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**No evidence of bowhunting in Magdalenian antler points:
comment on Langley and Lombard (2025)**

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Abstract:

In the study of prehistoric projectile points, the tip cross-sectional area method (TCSA) is often used to hypothesize about projectile delivery mode. In a recent article, Langley and Lombard applied this method, combined with point mass, to Magdalenian antler points from southwest France. Their results suggest the likelihood of bowhunting at some sites, and one point subtype, the Lussac-Angles point, is particularly highlighted as possible arrow tip because of its low TCSA and mass. However, the methods used in this study underestimate TCSA and mass, particularly when composite weapon tips are considered. Experimental evidence shows that Lussac-Angles points can be used with the spearthrower, and there is also archeological and experimental evidence of use with the spearthrower for fork-based points, another type of Magdalenian antler point that has a TCSA similar to the Lussac-Angles points. These findings refute the evidence of bowhunting in Magdalenian antler points and offer another example of the problems raised by the use of the TCSA method to reconstruct past weapon systems.

Keywords: antler industry, bow, experimental archeology, Magdalenian, projectile point, spearthrower, TCSA

Highlights:

Dimensions and mass of Magdalenian antler points do not support bow use.

Small antler points can be hafted to long and heavy projectile shafts.

Hypothesizing about weapon system requires contextual and traceological evidence.

Reconstructing the evolution of Paleolithic weaponry is a crucial issue in prehistoric archeology, given the significant implications of this evolution for hunter-gatherer subsistence. In particular, the invention of the spearthrower and that of the bow have been the subject of much attention. While these two weapons rarely preserve archeologically, the tips of their projectiles are very frequent in the archeological record. Research has thus turned to the identification of proxies of spearthrower or bow use that would be accessible through the analysis of these tips. One of the approaches most frequently used today is the TCSA method, where the cross-sectional area of the projectile tip is employed to hypothesize about projectile delivery mode (Hughes, 1998; Shea, 2006; Sisk and Shea, 2011; Lombard et al., 2024). Langley and Lombard (2025) recently applied this approach to assemblages of five antler point types from three Late Upper Paleolithic (Magdalenian) sites in southwest France, combining the points' TCSA and mass. They conclude that “the bow-and-arrow may have been part of the hunting arsenal at the two Pyrenean sites of Isturitz and La Vache”, because these two assemblages show high proportions of points with a TCSA in the range of “small-caliber dart/arrow tips”, and a mass below 3 g. One specific subtype of single-beveled point, the Lussac-Angles point, is particularly highlighted as “potentially having functioned as specialised Magdalenian arrow tips”, because of its especially small dimensions and mass.

The validity of the TCSA approach to identify projectile delivery systems has been regularly questioned in the last ten years (Newman and More, 2013; Villa and Roebroeks, 2014; Rots and Plisson, 2014; Clarkson, 2016; Hutchings, 2016; Sahle et al., 2023; Milks et al., 2024; Leder and Milks 2025; McKinny et al., 2025). In line with these studies, we show here that the methods used by Langley and Lombard are inadequate for the archeological material studied, and underestimate both the TCSA and the mass, particularly when the complete composite tips (i.e., antler points equipped with lithic inserts) are considered instead of the antler point alone. We also show that there is experimental evidence that Lussac-Angles points can be used effectively to tip spearthrower projectiles, and that among the Magdalenian assemblages from southwest France is another antler point type, the fork-based point, that also has a low TCSA (much like the Lussac-Angles points) but for which there is contextual and experimental evidence of use with the spearthrower. Together, these findings refute the evidence of bowhunting put forward by Langley and Lombard, and offer another example of the problems raised by the use of the TCSA method to reconstruct past weapon systems.

1. The TCSA formula is not appropriate for all points

The TCSA “predicts a case where the projectile, such as a bullet, pulverizes the target. This makes the area an important predictor of the size of the hole, which is then used as a proxy for the energy needed to penetrate to a lethal depth” (Sisk and Shea, 2011:3). It is supposed to relate to “the size of the hole that a weapon tip – regardless of material – can cut in the hide of a prey animal” (Langley and Lombard 2025). It is calculated by the formula $w t / 2$, with w = point maximum width, and t = point maximum thickness, both in millimeters. “Because most points are either lenticular or triangular in cross-section, a reasonable approximation of their actual TCSA can be calculated” with this formula, which is simply the formula for the area of the triangle or the lozenge (Shea, 2006:824, Sisk and Shea, 2011: fig.1).

However, the systematic use of this formula regardless of point material and cross-sectional morphology can lead to irrelevant results (Leder and Milks, 2025). The unbarbed antler points from the European Upper Paleolithic typically exhibit a cross-section that is either rectangular or rounded (circular or oval: fig. 1:1-12). In this case, “a reasonable approximation of their actual TCSA” is therefore rather the formula for the area of the rectangle ($w t$), or the ellipse $[(w/2)(t/2)\pi]$, or $w t \pi / 4$, which is approximately $w t \times 0.8$. Using the classic TCSA formula

(wt/2) with these points thus underestimates their actual TCSA by ca. 36% (for points with a rounded cross-section) or even 50% (for points with a rectangular cross-section).

Langley and Lombard do not provide information on the cross-sectional morphology of their points, it is thus not possible to recalculate their TCSA using either the rectangle or the ellipse formula. However, there is one possible test case: from the classic typological study by Pinçon (1988), we know that the single-beveled Lussac-Angles points, the smallest and most typologically homogeneous points studied by Langley and Lombard, usually display a rectangular cross-section (66.1% of the specimens analyzed by Pinçon). Their TCSA is thus more likely approximated with the rectangle formula: this means a TCSA in the order of 64 mm² instead of 32 (Langley and Lombard, 2025: table 5), putting this point type in the range of javelin/dart tips according to the authors' standard TCSA ranges (table 1). This would be even truer for the larger, single bevel-based and double bevel-based points in their assemblage.

The classic formula (wt/2) might actually be appropriate for antler barbed points, particularly the bilaterally barbed ones, whose cross-sectional morphology is closer to a lozenge or a triangle (fig. 1:13-16; Julien, 1982, 1995). Interestingly, these are among the samples with the highest TCSA in their assemblage (Langley and Lombard, 2025: fig.3), “in the lower range for large-caliber dart/javelin tips” at La Vache and “in the lower range for stabbing spears” at La Madeleine.

2. Antler diagenesis reduces point mass

Langley and Lombard weighed the archeological antler points and used “the <3 g weight cutoff [to] further isolate possible arrow tips”. But this method disregards the effects of bone and antler diagenesis, which always results in mass loss, most of it being due to loss of collagen (Hedges, 2002). The mass loss of bone during diagenesis was estimated ca. 20% (Hedges, 2002:323), but degradation experiments in a standardized environment showed it can reach ca. 60% after only 31 months of incubation (Lacel et al., 2021). Antler diagenesis has been less studied, but burial experiments with durations of 3 to 48 months resulted in mass losses from 15 to 30% (Simpson, 2011:120-132). These numbers only relate to early diagenesis, and are very likely below what might result from millennia of burial in a cave environment.

This can be illustrated with experimental Lussac-Angles points. In a previous experiment (Pétillon et al., 2011), we manufactured four single-beveled points from reindeer antler, replicating the morphology and mean dimensions of Lussac-Angles points as presented in Pinçon (1988). The four experimental points are actually slightly shorter, narrower and thinner than Pinçon's sample, and their caliber is close to that of the 48 Lussac-Angles points from Isturitz II studied by Langley and Lombard (fig. 2:6-9; table 2). Yet all the experimental Lussac-Angles points weigh between 4.1 and 5.4 g (mean: 4.9), all above the 3 g cutoff, while the mean mass of the archeological Lussac-Angles points from Isturitz II studied by Langley and Lombard is only 3.2 g, and nearly half the points in their sample weigh less than 3 g.

To further approximate mass loss due to diagenesis in this type of object, we measured and weighed a sample of 10 complete and nearly complete Lussac-Angles points from Marsoulas cave (fig. 2:1-5). The overall volume of the points was estimated both for the experimental and the Marsoulas points with the formula: length × width × thickness, in cm³; the approximate density in g/cm³ was then calculated. The density was used because the experimental and archeological Lussac-Angles points have similar morphologies but the points from Marsoulas are particularly small, so direct mass comparison is not significant.

The result (table 2) suggests that density loss between archeological and experimental points, all made of reindeer antler, is in the order of 45-50% $[(1 - 0.56/1.05) \times 100 = 46.7]$. The current mass of a Magdalenian antler point cannot be used as an indicator of its working parameters during its past use-life in the Paleolithic.

3. Magdalenian antler points are parts of composite tips

Most Magdalenian sites yield large assemblages of flint microliths, and traceological studies have shown that, besides other functions such as knives, a large number of them functioned as projectile inserts (Moss and Newcomer, 1982; Ibáñez Estévez, 1993; Plisson and Vaughan, 2002; Christensen and Valentin, 2004; Sano, 2009; Taller et al., 2012; Clemente Conte et al., 2017; Langlais et al., 2019; Gauvrit Roux, 2019; Gauvrit Roux and Pétillon, 2022). A few of them have been discovered in direct archeological association with osseous points (Allain and Descouts, 1957; Leroi-Gourhan, 1983, and see Tomasso et al. 2018 for an earlier case). Furthermore, Magdalenian points frequently display one or two longitudinal grooves which are interpreted as a housing for lithic inserts (Allain and Rigaud, 1986; Bosinski, 2010; Houmard, 2003; Houmard and Jacquot, 2009). The presence of one or two grooves is systematic on some subtypes, such as the Lussac-Angles points. This suggests that, although their osseous and lithic components are almost always found disassembled in archaeological contexts, composite projectile tips were of widespread use in the Magdalenian, even with antler points that do not have longitudinal grooves (Allain, 1979:100).

Adding lithic inserts to an antler point significantly increases the mass and TCSA of the projectile tip. For instance, one of the antler double bevel-based points used in our experiment (Pétillon et al., 2011) has a “bare” mass of 15.7 g and a caliber of 11×8.3 mm (hence a TCSA of 91.3 mm^2 with the rectangle formula); once equipped with two rows of microliths (fig. 2:10), its mass is 23.6 g, and its caliber 11×27 mm (hence a TCSA of 148.5 mm^2 with the lozenge formula, more appropriate for the cross-section of such composite tips). According to the TCSA standards (table 1), the antler point alone would thus fall in the dimensional overlap between stabbing spear and javelin tips, while the same point equipped with microliths would be in the upper range for stabbing spear tips. Functionally speaking, Magdalenian antler points should not be considered isolated from the composite technical system they were part of.

4. Lussac-Angles points work efficiently as dart tips

In the aforementioned experiment (Pétillon et al., 2011), four Lussac-Angles points were hafted to darts (2.7 m in length, 14 mm in diameter, 150-200 g in mass) and shot with a spearthrower at a 12 m distance at the bodies of two young female deer slaughtered before the experiment, alongside 30 other darts tipped with five different types of Magdalenian antler points. Considering the systematic presence of longitudinal grooves on Lussac-Angles points, three of the four experimental specimens were equipped with one lateral microlith. Each dart was shot repeatedly until the osseous point, the shaft or the hafting was damaged. In total, 10 of the 74 shots involved Lussac-Angles points.

A few indications can be drawn from the experimental results:

- Durability: the 4 darts with Lussac-Angles points were used 10 times before breakage, i.e., 2.5 uses per spear on average; for the 30 other darts, tipped with other point types, the mean number of shots is 2.1 (64/30).
- Precision: 5 of the 10 shots with Lussac-Angles points hit the target, a 50% success rate, while 61% of the shots were successful for the other point types (39/64).

- Successful penetration: 3 of the 5 hits with Lussac-Angles points (60%) successfully penetrated the animal's hide and flesh (the other two bounced off); for the other hits, this percentage is 69% (27/39).
- Penetration depth: one of the 3 shots with Lussac-Angles points that penetrated the hide hit the hip bone, which halted its penetration at 4 cm. The two others hit the thorax and penetrated 19 cm (shot 24:1, without microlith) and 33 cm (shot 28:1, with microlith). The 13 other shots without microliths that hit the thorax penetrated on average 14.5 cm, and the 14 other shots with microliths that hit the thorax penetrated on average 27.9 cm. The penetration of the Lussac-Angles points thus appears at the higher end of the penetration depths observed during the experiment.

These percentages must be taken with caution given the very small sample size. Still, they suggest that, as dart tips, this set of experimental Lussac-Angles points did not perform obviously worse than the other antler point types. Precision and successful penetration are slightly lower than average, while durability and penetration depth are slightly higher. Overall, the performance of the Lussac-Angles points as darts tips appears in the same range as the five other point types tested, three of which were much larger (Pétillon et al., 2011: table 1, fig. 6). These experimental results do not mean that the Magdalenian Lussac-Angles points were indeed used with the spearthrower. But since no experimental data is yet available on the performance of these points as arrow tips, the arrow hypothesis remains untested, leaving the dart one as better investigated and validated at the moment from an experimental point of view.

5. Magdalenian fork-based points are small, yet they were used as dart tips

Fork-based points are another type of Magdalenian antler points, common at Pyrenean and Cantabrian sites, and less frequent in the north of the Aquitaine Basin (fig. 3). The largest known assemblage is that of Isturitz levels I/F1. Chronologically, these points are dated to the transition between the Late Middle and Early Upper Magdalenian, ca. 16500-15500 cal BP (Pétillon, 2016). Langley and Lombard (2025) write that “the fork-based points seem to have a high average TCSA value of 103 mm² that would place many in the lower end of the stabbing-spear category”. This is not exact, and apparently due to an incorrect reading of table 1 in Pétillon and Cattelain, 2022 (Langley and Lombard used the maximum values, 17.2 × 12 mm, instead of the mean). In reality, fork-based points have a mean width and thickness of 9.3 × 7.1 mm, which implies a mean TCSA of 33 mm² with the classic formula (wt/2). Since the fork-based points usually have a rectangular cross-section (76% of the specimens at Isturitz: Pétillon, 2006:59), the rectangle formula (wt) would be more appropriate, resulting in a TCSA ca. 66 mm². But in any case, their TCSA is very close to that of the Lussac-Angles points studied by Langley and Lombard (see above: 32 or 64 mm² depending on the formula used).

Two projectile experiments with replicas of fork-based points were organized in 2003-2004 (Pétillon, 2006; Pétillon and Cattelain, 2022). In total, 78 experimental fork-based points were manufactured from reindeer antler. Half of them were hafted to arrow shafts and the other half to dart shafts. The projectiles were shot with bow or spearthrower several times until the point, shaft or hafting was damaged. A total of 618 shots were performed. The targets were two dead calves (in 2003) and two dead fallow deer (in 2004), shot at a distance of 10-13 m. At the end of the experiments, 14 of the 78 fork-based points showed proximal fractures on one or two of the fork's tines (fig. 3). These fractures were always the result of a spearthrower shot, and never occurred with the bow. This difference is probably due to the much greater size and mass of darts compared to arrows in this experiment, as well as their more irregular

trajectory: these parameters increase bending forces upon impact, sometimes resulting in the snapping of the base. Comparable experimental results were obtained on the stem of Solutrean shouldered points (Rots and Plisson, 2014:159) and on Gravettian tanged points (Coppe et al., 2023), suggesting that equivalent mechanical phenomena are at work despite the difference in point material.

Proximal fractures are very frequent on the archeological fork-based points: at Isturitz, out of 419 specimens, 95 show fracture damage at the fork, and most fractures (68%) have similar morphologies as the experimental sample. The similarities between the archeological and experimental samples show that the Isturitz fork-based points were probably used to tip darts propelled with a spearthrower, rather than arrows shot with a bow.

Osseous foreshafts provide additional evidence for the identification of fork-based points as dart tips. These implements were hafted to fork-based points to form two-piece projectile tips, and typically have a rounded cross-section with a diameter ca. 8-11 mm (Pétillon, 2006:64-65). One of the largest is a 344 mm long fragment found isolated in the Tuc d'Audoubert cave, near an antler fork-based point that was doubtlessly hafted to it (fig. 4; Bégouën, 1926:224). The antler point is of average caliber for fork-based points (9 mm width \times 7 mm thickness), but the foreshaft (made of sperm whale bone: McGrath, van der Sluis et al., 2025) has an almost square cross-section of 14 \times 13 mm. This shows again that points not bigger than Lussac-Angles points could be hafted to wide and thick shafts, with a diameter of at least 14 mm, clearly above the size of arrows (Pétillon and Cattelain, 2004).

6. Discussion

Once the TCSA has been recalculated with a more appropriate formula, and the mass loss due to antler diagenesis has been taken into account, it appears that even the smallest point types analyzed by Langley and Lombard are above the size range for arrow tips according to their standard TCSA ranges. This is even truer when considering the complete composite tip (with hafted microliths) instead of the isolated antler point. Furthermore, there is experimental and archeological evidence that even small-caliber point types such as the Lussac-Angles points and the fork-based points can be – and, in the case of the fork-based points, have been – hafted to dart-sized projectiles used with the spearthrower. There is thus no argument to support the “likelihood [of bowhunting] especially for the Pyrenean sites of Isturitz and La Vache” (Langley and Lombard 2025:9).

We do not intend to demonstrate that all Magdalenian antler points were dart tips used with the spearthrower, or that the existence of the bow during the Magdalenian is impossible. Our point is methodological. The rationale behind using the TCSA to identify projectile delivery mode is that, “if the tip is designed to open a hole large enough for the shaft to enter unimpeded, then the tip cross-sectional area must be larger than the shaft area” (Hughes, 1998:353), and since each weapon type is characterized by specific shaft dimensions, the TCSA is “an effective discriminator of different functional classes of lithic weapon armatures” (Shea, 2006:824), with “a clear separation in the TCSA of different projectile types (bow/arrow, spearthrower/dart, throwing spears)” (Sisk and Shea, 2011:3). However, this assumption is inexact. A projectile shaft is not a pure cylinder: it is an object that tapers, usually at both ends. By adjusting this tapering, and by placing the joint between the shaft and the tip more or less close to the distal end of the projectile, it is possible to haft points of different sizes to similar shafts. The composite tip from Tuc d'Audoubert, with its antler fork-based point and sperm whale bone foreshaft, shows how Magdalenian hunters could haft a short point with a caliber of 9 \times 7 mm to a long tapering foreshaft, which was itself hafted to a projectile shaft at least 14 mm in diameter. Ethnographic projectiles offer similar examples.

For instance, in the Santa Cruz Islands, composite bone tips made of a point and a foreshaft, long standalone bone points, and very short and thin points are all hafted to identical arrow shafts 10-12 mm in diameter, even though the length, width and thickness of these three types of arrow tips are all different: on average $248 \times 9 \times 7$ mm for the composite bone tips, $205 \times 7.8 \times 6.6$ mm for the long bone points, and $46.6 \times 3.6 \times 3.3$ mm for the short points (fig. 5, and see Pétillon et al., 2013). This would imply a TCSA in the range of, respectively, 49.5, 40.4 and 9.3 mm² (the ellipse formula, $w\pi/4$, was used for TCSA calculation because the points' cross-section is rounded). These values would put the first type in the dimensional overlap between un-poisoned arrow tips and dart tips, the second type clearly among un-poisoned arrow tips, and the third type among poisoned arrow tips, according to the TCSA standards (table 1; as the points are hafted, we could not measure their mass as additional argument).

The Magdalenian evidence strengthens the idea that the TCSA and mass of archeological points are not reliable predictors of projectile delivery mode. It also shows that the standard ranges used in the TCSA approach for the different categories of projectiles might only have limited relevance for antler points from the European Upper Paleolithic. These standards are calculated from a sample that comes from relatively few regions of the world (mostly southern Africa and North America: Lombard et al., 2024), thus not necessarily reflecting the full range of possible variability in projectile design; and this sample includes mostly stone and metal ethnographic points that greatly differ, in material and cross-section morphology, from the archeological assemblage considered here (Clarkson 2016, and see Marsh et al. 2024 and Milks et al. 2024 for the applicability of ethnographic material to interpret archeological data).

What Langley and Lombard do show is that there are significant size differences between antler point types, and between sites, in their assemblage. We argue that part of this variability is chronological: the smallest type, the Lussac-Angles points, is dated to the Early Middle Magdalenian (Pétillon, 2016); the samples from Isturitz I and La Vache, although coming from ancient excavations and chronologically heterogeneous, likely include a large majority of material from the Early Upper Magdalenian (Pétillon, 2006; Langlais, 2010; Pétillon et al., 2023); and the sample from La Madeleine, which yielded the largest point types in the assemblage studied, is poorly dated but probably dominated by antler points from the Late Upper Magdalenian (Bouvier, 1977; Collective, 2014).

This dimensional variation remains to be interpreted. But this interpretation should consider all point types, as well as all components of composite projectile tips. To attempt identifying the delivery mode of Upper Paleolithic projectiles, one must not only consider the antler points, but also the microliths and foreshafts which were often part of the same system. A robust interpretive framework should also consider that beyond mechanical efficiency and ballistics, other determinants may lead to dimensional changes in weapon tips, such as social and stylistic considerations (Larick, 1985; Wiessner, 1983; Lemonnier, 1987; Pétrequin and Pétrequin, 1990). In any case, without contextual, experimental and traceological arguments, there is no reason to favor the hypothesis that dimensional variability is linked to changes in projectiles delivery system.

CRedit authorship contribution statement

Jean-Marc Pétilon: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Data curation, Conceptualization. Eugénie Gauvrit Roux: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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Weapon type	Mean	SD	Range	Median
Poisoned arrow tips	11	7	4–18	8
Un-poisoned arrow tips	32	18	14–50	30
Dart tips	61	18	43–80	62
Javelin tips	66	24	42–90	63
Stabbing spear tips	140	60	80–200	128

Table 1. Calibrated TCSA standards in mm² for five weapon types following Langley and Lombard (2025).

Reference	Sites	Number	Length	Width	Thickness	Mass	Overall volume	Approx. density
Pinçon, 1988	La Marche, Angles-sur-l'Anglin	132	77.9	11.5	8.5	?	7.61	?
Langley and Lombard, 2025	Isturitz II	48	?	9.5	6.6	3.2	?	?
This study	Marsoulas	10	45.9	8.3	6.7	1.5	2.59	0.56
Pétillon et al., 2011, and this study	experimental	4	72.0	8.9	7.3	4.9	4.66	1.05

Table 2. Mean dimensions (in mm), mass (in g), overall volume (length × width × thickness in cm³) and approximate density (in g/cm³) of the archeological Lussac-Angles points from La Marche and Angles-sur-l'Anglin studied by Pinçon (1988), the archeological Lussac-Angles points from Isturitz II studied by Langley and Lombard (2025), ten archeological Lussac-Angles points from Marsoulas, and the experimental Lussac-Angles points used in the projectile experiment by Pétillon et al. (2011).



Figure 1. Sample of Magdalenian antler points with representative cross-sections. Lower Magdalenian: 1, double point with longitudinal grooves, Saint-Germain-la-Rivière lower assemblage. Middle Magdalenian: 2, point with lanceolate base, Saint-Germain-la-Rivière upper assemblage; 3, double bevel-based point, Roc-de-Marcamps; 4, double bevel-based point, Combe-Cullier UA4c; 5, single bevel-based point, Oulen; 6, single bevel-based point, Marsoulas; 7, single bevel-based point, Roc-de-Marcamps 2; 8, single bevel-based point, Tastet US306; 9, mesial fragment of point with longitudinal grooves, Saint-Michel. Upper Magdalenian: 10, double bevel-based point, Duruthy 3; 11, fork-based point, Espalungue; 12, fork-based point, Laa 2 C3; 13, bilaterally barbed point, Duruthy 3; 14, bilaterally barbed point, Morin AIV; 15, unilaterally barbed point, Morin BII; 16, unilaterally barbed point, Espalungue.



Figure 2. Experimental and archeological antler bevel-based points. 1-5: single bevel-based points, Lussac-Angles type, from Marsoulas (collections of the Muséum d'Histoire Naturelle de Toulouse). 6-9: experimental single bevel-based points, Lussac-Angles type. 10: experimental double bevel-based point equipped with two rows of flint microliths. 6-10 are from the experiment by Pétilion et al. (2011).



Figure 3. Antler fork-based points. 1-4: fork-based points from Isturitz I/F1 (Saint-Périer and Passemard excavations, collections of the Musée Basque de Bayonne and the Musée d'Archéologie Nationale de Saint-Germain-en-Laye). 5-7: comparison between experimental (left, greyscale) and archeological (right, color) proximal fractures on fork-based points. 5: breakage of the proximal part of a tine. 6: complete breakage of a tine. 7: complete breakage of the two tines. All experimental fractures are from spearthrower shots.

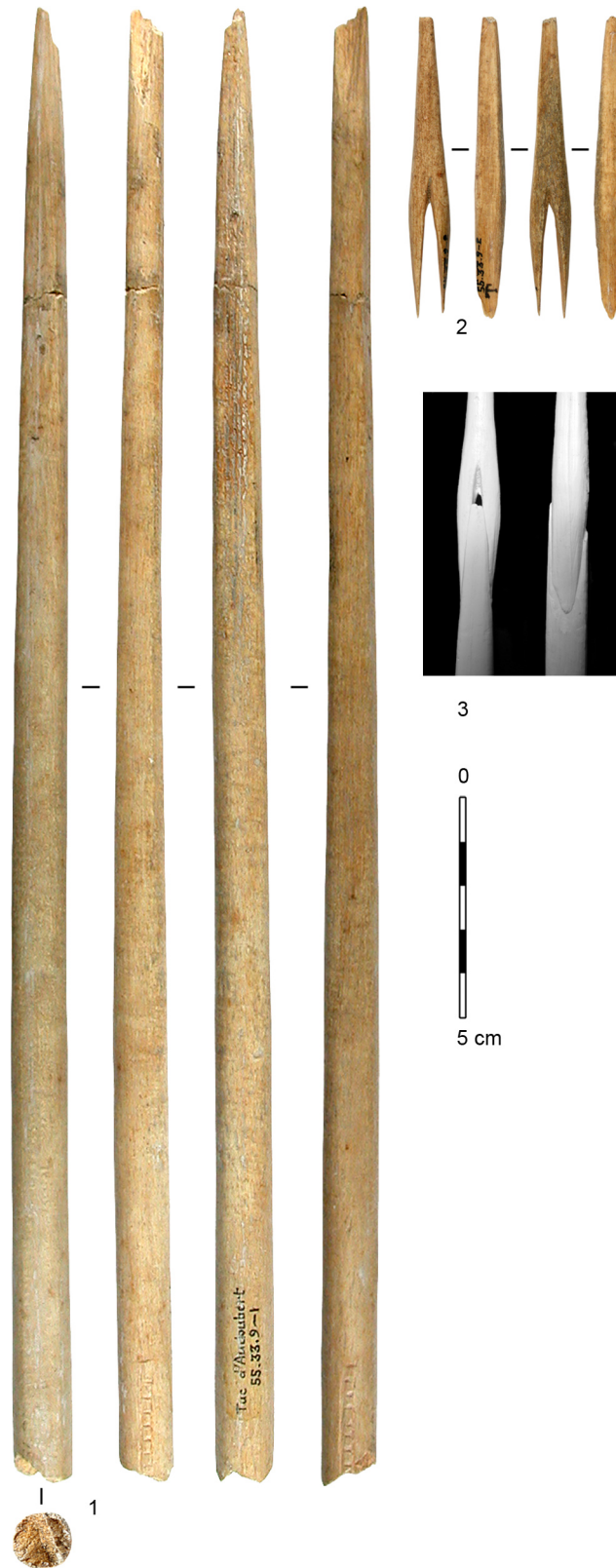


Figure 4. Composite tip from the Tuc d'Audoubert cave (Musée de l'Homme, Paris). 1: fragment of sperm whale bone foreshaft. 2: antler fork-based point. 3: reconstitution of hafting arrangement with resin casts of the two elements.



Figure 5. The three types of points on the Santa Cruz arrows: photograph and radiograph (Musée d'Aquitaine, Bordeaux; after Pétilion et al., 2013, with scale correction). 1: composite point; 2: large point; 3: small point. Radiographs: M. Bessou, UMR 5199 PACEA.