitting technique was nonetheless excluded in previous studies. We explore the reasons for this and the particularities of the different antler debitage techniques evidenced in the Western Upper Paleolithic.

Based on current knowledge, it is widely thought that prehistoric bone and antler working followed a linear evolution from simple to complex and from low to high skill levels. While the order of appearance of the various techniques cannot be disputed, the permanence of some of them, their role in technical systems, and their efficiency, can be reconsidered.

Antler debitage e or the production of blanks from antler e is a good illustration of these issues. From the Aurignacian period (ca. 39000e28000 BP) on, antler was widely used in Western Europe to manufacture tools and weapons. Studies of archaeological assemblages (Liolios, 1999; Tejero, 2010) have concluded that cleaving was the only technique used by Aurignacians. By analogy with wood working, this technique has been defined as a dislocation of material through the insertion of a thin edge into the fibrous structure (Liolios, 2002). Antler is not a very fissile material, however, and the results of unsuccessful experiments suggested that no procedure yet existed that was well adapted to antler working. The groove and splinter technique e consisting of prying out a long thin strip after cutting two deep parallel grooves on either side and into the soft tissue - appeared during the Gravettian (ca. 29000e20000 BP) and is considered by archaeologists to be the first technique that was well adapted to making tools from antler. Using this technique, it is possible to obtain regular blanks with predetermined dimensions (Goutas, 2009), which was not possible in experiments using the cleaving technique (Liolios, 1999; Tejero et al., 2012).

Based on this information, researchers have considered antler debitage by cleaving to be an archaic and poorly adapted technique. Prehistoric artisans nonetheless continued using it during the Gravettian, Solutrean (ca. 20000e18000 BP; Goutas, 2004; Agoudjil, 2005).

During Badegoulian period, antler debitage procedure is original (19000e17000 BP; Allain et al., 1975; Pétillon and Ducasse, 2012). It consists of flaking by direct percussion (ibid). This latter does not surprise some researchers, since the Badegoulian culture is already viewed as atypical due to the nature of its lithic debitage techniques. Direct percussion was nonetheless excluded from the analytical framework applied to Aurignacian assemblages because it was considered to be too imprecise and difficult to use with antler (Liolios, 1999). While it is true that when antler is still attached to the animal it is very strong and shock-resistant, because of its organic fraction, once it is detached, it dries, loses its collagen, and becomes less resistant. Moreover, direct percussion was the most common, and probably best controlled, technique used by prehistoric artisans. Preconceptions concerning direct percussion arise from the fact that this technique is poorly known outside of the domain of lithics.

In the context of a Ph.D. thesis, one of us (M. B.) has studied Solutrean assemblages in southwestern France. Solutrean culture develops over a short period during the Last Glacial Maximum. Solutrean groups are distributed in southwest Europe, in France and the Iberian Peninsula. They are distinguished by an original production of lithic foliaceous points. These points are not only exceptional by their shape but also because of the later stage of their processing which generally involves the pressure technique. However, pressure flaking tools, and Solutrean bone tools in general, are poorly known.

We studied assemblages from 4 major sites excavated in the early twentieth century: Laugerie-Haute, Badegoule, Fourneau du Diable (Dordogne) and Roc de Sers (Charente). The archaeological collections are preserved at the Musée d'Archéologie National (Saint- Germain-en-Laye, Yvelines, France) and the Musée Nationale de Préhistoire (Les Eyzies-de-Tayac, Dordogne, France). One of us (M. B.) has observed that antler tools of these assemblages were predominantly manufactured using the splitting technique - parting by stroking e in contrast to previous authors who assumed that the groove and splinter technique was predominant. In the Solutrean context, pressure flaking tools, of which we have made experimental examples in order to understand how they were manufactured, provide a good example of the use of the splitting technique.

1. Technical parameters and criteria of identification

1.1. ANTLER AS A RAW MATERIAL

Antler is a heterogeneous material. Its morphology and structure vary depending on the species (Billamboz, 1979; Fig. 1). Reindeer (Rangifer tarandus) antler has a thick cortical tissue surrounding a spongy tissue with compact alveoli, while the Red Deer (Cervus elaphus) antler has a thinner cortical tissue surrounding a spongy tissue with open alveoli (Bouchud, 1966, 1974). The thickness of the compact tissue is an important parameter as this is the part from which tools are manufactured. The morphology and internal structure of antler also varies depending on the gender, age and diet of the animal (Bouchud, 1966; Billamboz, 1979). On a single antler, the proportion of cortical and spongy tissue varies depending on the anatomical part and the phase of development (Averbouh, 2000). Its physical properties can also vary. During its formation, antler is rather soft. Just before it is shed, it becomes hard due to its calcification (Provenzano, 2001). After it is shed, the collagen gradually decomposes and the antler becomes brittle. It can then be altered by weathering processes (Behrensmeyer, 1978).

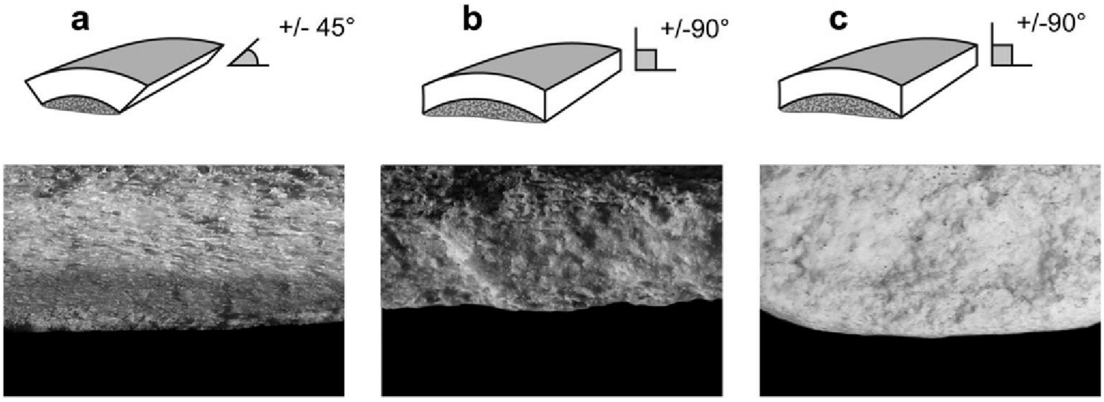
1.2. FRACTURE PLANE

Fracturing produces a feature designated as the fracture plane. Based on the angle and texture of the fracture plane, it is possible to determine whether bone was dry or fresh when it was fractured (Villa and Mahieu, 1991). While antler and bone do not have the same morphology or structure, the criteria of identification appear to be identical for both materials. On fresh antler, the fracture plane is acute (less than 45°) and has a fibrous texture (Fig. 2a). On dry antler, the angle is close to 90° and the surface is rough (Liolios, 1999; Pétillon and Averbouh, 2012; Fig. 2b). The fracture plane of a fossilized antler can also be 90°, but the surface has a very chalky texture (Fig. 2c).

While the fracture planes created by direct and indirect percussion cannot be distinguished from each other, the direct percussion hammer and intermediate tool used for indirect percussion do not produce the same traces. On bone, direct percussion creates notches (negative flake scars), cracks, pits (depressions on the bone surface), micro-striations (hammer skid-marks on the surface) and splinters (e.g. Blumenshine and Selvaggio, 1988, 1991; Villa and Mahieu, 1991; Galan et al., 2009). On antler, only notches and impact points have been identified (Pétillon and Ducasse, 2012). Indirect percussion using an intermediate tool results in pounding traces in the spongy tissue (Rigaud, 1984; Liolios, 1999; Goutas, 2004; Tejero, 2010). In all cases, the visibility of the traces depends on the state of preservation of the artifacts.

Figure 1. *Morphology and structure of: a) reindeer antler, b) red deer antler*

Figure 2. *Surface and angle of fracture plane of: a) fresh antler, b) dry antler; c) fossil antler (archaeological).*



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2. Experiments with Aurignacian and Badegoulian debitage

Experimental and archaeological data show that debitage by direct and indirect percussion are also distinguished by their procedure and by the morphology of the blanks and waste products obtained.

2.1. AURIGNACIAN DEBITAGE BY CLEAVING

Until recently, it was thought that indirect percussion was the only antler debitage technique used during the Aurignacian. Experiments led to the proposal of two cleaving methods: one with reindeer antler (Liolios, 1999), the second with red deer antler (Tejero, 2010).

The first method is realized on a segment of fresh reindeer antler. A large and resistant intermediate tool is inserted into the spongy tissue and progressively implanted by percussion. The radial pressure of the tool creates a fissure in the cortical tissue. When the cortical tissue is thin, the fissure spreads and cleaves the shaft in two (Fig. 3a; Liolios, 1999). It is not possible to obtain long and thin blanks using this method: the longer the segment, the wider the blank.

The second method is realized on a segment of red deer antler whose cortical tissue is approximately 0.5 cm thick. The sharp edge of an intermediate tool is placed on the cortical tissue at one end of the segment. It is then struck by percussion to initiate a fissure. A conical intermediate tool is then inserted into the spongy tissue on the same end to enlarge the fissure and hold it open. The fissure is progressively lengthened with the sharp intermediate tool. The pressure increases and initiates a second fissure parallel to the first one. The progressive enlargement of the initial fissure propagates both fractures until the end of the segment (Fig. 3b). The morphology and dimensions of the blanks obtained are highly variable.

With the first method, it is difficult to control the propagation of the fissure, which often deviates obliquely. The flakes obtained are thus very short (Liolios, 1999). With the second method, the fissure is more or less directed with the two intermediate tools. To redirect an oblique fissure, the experimenter proposes bipolar cleaving: a new fissure is initiated at the other end of the segment. When this second fissure reaches the middle of segment, the segment is placed on an anvil and fractured by direct percussion in order to join the two fissures (Tejero et al., 2012).

With both methods, the productivity is irregular and the dimensions of the products are highly variable. Their width is always random. With the first method, the starting point of the fissure is not chosen. In the second method, the location of the parallel fissure produced by the wedge is also not chosen.

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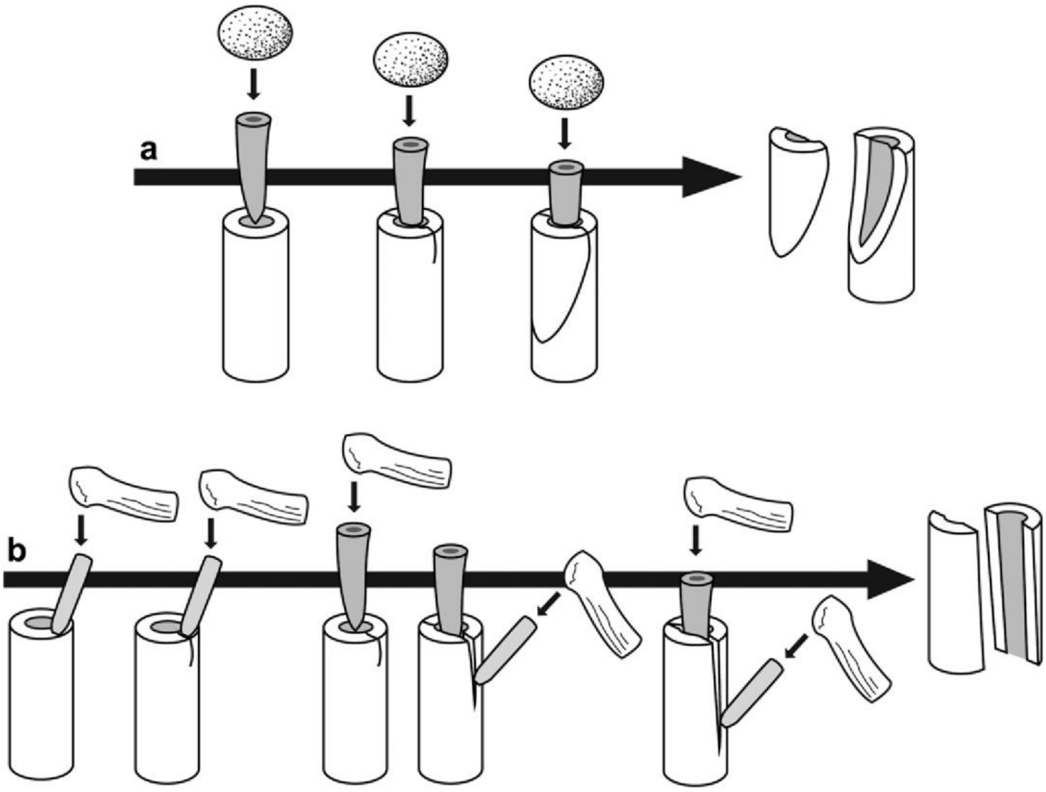
Figure 3. *Debitage by cleaving: a) Method 1, b) Method 2 (after Liolios, 1999; Tejero et al., 2012).*



2.2. BADEGOULIAN DEBITAGE BY FLAKING

Numerous antler flakes have been found in the Badegoulian layers of Abri Frisch (Indre, France; Allain et al., 1975) and Cuzoul de Vers (Lot, France; Clottes and Giraud, 1989). These flakes are short and wide, sometimes shaped like a roof tile. Some of them have been refitted. Impact notches indicate perpendicular percussion with very heavy stone hammers. Dispersed impact points on the antler suggest repeated shocks. According to these authors, Badegoulian debitage would thus consist of the removal of blanks from a whole or partial antler through the successive detachment of flakes by direct percussion. The flakes would therefore the waste-products (Pétillon and Ducasse, 2012).

Experiments were realized using fresh reindeer antler. The antler was placed on a limestone anvil with acute corners and struck with a cobble weighing 1-1.5 kg. The first flakes were difficult to detach, but the progression of the work then became easier. The percussion sometimes created fissures into which a wedge could be inserted in order to remove larger pieces. The final product was an elongated blank with negative flaking scars on its lower face (Allain et al., 1975; Rigaud, 2004; Fig. 4). This process was fast, but produced a large quantity of waste: only 1/3 of the volume of the beam was usable.

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3. Solutrean debitage by splitting

3.1. ARCHEOLOGICAL MATERIALS

In the context of Ph.D. research on Solutrean bone industries in southwestern France, one of us (M.B.) has identified 102 pressure flaking tools made from reindeer antler, probably used to shape foliate points. In the archaeological assemblages that we have studied, there is no waste from the production of these tools. However, the blanks of pressure tools were only slightly worked (Fig. 5). Their dimensions are close to the initial dimensions. The lateral edges are fracture planes, which were only partly shaped by chopping (Fig. 6). Therefore, the traces of debitage are still visible. We hypothesize that the blanks were produced by fracturing.

These pressure flaking tools are elongated and have an ovate, trapezoidal or concave-convex section and a rounded tip. The average length of the whole pieces is 12.8 cm; the smallest is 5.2 cm and the longest 22.7 cm. The average width is 2 cm. The thickness of the compact tissue of most specimens is between 0.7 cm and 1 cm, which corresponds to the beam of a fully developed male reindeer antler. Most of the fracture planes are oblique, indicating that the antlers were fractured when fresh. Some pieces have percussion marks on their lateral edges (Fig. 7). This is probably the result of direct percussion, but the traces are few and highly altered.

We can thus assume that the objective to manufacture these pressure flaking tools was to produce long, regular and calibrated blanks that would require a minimum of subsequent shaping.

3.2. NEW EXPERIMENTS

3.2.1. RAW MATERIALS AND TOOLS

We began our experiments with reindeer antler segments since this is one of the most abundant waste products in Solutrean assemblages (Inline Supplementary Fig. S1), along with the basal parts cut at the starting point of the beam (Inline Supplementary Fig. S1).

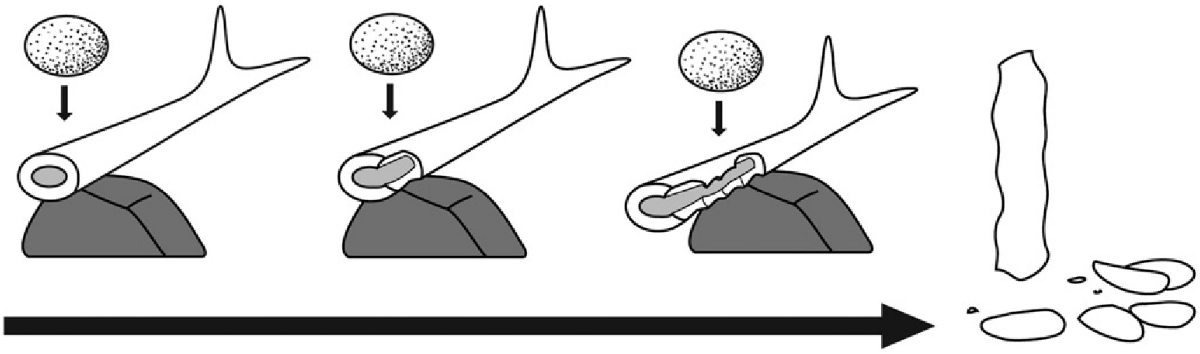
Inline Supplementary Fig. S1 can be found online at http://dx. doi.org/10.1016/j.jas.2012.07.006.

All experiments except one were realized with raw material of the same quality as that found in the archaeological assemblages: fresh or semi-fresh male reindeer antler from Lapland. Some blood was still trapped in the spongy tissue. The seven segments used (Fig. 8a) originate from the lower part of the beam and, in one case, probably from the second tine. They were pre-cut at both ends with a mechanical saw. Their lengths were between 7.7 and 15.5 cm, their diameters between 2.6 and 3.5 cm, and the thickness of their cortical tissue between 0.7 cm and 1 cm. All segments were worked outside where the temperature was fro 18° to 20 °C. One specimen was fractured while frozen (it was kept in a freezer for one night at -20 °C).

In one case, we used a whole shed antler from a young reindeer (Fig. 8b). It was very dry and fissured. Its surface was green from weathering. The thickness of its cortical tissue was 3 mm at the top of the beam, 4 mm at the bottom of the beam and 6 mm at the basal part. The tines were removed to facilitate holding it in place during the operations.

- Our experimental tools would have been available in the Solutrean environment:
- One Intermediate tool made from an antler tine (Fig. 9a) whose tip was beveled by grinding on a sandstone;
- One 1.5 kg cobble used as hammerstone (Fig. 9c);
- Two anvils, one made from wood (Fig. 9d), for the indirect percussion activities, and one consisting of a large flint block with a concave working surface (Fig. 9e) for the direct percussion activities.

Figure 4. *Debitage by knapping of an antler object (after Allain et al., 1975; Pétillon and Ducasse, 2012).*



3.2.2. TEST 1: INDIRECT PERCUSSION

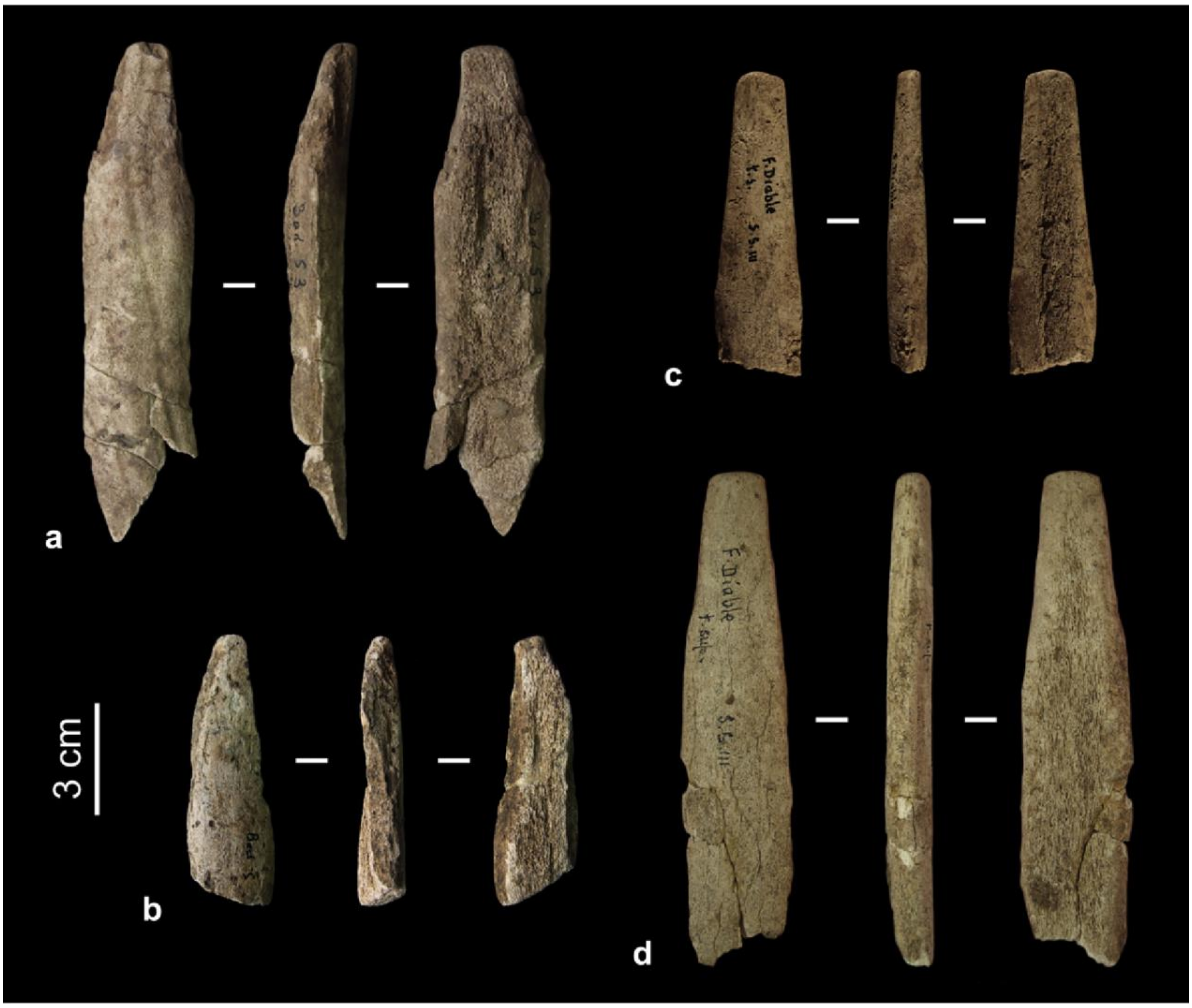
We tested both of the methods proposed for Aurignacian debitage.

3.2.2.1. Method 1. Attempts to cleave starting from the spongy tissue produced results that correspond to those described by D. Liolios (Liolios, 1999). On the first segment, three fissures began simultaneously, and two of them deviated obliquely to form a short sub-triangular flake with a thin distal end (Inline Supplementary Fig. S2). The morphometric features of this blank do not correspond to those of Solutrean pressure flaking tools. Intensive shaping would have been necessary to give it the appropriate morphology, which is not consistent with the archeological specimens. The remaining waste product consists of a large portion of the segment, but D. Liolios does not suggest any solutions for continuing with the debitage.

Inline Supplementary Fig. S2 can be found online at http://dx. doi.org/10.1016/j.jas.2012.07.006.

3.2.2.2. Method 2. We were not successful at cleaving the antler by indirect percussion on the compact tissue as we were unable to initiate any fissures. The compact tissue was simply crushed at the point of contact with the tip of the intermediate antler tool (Inline Supplementary Fig. S3). Additional tests with sharp intermediate flint tools were also unsuccessful.

Figure 5. *Solutrean pressure flaking tools: a and b) Badegoule (Dordogne, France), coll. Cheynier, Musée d'Archéologie Nationale (France); c and d) Fourneau du Diable (Dordogne, France), coll. Peyrony, Musée National de Préhistoire (France).*



Inline Supplementary Fig. S3 can be found online at http://dx. doi.org/10.1016/j.jas.2012.07.006.

There are several possible explanations for this failure. First, the ends of our experimental segment were not chopped like the archaeological samples but pre-cut with a mechanical saw. This may have made them more resistant to cleaving because of a flat section. Secondly, fracturing may be difficult or impossible when the compact tissue is very thick. On our experimental pieces, this thickness is greater than that of the experimental pieces described above, but the difference is sometimes only 0.1 cm, and thus cannot be the sole cause of this failure.

A third factor may be state of freshness of the antler. We therefore performed the same operation on dry antler. The result was somewhat better. Indirect percussion was efficient when we made use of the desiccation fissures already present, but it became more difficult on the basal part of the antler where the compact tissue was thicker. The opened fissures systematically deviated obliquely, however, and it was impossible to precisely control their direction. The morphology of the blanks obtained was thus very random.

The application of indirect percussion to dry antler was therefore not conclusive. We nonetheless obtained a blank that we were able to shape into a pressure flaking tool and use to shape a shouldered point (Inline Supplementary Fig. S4). It is generally assumed that prehistoric artisans used fresh antler to manufacture tools (Averbouh, 2000). However, the pressure flaking tool that we made from dry antler was as effective as others from fresh antler and used by one of us (S.M.) to manufacture hundreds of shouldered points in a previous experimental program (Geneste and Plisson, 1989; Geneste and Maury, 1997). The indirect percussion technique nonetheless appears to be poorly adapted to cleaving reindeer antler.

Inline Supplementary Fig. S4 can be found online at http://dx. doi.org/10.1016/j.jas.2012.07.006.

Figure 6. *Fracture plane on a Solutrean pressure flaking tool: a) shaped, b) unworked, from Le Fourneau du Diable, coll. Peyrony, Musée Nationale de Préhistoire (France).*

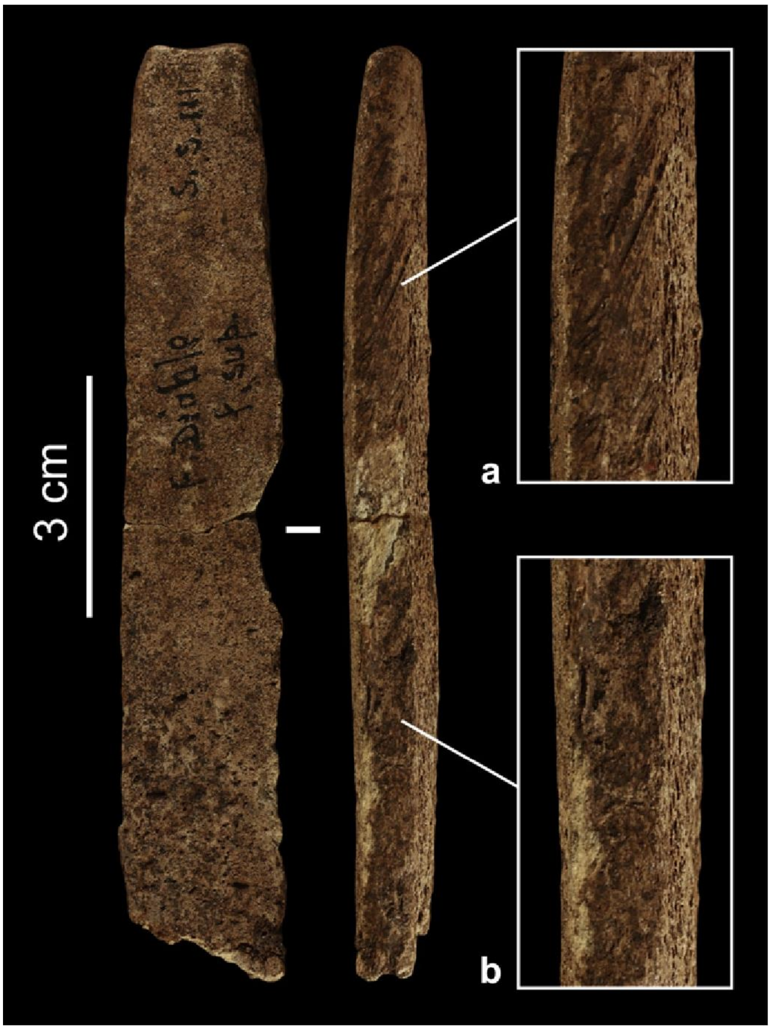
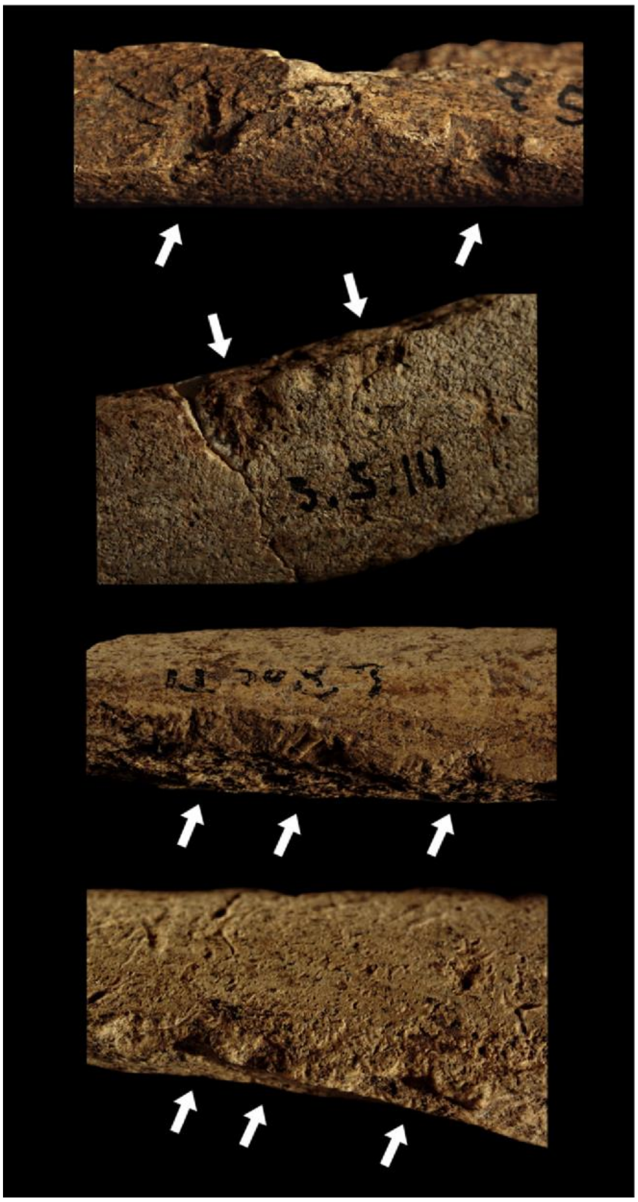


Figure 7. *Archaeological percussion marks. Samples from Badegoule (Dordogne, France), coll. Cheynier, Musée d'Archéologie Nationale (France), Le Fourneau du Diable (Dordogne, France), coll. Peyrony, Musée National de Préhistoire (France) and Roc de Sers (Charente, France), coll. Henri Martin. Musée d'Archéologie Nationale (France).*



3.2.3. TEST 2: DIRECT PERCUSSION

The presence of percussion marks on the lateral edges of the Solutrean pressure flaking tools led us to test direct percussion. Because we found no flakes in our archaeological collections similar to the ones described in the Badegoulian assemblages, we tested a method other than that proposed by J.-M. Petillon and S. Ducasse (Pétillon and Ducasse, 2012).

We chose a technique known to have existed since the Lower Paleolithic and widely used for stone flaking (Bordes, 1947; Mourre, 2004) and bone fracturing (Vincent, 1993): direct hard hammer percussion on an anvil.

3.2.3.1. Operation 1. Since the blanks of the pressure flaking tools are long, our first objective was to split an antler segment longitudinally. This process was quite simple: the segment was laid on the anvil and struck transversally on one end, while the opposite side remained in contact with the anvil surface. The striking motion was perpendicular to the anvil in order to generate a counter-blow (Fig. 10a). After two or three blows, two fissures appeared, one on the hammered end and one on the anvil end. The fissures met to form a single fissure in the longitudinal axis, separating the segment in two (Fig. 11b and d). The same operation was performed at the opposite end (Fig. 10b), and then in the middle part of the segment (Fig. 10c). The fissures produced at both ends and, in the middle, joined together in the longitudinal axis (Fig. 11a and c). The two halves were then separated (Fig. 10d). The whole procedure took only a few minutes.

Results: this procedure separates the initial segment into two wide halves with a fracture plane on their lower surface (Fig. 12). Since the archaeological pressure flaking tools are narrower than these pieces, with fracture planes forming their lateral edges, we decided to longitudinally split these half segments into two pieces.

Figure 8. *Reindeer antler used for the experiments: a) beam segment, b) whole antler.*

3.2.3.2. Operation 2. The spongy tissue on the lower side of the half segments was removed by scraping with a flint flake (Fig. 13a), resulting in a concave-convex section. The concave lower face was placed on the anvil and one end of the upper convex face was struck with a cobble (Fig. 13b). A fissure appeared in the center of the dorsal convexity where there is the least resistance to impact. This operation was repeated at the opposite end, and then in the middle part of the segment (Fig. 13c and d). The fissures met and longitudinally split the piece into two parts (Fig. 14).

Figure 9. *Tools used for the experiments: a) experimental intermediate tool compared with an archaeological intermediate tool from Le Fourneau du Diable, coll. Peyrony, Musée National de Préhistoire (France); c) hammer; d) wood anvil; e) lithic anvil.*

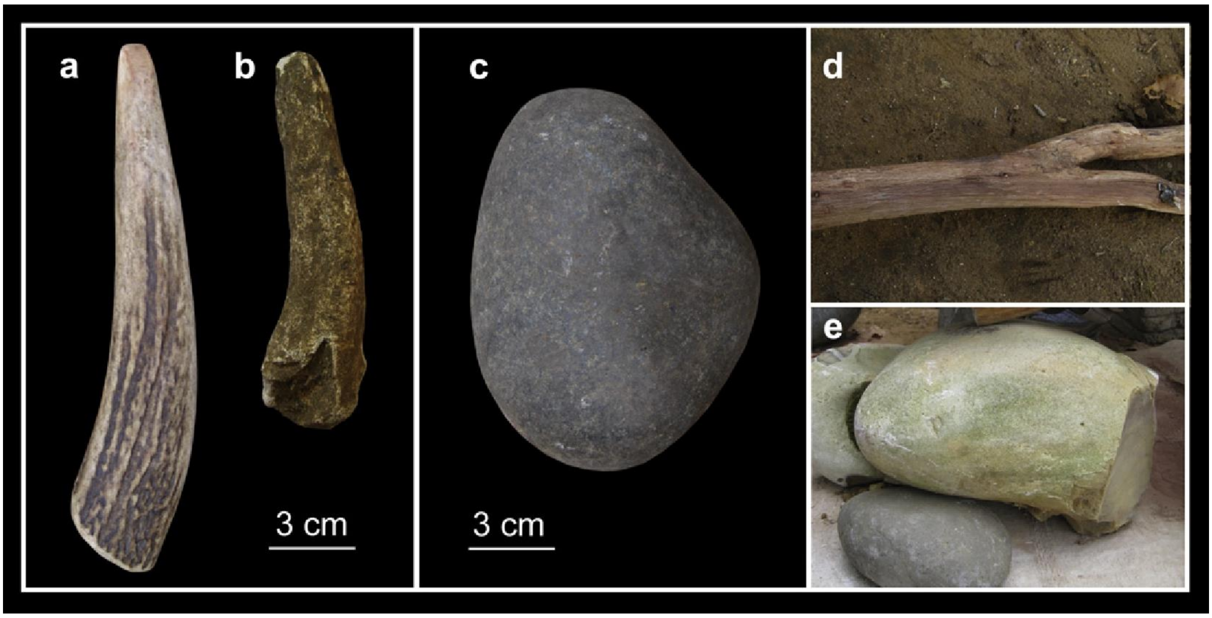
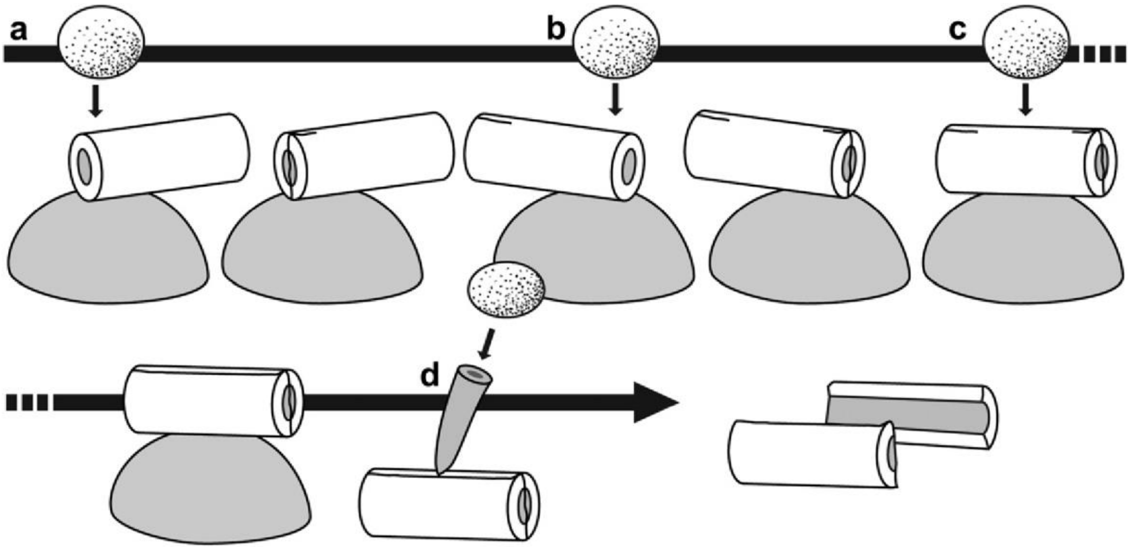


Figure 10. *Sequence 1: splitting a beam segment in two parts by direct percussion on an anvil.*



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3.2.3.3. Comments about the fissures. The fissures are more prone to initiate on a narrow face of the segment (anterior and posterior faces of the antler). Percussion on the wide face (lateral face of the antler) failed on our 3rd segment but succeeded on the 6th.

To verify that the flat ends of the segments cut with a mechanic saw had no effect on our experimental results, we reproduced the full operation with a beam cut by chopping (segment n°7), in the same manner as were the Solutrean pieces. We did not observe any differences (see Fig. 11c and d).

On two segments with a circular section and the thickest compact tissue, during the first operation, the direct percussion resulted in the initiation of four fissures, two in the vertical axis and one in the horizontal axis. For the second operation, consisting of splitting the halves, the appropriate fissures were therefore already present at both ends.

When the shaft was short, such as with segment n°1 (7.7 cm long), only a few blows were necessary to split the segment. With the longest shafts (13.9 cm and 15.5 cm), it was necessary to strike along the shaft several times to propagate the fissure. Progressive striking is the best way to ensure a generally straight propagation of the fissure.

The segments have an ovate or circular section. They may nonetheless be angular at the beginning of the second tine or in the middle of the beam. The ridges serve as guides for the fissures and can cause them to deviate from the main axis of the shaft, such as with segment n°3.

Splitting the segment from the anterior or posterior face of the antler is not risky because the curvature of the antler in front view is low. The profile curve is much higher and requires more attention. Therefore, with segment n°5, the second splitting operation produced only three blanks because the fissures followed the natural curvature of the antler (Inline Supplementary Fig. S5). However, the failure of the second operation may also have been due to condition of the antler, which was fractured while it was frozen, and thus more brittle, causing the fissures to spread faster.

Inline Supplementary Fig. S5 can be found online at http://dx. doi.org/10.1016/j.jas.2012.07.006.

4. Comparisons of experimental and archaeological objects

4.1. PRODUCTIVITY

In order to preserve examples of all stages of the procedure, we did not completely split all of the segments (Fig. 15). Normally, a segment can potentially yield four blanks. The productivity of splitting by direct percussion on an anvil is optimal because there is no waste.

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Figure 11. *Longitudinal fissure: a) beam segment n°3; c) beam segment n°7. Perpendicular fissure: b) beam segment n°3; d) beam segment n°7.*

Figure 12. *Product of sequence 1 (beam segment n°4).*

The collections we studied originate from excavations conducted in the first half of the 20th century. At this time, waste products were not always recovered. As a result, waste products, as well as unmodified blanks, are often absent in museum collections. The fact that direct percussion on an anvil does not generate waste, and probably very few accidents, could also explain the absence of these pieces in the archaeological collections.

If cutting the beam is a prerequisite for direct percussion (which is not certain), then the use of this technique can be deduced from the presence of unmodified segments and waste resulting from their production.

4.2. MORPHOMETRY

To achieve an optimal productivity, each blank must possess the qualities necessary for the manufacturing of the final object. The advantage of the splitting method that we propose is that it produces four blanks with the same morphometric features.

4.2.1. GENERAL MORPHOLOGY

The blanks produced have straight profiles, a straight or slightly curved outline and a triangular to trapezoidal section. We shaped one of the experimental blanks into a pressure flaking tool. To create a concave-convex section, we had only to remove the spongy tissue. We produced the final shape by tangentially chopping the lateral edges with a large flint blade. The resulting pressure tool falls well within the range of variability of the archaeological examples (Fig. 16).

4.2.2. DIMENSIONS

The lengths and thicknesses correspond to those of the split segment. The width corresponds to a quarter of its circumference. With our method, the dimensions of the blank can be determined through the selection of the beam segment. Though our archaeological and experimental samples are not statistically significant, the widths of our experimental blanks fall within the average range of those of the Solutrean pressure flaking tools, around 2 cm (Table 1).

Figure 13. *Sequence 2: splitting a blank from the first sequence into two parts by direct percussion on an anvil.*

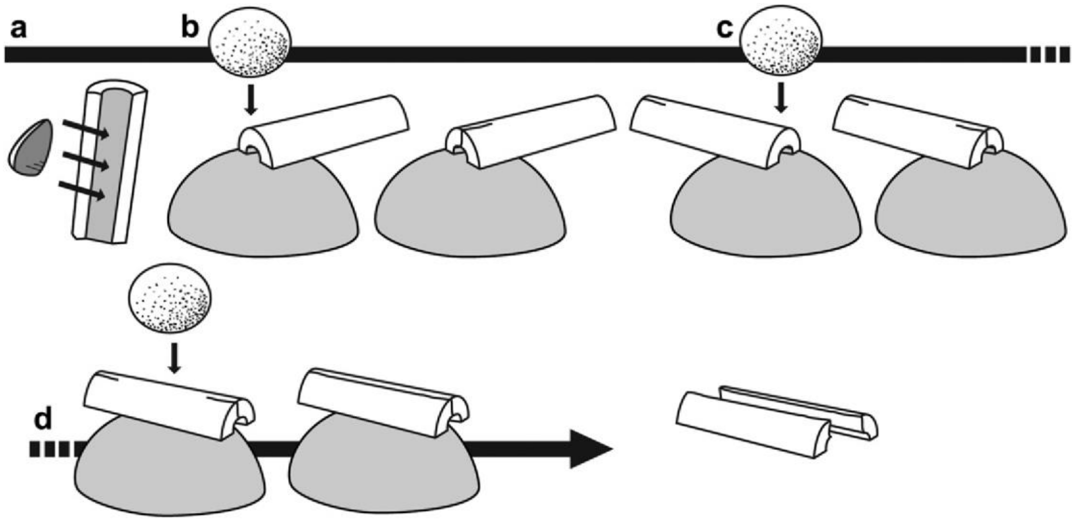


Figure 14. *Blanks resulting from sequence 2 (beam segment n°4).*

4.2.3. EDGE OUTLINE

The regularity of the blanks is an important criterion for the manufacturing of the final tool. It depends on several factors:

- The regularity of the selected segment. The best results are obtained with the straightest segments, with an ovate or circular section;
- The number and intensity of blows. Each blow generates a fracture plane. The more violent the blow, the more extended the fracture plane and the deeper the percussion notch. In this case, the propagation of the fracture is poorly controlled, however. When the blow is weak, the fracture plane is short and the notch barely visible. The propagation of the fracture is well controlled but the fracture planes are more numerous. Too many blows can also produce small secondary fractures that weaken the material and increase the irregularity. To produce a regular blank, a balance must therefore be achieved between the number of intensity of blows.

4.3. TRACES

Here we compare the marks visible on the experimental and archaeological blanks.

4.3.1. FRACTURE PLANES

The lateral edge of an experimental blank is composed of a succession of several fracture planes. Each plane is separated from the previous one by an oblique ridge (Fig. 17a), which is positive or negative, depending on the side of the fracture plane. There is sometimes an additional tearing of fibers (Fig. 17b).

Antler, like bone, has an internal lamellar, as well as concentric, structure (O'Connor, 1987). The fissures can propagate longitudinally, but also pass between the different superposed layers. Therefore, the fissure can pass below the first external layer and produce a small lip (Fig. 17c). A sufficiently hard blow can produce a cone of percussion under the impact point (Fig. 17d) and an excess of energy can produce multiple radiating cracks (Fig. 17e). All of these features have been observed on the archaeological pressure flaking tools.

4.3.2. HAMMER TRACES

On antler, the point of contact with a hammer has the form of a depression (Fig. 18a). It is rather superficial and difficult to see with the naked eye, but perceptible by touch. This depression is often accompanied by a jagged zone on the surface produced by the skidding hammer (Fig. 18b). A desquamation can also appear in the percussion zone (Fig. 18c) or along the edge of the percussion point (Fig. 18d). The desquamation resembles a micro-lip. All these marks are very superficial and therefore difficult to identify on archaeological specimens. A poor state of preservation can also prevent comparisons with experimental traces.

The percussion points on the archaeological pieces (see 2.1) nonetheless indicate the use of a hammer whose active edge was more irregular in shape than the one that we used (see Fig. 7).

The similarity of the full range of preserved technical traces on the archaeological and experimental specimens suggests that the blanks used to manufacture Solutrean pressure flaking tools were produced by direct percussion on an anvil.

Figure 15. *Experimental products from direct percussion on an anvil a) half segments, b) blanks, c) pressur tool.*

Figure 16. *a) Experimental pressure flaking tool (beam segment n°4); b) archaeological pressure flaking tool, from Le Fourneau du Diable, coll. Peyrony, Musée National de Préhistoire (France).*

5. Discussion

5.1. TECHNICAL SIMPLICITY?

In the domain of lithic materials, direct percussion on an anvil has long been considered as a brutal and imprecise technique, which did not allow the artisan to control the morphology of the flakes produced (Mourre, 1996, 2004). Researchers seem to have assumed the same is true for antler working. For example, in the context of an experimental analysis of Badegoulian techniques using direct percussion on an anvil, Allain et al. (1975, p. 67) stated that "it was necessary to ensure the results of this brutal and primitive method and, with great regret, we decided to massacre a fresh reindeer beam with a cobble".

We believe that this preconception is linked to the apparent simplicity of the technique. Simplicity is often seen as a lack of adaptation. A method is well adapted, however, when it permits an efficient realization of the intended results. G. Simondon argued that technical objects evolve through a simplification of the elements that materialize the principle on which they are based (Simondon, 1958, quoted by Maigrot and Plisson, 2006). Therefore, on the contrary, the simplicity of a technique can indicate that an optimal compromise has been found between the means employed and the intended result.

This preconception may also emerge when a theoretical "understanding" of this technique is confused with its practical "realization". While it involves easily accessible material means e an action, indirect percussion, and two tools, a hammer and an anvil e it also requires certain skills that are not so easily accessible e the capacity to select appropriate raw materials and the ability to realize the action, for example. We must be careful not to consider a technique as being poorly adapted simply because we do not possess the required skills.

Table 1. *Dimensions of experimental products.*

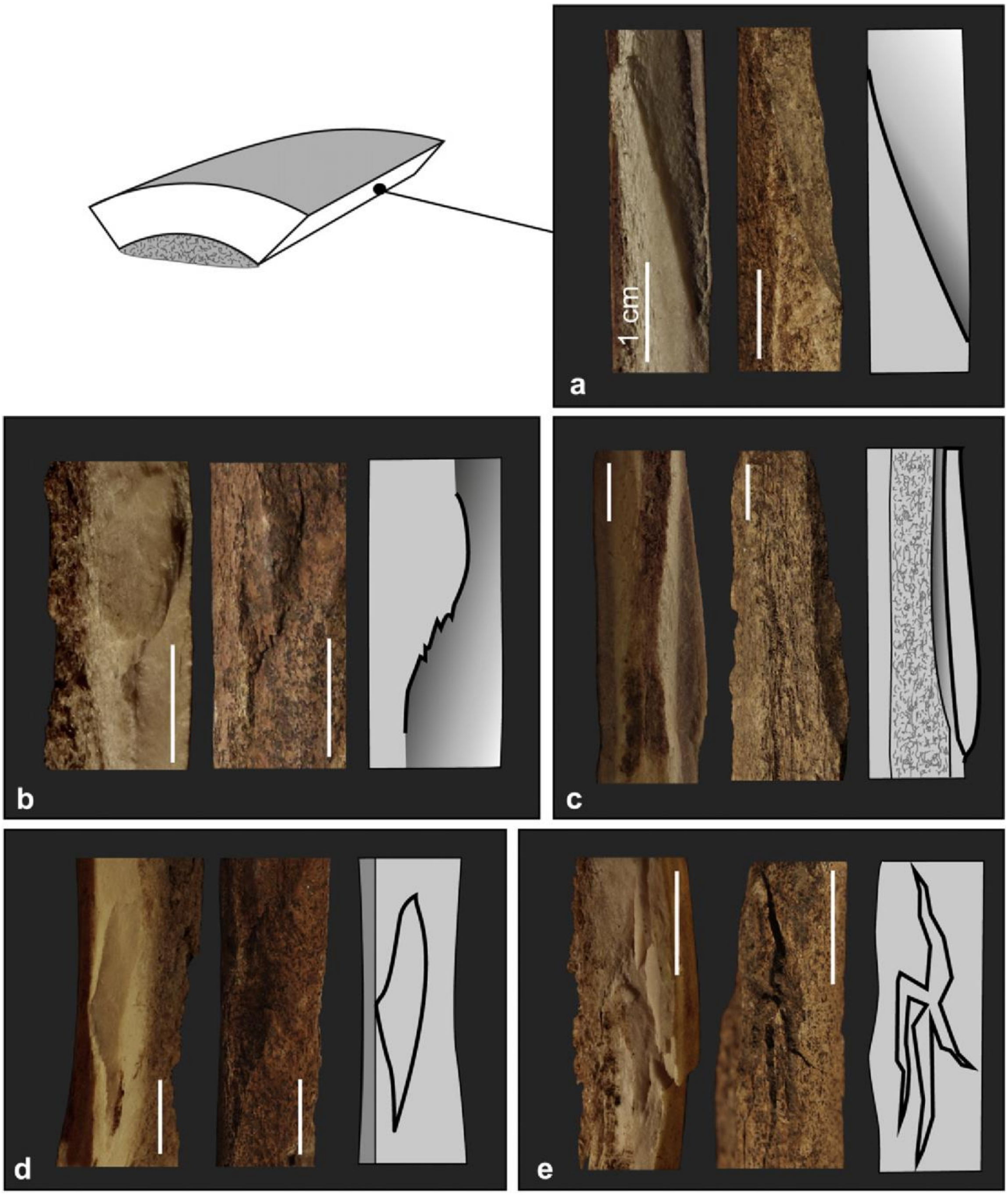
Section	Type	Length (cm)	Width (cm)	Cortical
n˚3	Half-beam	7.7	3.5	0.7
n˚3	Half-beam	7.7	3.5	0.7
n˚4	Half-beam	13.9	2.7	0.9
n˚4	Blank	13.9	1.8	0.9
n° 4	Blank	13.9	1.7	0.9
n˚5	Half-beam	15.5	3.2	0.7
n˚5	Blank	15.5	2.1	0.7
n˚6	Half-beam	12.4	2.6	1
n˚6	Blank	12.4	2.2	1
n˚6	Blank	12.4	2.1	1
n˚7	Blank	12.7	2.2	0.8
n˚7	Blank	12.7	2	0.8
n˚7	Blank	12.7	1.9	0.8
n° 7	Blank	12.7	1.8	0.8

5.2. DIFFICULTY OF IDENTIFICATION

A poor understanding of this technique is coupled with an insufficient knowledge of the raw material considered here: cervid antler. While direct percussion was the main technique used in Paleolithic stone working, antler can also be transformed by grooving, chopping, sawing, grinding, etc. When still attached to a live animal, cervid antler is shock resistant. Therefore, among all the possibilities, direct percussion is probably the last technique that one would choose to work antler.

Due to a lack of experimental reference bases, it is currently difficult to identify human induced fractures on antler. Our experiments show that impact traces resulting from direct percussion are similar on bone and antler. More precise comparisons are nonetheless still needed. Some features, such as surface desquamation, may be specific to antler. However, the superficial nature of the traces is an obstacle to their identification as antler is highly susceptible to natural alterations. It is also difficult to identify antler splitting by direct percussion since this technique produces few specific waste products. Only failed blanks could confirm the use of this technique. In addition, most blanks were transformed into tools and the percussion marks have thus been obliterated by subsequent shaping actions. Solutrean pressure flaking tools are an exception.

Figure 17. *Marks on fracture plane made by direct percussion on an anvil (from the left to the right: experimental, archaeological, schematic): a) oblique ridge; b) tearing; c) tongue; d) notch; e) craks.*



5.3. RAW MATERIALS

In our experiments, our success at obtaining regular blanks using the percussion on an anvil technique to split reindeer antler is probably due to the nature of the raw materials that we used.

A homogeneous material is easier to split than a heterogeneous one, as it is well known for lithic material. In our experiments, we used fully developed reindeer antlers from Lapland, which had a very thick and dense compact tissue and very little spongy tissue.

They were thus particularly homogeneous and prone to splitting. It is not certain that our technique would have been efficient with insufficiently developed reindeer antler or with red deer antler.

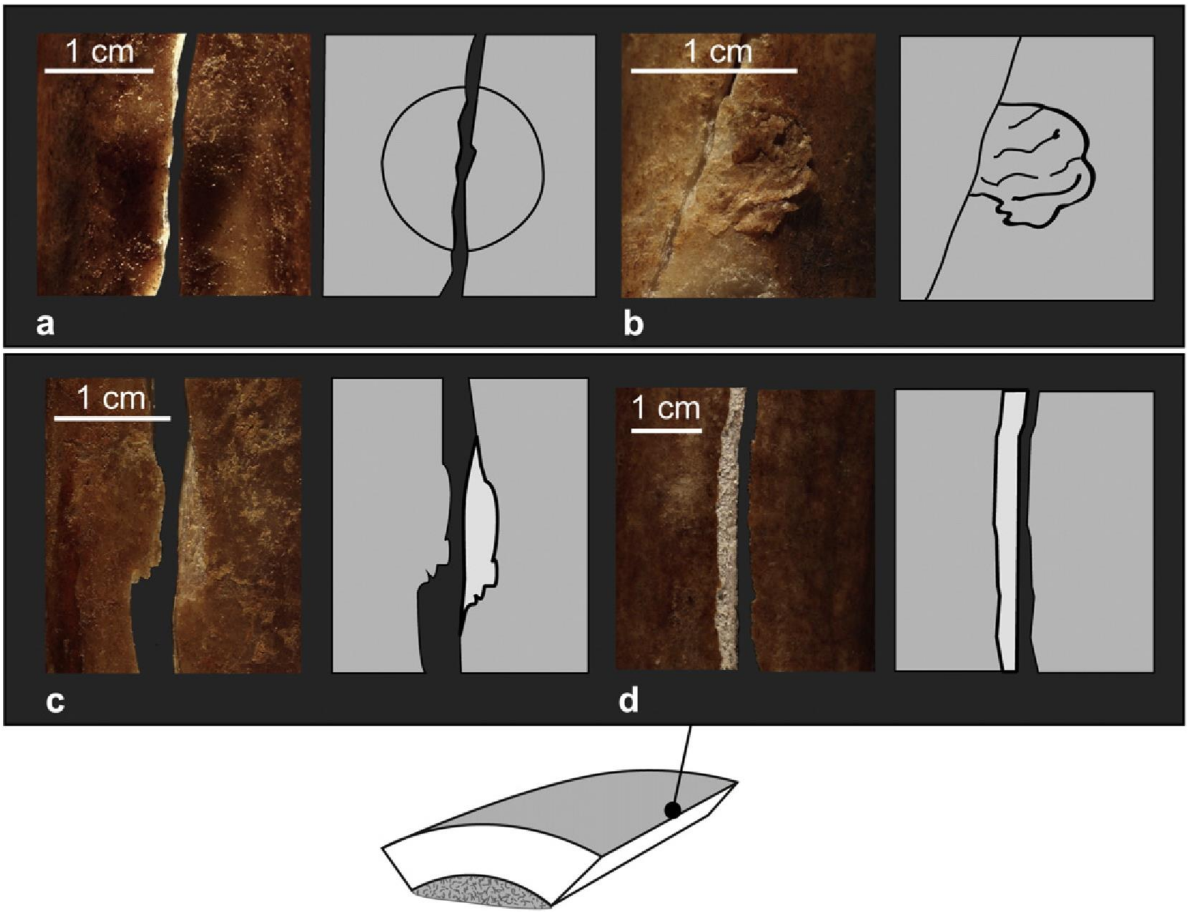
We must keep in mind that the procurement of good raw materials is much more problematic today than it was for Paleolithic hunters. Not only have reindeer moved to the circumpolar regions, but the natural territory of red deer has been considerably reduced. In addition, there is now a modern selective pressure to the detriment of the tallest males. This has resulted in a reduction of the size of deer (A.S. Syrovatko, personal communication) and, consequently, of the available antler. Reindeer farming in temperate latitudes does not provide a viable alternative since the animals do not live in their natural conditions and are artificially fed.

If splitting techniques are correlated with raw material characteristics, we could expect different technical strategies depending on the type of antler exploited. The Solutrean territory covered different biotopes in France, Spain and beyond the Pyrenees. In Southern latitudes, the source for large antler was not reindeer, but red deer. At present, however, little is known about Solutrean red deer antler technology in Spain. Perhaps the technique recently proposed for various Aurignacian assemblages in Spain (Tejero et al., 2012), which is based on indirect percussion, was also practiced by Solutrean artisans. Inversely, we could hypothesize that reindeer antler was processed by direct percussion during the Aurignacian, as has been proposed for Hyènes cave (France; Tartar, 2012).

However, attempts at cleaving antler, at least in the manner that they were carried out in previous experiments, do not give an impression of efficiency, as has been acknowledged by at least one author (Liolios, 1999). The morphology and dimensions of the resulting blanks are difficult to control, which is contradictory to the production of standardized objects, such as projectile points. Moreover, the number of blanks produced per segment is random. Debitage techniques that do not correspond to the expected products are uncommon. Such a situation does not correspond to a sufficient degree of productivity. Moreover, elements for a close comparison between experimental and archaeological production are missing.

Though we have not tested red deer antler, our own attempts at reindeer antler splitting by indirect percussion were no more successful than those of previous experiments (Liolios, 1999). Our first impression is that the stronger the antler, the less efficient is this technique, though further experiments taking into account more parameters will be necessary before we can reach a conclusion. For the moment, based on previous studies (Allain et al., 1975; Liolios, 1999) and our present contribution, direct percussion seems to yield very contrasting results. Is it be possible that the main reason for this divergence is linked to the density and thickness of the compact tissue of the antlers being worked?

Figure 18. *Superficial experimental percussion marks: a) Hollow; b) jagged zone; c) limited desquamation; d) extended desquamation.*



6. Conclusions

Pressure flaking tools are not the only Solutrean artifacts whose blanks were made by splitting. This is also true for most of the other implements whose manufacturing did not completely shape the blank. Only half of the intermediate tools show evidence for the groove and splinter technique, while Solutrean projectile points show only traces of splitting (Baumann, in progress). In fact, regardless of the particular technique used, throughout the Upper Paleolithic in Western Europe there is no interruption in the use of the debitage by fracturing technique. According to current knowledge, this was the only technique used to produce blanks during the Aurignacian (Liolios, 1999); it continued to be used during the Gravettian, despite the emergence of the groove and splinter technique (Goutas, 2004), and prevailed once again in the Solutrean. From this perspective, Badegoulian debitage by direct percussion appears less typical than it is often considered by researchers.

Concerning the technique that we propose for the manufacturing of Solutrean pressure flaking tools - direct percussion on an anvil -, its ease of execution, its capacity to be reproduced, the regularity of the blanks obtained and its optimal productivity are all elements that justify its recurrent use through time; not only in the Solutrean. This technique demonstrates that percussion techniques are well adapted to reindeer antler working, allowing this material to be worked in a precise and efficient manner and enabling a good control of the dimensions and morphologies of the resulting products. These are qualities that are usually attributed to the groove and splinter technique. From this new perspective, we can once again wonder why one technique was chosen over another.

In the Solutrean assemblages of southwestern France, only the blanks for intermediate tools were indisputably made by the groove and splinter technique. Since these tools were designed to repeatedly withstand very strong blows, they probably would have been weakened by the micro-cracks induced by percussion on an anvil. The coexistence of both of these techniques suggests that they could be complementary in some way. In any case, the idea that the groove and splinter technique represents a definite advance over fracturing is no longer valid. We might even question whether the significance of the groove and splinter technique has not been emphasized by previous experimental circumstances: if the antlers employed are of a mediocre quality, and have thin compact tissue and abundant spongy tissue, this technique is much appropriate than splitting by direct percussion, and also requires much less skill. From an archaeological perspective, the waste products associated with the groove and splinter technique are much easier to identify than those produced by percussion techniques, these latter being frequently confused with alimentary remains or with fragments of a taphonomic origin, and thus being excluded from museum collections and inventories. If we add to this the preconceptions of "simplicity" ascribed to percussion techniques in the context of osseous materials, and more generally to any simple process, we have a merging of ingredients that have minimized the role of percussion in the bone and antler[1] working traditions of the Upper Paleolithic.

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