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Gravettian weaponry: 23,500-year-old evidence of a composite barbed point from Les Prés de Laure (France)

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ABSTRACT

Understanding hunting technology is pivotal in the study of adaptive and innovative forces that influenced the evolution of prehistoric societies. The manufacture, design and use of hunting weapons involve technical processes such as those of tool miniaturization, blank standardization and projection modes, but also influence broader demographic structures such as human subsistence strategies, territorial organization and socio-economic structures. Here we present a unique discovery from a newly discovered site at Les Prés de Laure (Var, France). Excavations revealed a multi-stratified open-air site with archaeological units that were rapidly buried by the alluvium of the Jabron River. In a Gravettian layer dated between 25 and 23.5 ka cal BP, within an area apparently dedicated to horse carcasses processing and consumption, 11 backed points were discovered in direct association with altered bone remains. Wear and residue analysis of the lithic backed points in combination with complementary experimental data converge to indicate that the find represents a bone point armed with lithic barbs and used as hunting weapon. This discovery provides new evidence for the manufacture and use of hunting weaponry in a Gravettian context and stimulates discussion on Paleolithic weapon function and design, offering a unique window into the characterization of prehistoric hunting strategies.

1. Introduction

How prehistoric hunting weapons were manufactured, designed and used is central to studies on the adaptive and innovative forces that influenced the behavioral evolution of our species (Straus, 1993). Such questions become prominent when discussing why and how bladelet technologies developed and generalized during the Upper Pleistocene (Elston and Kuhn, 2002). In Eurasia, bladelet technology dispersed during the Upper Paleolithic resulting in the production of miniaturized and standardized blanks (Bon, 2005). This miniaturization is classically associated with the development and diversification of weapons (Chesnaux, 2008; Crombé et al., 2001; Fischer, 1989; McDonald et al.,

2007), even though numerous archaeological examples (Christensen and Valentin, 2004; Finlayson and Mithen, 1997) provide alternative interpretations (notably knives).

The study of hunting technology provides insights into broader processes related to the history of techniques, such as the process of miniaturization and the evolution of weapon delivery systems. Hunting equipment also depicts broader aspects of human life, such as the way past societies were organizing their subsistence, occupying their territories and managing their resources. The diversification through time of hunting weapons and their sophistication ultimately mirrors changes in the way prehistoric societies were socio-economically organized (Knecht, 1997).

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Research on hunting technology requires a general reflection on the way weapons were designed, hafted and used. Apart from pointed wooden spears (Thieme, 1997), a weapon is composed of a projectile head (manufactured out of stone or organic material) that is secured by glue and/or bindings to a shaft manufactured from organic material. In the present study, we approach a composite weapon as one that requires multiple lithic insets or multiple materials combined in the projectile head (e.g. lithic and organic). The choice for a specific weapon design and a specific projecting mode depends on various factors such as the hunted prey and the hunting environment, the available raw materials, the technological traditions, as well as the beliefs of the society. However, the rarity of direct archaeological remains of composite tools hampers a solid understanding on how prehistoric hunting weapons were designed as well as how they varied geographically and changed through time.

So far, reconstructions of weapon design have mainly relied on the results of functional and experimental studies (e.g. Barton and Bergman, 1982; Chesnaux, 2008; Knecht, 1997; Nuzhnyj, 2007; O'Farell, 2004; Pétilion et al., 2011; Philibert, 2002; Plisson, 2005; Soriano, 1998; Weber, 2012; Yaroshevich et al., 2013). While convincing, such demonstrations are not direct evidence and are strongly influenced by comparisons with ethnographic and modern examples. Well-preserved Mesolithic specimens may also provide a source of inspiration (e.g. Bárta, 1989; Dolukhanov, 2008; Zhilin, 2015) as well as the rare Paleolithic examples (Abramova, 1984; Allain and Descouts, 1957; Leroi-Gourhan, 1983). In addition, due to taphonomic factors, post-depositional disturbances and/or excavation and analytical techniques, osseous and stone points have generally been dealt with separately in archaeological research (Nelson, 1997). Final interpretations systematically suffer from the lack of direct archaeological evidence for the combined use of both materials in a composite arrangement.

Discussions on the origin of composite projectile point technologies benefit from various but independent lines of evidence. Convincing functional evidence for the first stone points used as projectiles dates back to about 250 ka in Europe (e.g., Biache-St-Vaast, France, Rots, 2013), at least about 100 ka in North Africa (e.g., Sodmein Cave, Egypt, Rots et al., 2011; Ifri N'Ammar, Morocco, Tomasso and Rots et al., 2017), over 77 ka in South Africa (e.g., Sibudu Cave, Rots et al., 2017) and around 70 ka in the Near East (e.g. Umm el Tlell, Boëda et al., 1999). The earliest bone points date back to ca. 100ka ago in South Africa (Henshilwood et al., 2001) while appearing in Eurasia only around 40ka ago in the context of the Upper Paleolithic (McBrearty and Brooks, 2000). In Europe, the combination of osseous points and lithic microliths in composite projectile points is inferred from the early beginning of the Upper Paleolithic based on their association in several archaeological records (Pétilion et al., 2011). Lithic and ivory fragments, found together embedded in a mammoth bone in the Yana site (Siberia), also appear as early evidence (ca. 30–35 ka cal BP) of the use of composite weapons for hunting megafauna (Nikolskiy and Pitulko, 2013).

In contrast with this inferred timing, the oldest currently known direct evidence of composite projectile weapons postdates the Last Glacial Maximum (LGM), and relates to an approximate period between 19 ka and 15 ka cal. BP. Discoveries were made at the sites of Pincevent (Leroi-Gourhan, 1983) and La Garenne (Allain and Descouts, 1957; Houmard, 2003) in France, Afontova Gora (Abramova, 1984; Graf, 2008), Talitskij (Gvosdover, 1952) and Kokorevo I (Abramova, 1982) in Siberia.

None of these finds has been the subject of a recent multidisciplinary study. At Pincevent, A. Leroi-Gourhan (1983) describes a fragment of a reindeer antler point with bladelets inserted in both grooves. The diameter of the antler point alone is around 5–6 mm and it measures 12 mm in diameter with the bladelets included. The bladelets are between 12 and 21 mm long. At la Garenne, the reindeer antler points have only one groove (Houmard and Jacquot, 2009). In one of these antler points, several fragments of stone elements were identified.

The composite point of Afontova Gora is poorly documented: Z. Abramova (1982) provides second-hand information, with reference to V.I. Gromov, but indicates that the described point was lost. For the find of Talitskij, M.D. Gvosdover (1952) documents the insertion of seven backed bladelets, poorly standardized in length, on both sides of a reindeer antler point. Finally, for Kokorevo I, Z. Abramova (1982) identifies reindeer antler points with a single groove. In two of these points, backed bladelets have remained hafted in the groove (1 backed bladelet for the smallest fragment, 8 backed bladelets for the longest point) and form a continuous cutting edge that emerges no more than 1 mm from the groove.

All these post-LGM examples show a relative homogeneity: they all associate a reindeer antler point with stone backed bladelets hafted in one or two rows. These bladelets function only as cutting edges and not as barbs that retain the weapon in the prey. Nonetheless, during the Magdalenian, especially from 16 to 13.5 ka cal. BP, another type of projectile point is represented by barbed osseous points (Pétilion, 2016). Also use-wear analysis on microliths suggests the use of lithic barbed points at some Upper Paleolithic sites (Yaroshevich et al., 2013). The first direct evidence of barbed composite points dates to the Mesolithic with several discoveries, notably in northern Europe (Kozłowski, 2009; Larsson and Sjöström, 2010; Peterson, 1951; Svoboda et al., 2007). At these sites, designs with “cutting edges” occur in association with “barbed” designs. One or two rows of barbs (5–6 barbs per point in known examples) are inserted into osseous or wooden points. The point of Oleni Ostrov is original in its design with only one row of bladelets forming a continuous cutting edge on a self-barbed wooden point (Kozłowski, 2009). Use-wear analysis also confirms the use of barbed composite points in the Mesolithic (Chesnaux, 2014, 2008).

A discovery made at the site of Les Prés de Laure in Comps-sur-Artuby (Var, France) provides new insight into Paleolithic weaponry. A set of 11 backed points was found in association with osseous fragments in a layer dated to 25–23.5 ka cal. BP. Here we present the results of a multidisciplinary study of this find involving residue, use-wear and technological analysis combined with experimentation, a micro-morphological study, spatial analysis, and a multi-proxy analysis of the osseous remains. We propose that the association of the different artefacts reflects an *in situ* degradation of a composite barbed point, representing the oldest and the soundest evidence of composite projectile points known to date.

2. Material and methods

2.1. Context and occupations at the site of Les Prés de Laure, France

The Liguro-Provençal arc, a narrow corridor south of the Alps, plays a pivotal role in discussions on the processes of cultural and demographic interactions between Western and Eastern Europe (Naudinot et al., 2017; Porraz et al., 2010). Importantly, this region is of interest to investigate technological changes that happened before and after the Last Glacial Maximum (LGM), which is represented archaeologically in this region by the succession from the Gravettian to the Epigravettian techno-complexes. Many sites of this period are scattered throughout the region, including the well-known painted cave of Cosquer and the Balzi Rossi complex where several burials and Venus figurines have been discovered.

In 2012, a new research program focusing on Alpine prehistoric occupations led to the discovery of Les Prés de Laure (Porraz et al., 2014), an open-air site located at an altitude of ca. 850 m asl. and ca. 50 km from the Mediterranean coast (Fig. 1), in the middle valley of the Jabron river (Costa et al., 2015). Excavated since 2013, several occupations attributed to the late Gravettian and early Epigravettian have been recognized. The site formed by a succession of fine alluvial silts that contributed to the excellent preservation of the archaeological remains, notably in terms of spatial organization.

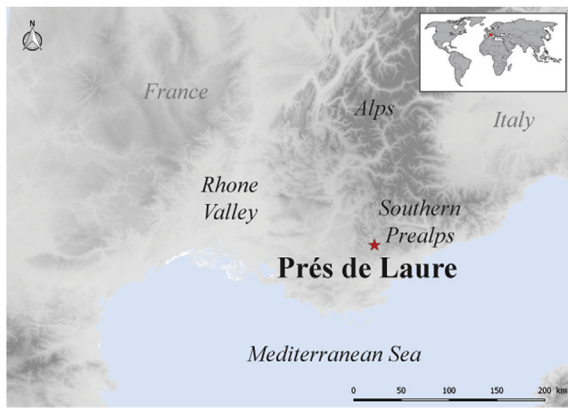


Fig. 1. Location of Les Prés de Laure (Var, France).

Sector 5 of Les Prés de Laure was excavated over a surface of 9 m² (Fig. 2). The stratigraphy comprises 13 stratigraphic units (SUs) over a thickness of ca. 1 m (Fig. 3). These alluvial deposits overlie a gravel-rich bed (ancient riverbed) on top of the limestone and glauconious bedrock. Archaeological artefacts are present in five of the 13 SUs. This study focuses on the SU L17, which presents characteristics of an ancient fluvial paleosoil.

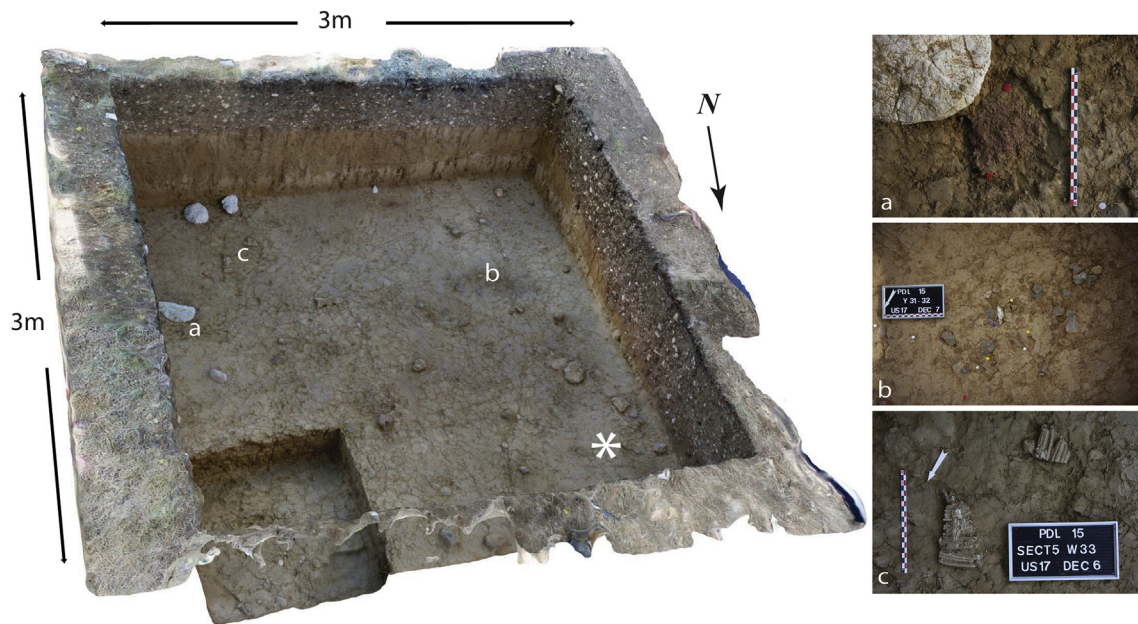
SU L17 has a relatively low artifact density (0.62 pieces per L of sediment). Various archaeological items were plotted, predominantly consisting of lithic remains (n = 675) together with a few limestone blocks (n = 10) and faunal remains (n = 38). In addition, we identified 8 areas with reddish sediment (up to 200 cm²). Two horse teeth were selected for AMS radiocarbon dating and provided ages of 25488–24731 cal. BP (20840 ± 100 BP, Poz-77717) and 23981–23271 cal. BP (19610 ± 120 BP, Poz-87865). Dates were calibrated using the IntCal13 curve on Oxcal with a 2 sigma range (Reimer et al., 2014).

The SU has a thickness of 15–20 cm and its micro-topography indicates a slight slope toward the north-east. It is composed of superposing fine alluvial silts (2–4 cm thick) (Fig. 4) in which pedological and/or pedo-climatic processes developed (e.g. platy to sub-rounded soil structure, *in-situ* vegetation growth) and also remains of

anthropogenic activities were visible (burnt fragments of soils and organic matter) (S1). The SU is totally de-carbonated and eluviated as a result of repeated freezing/thawing processes and snow melting, but no traces of soil movement were noticed. In the upper part of SU L17, where most of the anthropogenic features were encountered, increased traces of biological activity and a well-developed soil structure suggest temporary mild conditions associated with soil pedogenesis and reduced flooding. The latter are indicators of landscape stability, favorable to human settlement in the valley.

Artefacts were recovered over the entire excavated area and their orientation and inclination and the absence of a size-related distribution indicate that no major post-depositional disturbance took place (S2). We plotted 267 lithic pieces and collected 343 fragments and flakes under 2 cm during sieving. The techno-economic analysis allows estimating of a high “minimum number” of blocks (Porraz, 2008). The assemblage (S3) reveals the import of isolated products and few *in situ* knapping events. We argue that this lithic assemblage reflects activities oriented toward the consumption of tools and not toward their manufacture or replacement. Most pieces document the exploitation of local chert resources (mainly pebbles from the Jabron river nearby). Only one burin spall and one blade document long-distance circulations, with cherts originating from the Oligocene formation of the Alpes-de-Haute-Provence, ca. 70 km to the west. The lithic assemblage documents a low number of formal tools. We identified 13 backed points. Most of them (11) are backed points with oblique truncation, found in association with osseous fragments and these are the subject of the following study. The two other points differ in their morphology and were found separately. It concerns two distal fragments of backed points with inverse retouch at the apex, traditionally classified as microgravette in Gravettian contexts. The use-wear analysis of these two fragments revealed impact-related damage that is suggestive of an axial hafting.

Similar to the lithic remains, the faunal remains (S4) are distributed over the entire excavated area. They are however more numerous and larger in size towards the southern and eastern part of the excavation, and mostly chips of bone or tooth of ca. 1 cm long were found in the north-west part. Faunal remains are intensively altered and fragmented, but dental remains are relatively well preserved. Morphological identification allows the recognition of only one species in the faunal



Generated with Agisoft PhotoScan

Fig. 2. Les Prés de Laure: archaeological surface of the SU L17 (sector 5) as exposed in 2015 with details on (a) an *in situ* concentration of iron oxides (b) a concentration of flakes and (c) an intentionally broken horse mandible. The * indicates the location of the discovered 11 lithic backed points.

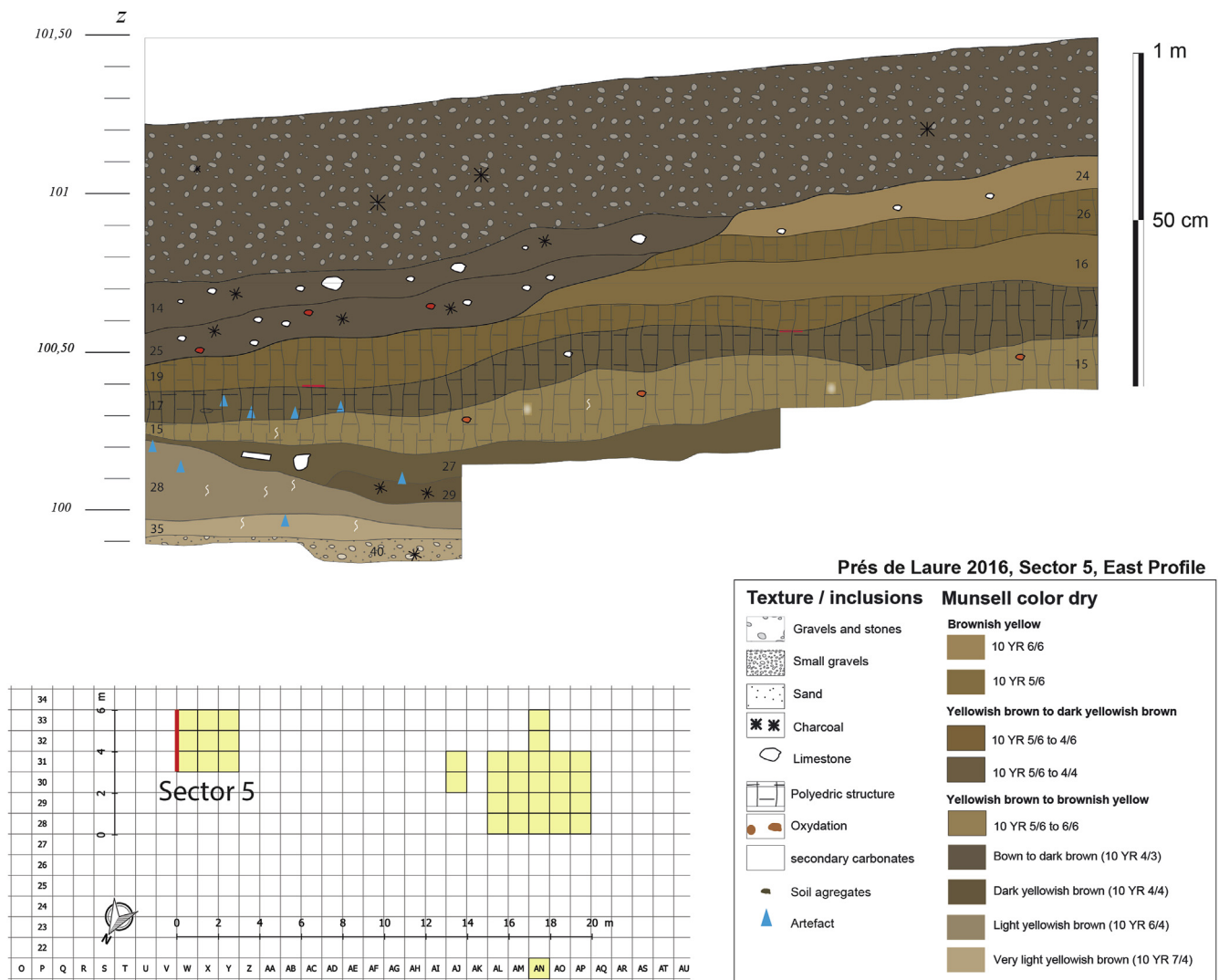


Fig. 3. East profile of sector 5 of Les Prés de Laure.

assemblage of SU L17: *Equus ferus*, i.e. horses. Four dental groups, composed of at least 12 teeth belonging to three individual horses, are present in the studied assemblage. Eruption and wear stages as well as the stage of dental development and the crown height measurements allowed estimating the age at death of the horses (Fernandez and Legendre, 2003). They belong to different age classes: a young of ca. 2 years old, an adult of 6.5–8.5 years old and an old specimen of at least 16 years old. Preservation of the remains was insufficient to allow observing cut marks or other kinds of anthropogenic marks on the bones; however, evidence of intentional bone breakage is identifiable on the dental remains of at least one equid mandible (Fig. 5). Combined with other archaeological evidence, this seems to indicate that the area was dedicated to the processing of horse carcasses and that *in situ* consumption occurred here.

While excavating the SU L17, we noticed a peculiar concentration of 10 small lithic backed points in an area of ca. 1/16 of m² (Fig. 6). One additional backed point was discovered while sieving the sediment of the same 1/4 m². The backed points found *in situ* were distributed along both sides of altered fragments of an elongated osseous remain of ca. 11 cm long with a north-west orientation; two backed points were directly in contact with it. All pieces were vertically distributed over a thickness of less than 10 mm. The density, the association and the organization of lithic and osseous remains in a sedimentary context that suffered little disturbance suggests the set of artefacts formed a single

implement.

2.2. Methods

A multidisciplinary analytical study was performed on the finds integrating an analysis of technology, raw material, residues and use-wear combined with experimentation and a spatial analysis. In addition, a study of the micromorphology, the bone fragments and the fauna was performed. Detailed methods are presented in SI (S5). Only essential information is provided below.

A 500 cm² and 6 cm thick block of sediment surrounding and including the osseous fragments and the lithic implements was plastered in the field and excavated under controlled conditions in the CEPAM laboratory. 3D scanning and photogrammetry were performed before and at several intervals during the excavation. Excavators wore starch-free gloves to prevent contamination (i.e. residues).

ZooMS collagen fingerprint analysis (Buckley et al., 2009) was carried out on a small bone chip of the osseous element sampled in the field with sterile tools. Bone remains were further examined in more detail using a stereoscopic and metallurgical microscope, a scanning electron microscope coupled with energy dispersive spectrometry (SEM-EDS IT-100) and a micro-CT-scan.

The backed points were studied successively for residues, technology, use-wear traces and raw materials. Residue analysis was

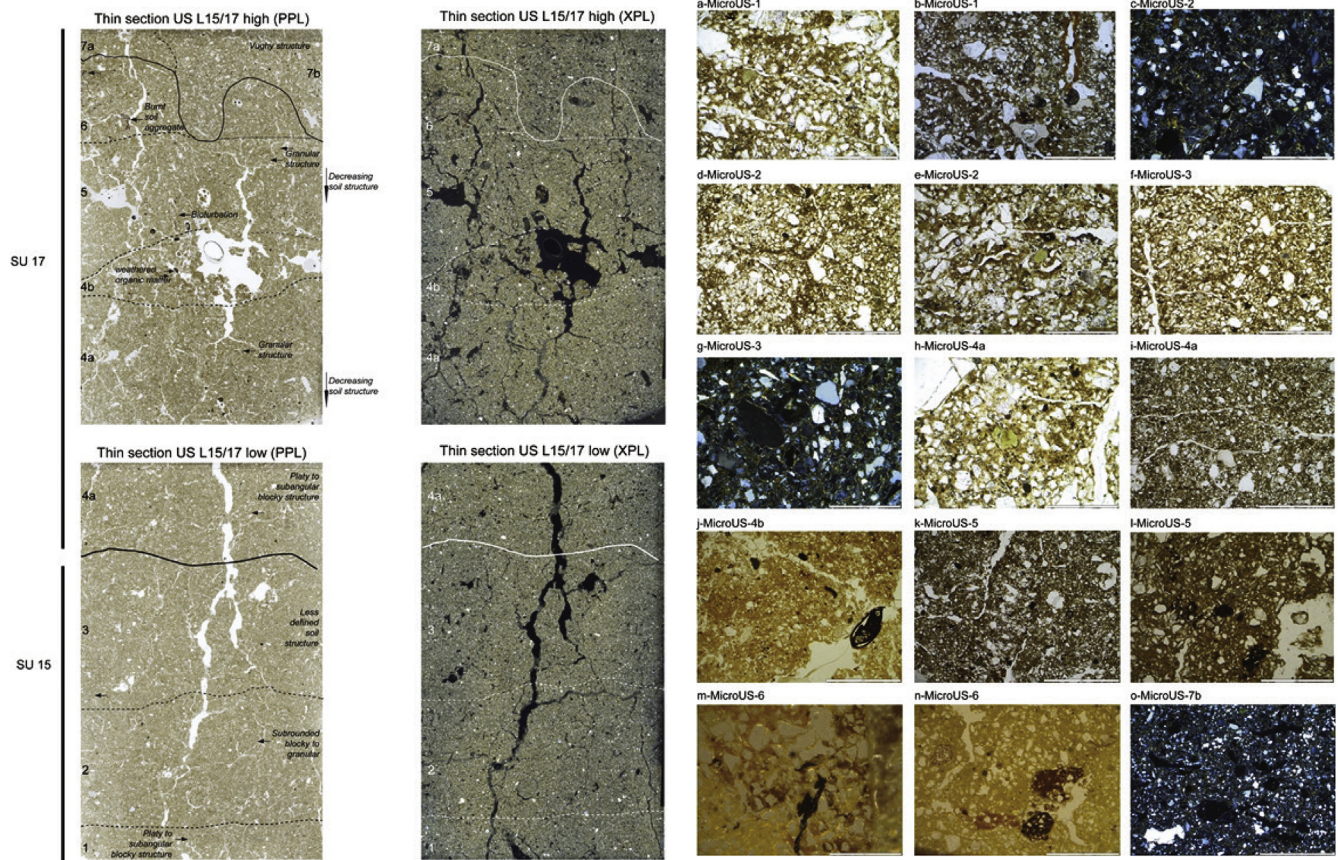


Fig. 4. (left) Scan of the two thin sections with the identification of microstratigraphic units and pedological features. (right) Microphotographs of some of the sedimentological and pedological features observed in stratigraphic unit L15 and L17: plane polarized light (PPL), crossed polarized light (XPL), incident light (IL). (a) fine unaccommodated planar voids defining a sub-angular blocky structure (PPL), (b) illuviation features with oxidized clay coatings and dusty clayey coatings (PPL), (c) granostriated b-fabric (XPL), (d) granular structure with accumulation of fine material around the aggregates maybe as a result of stress and pressure (PPL), (e) dusty and oxidized clay coatings in irregularly shaped voids (PPL), (f) partly accommodated planar voids defining a sub-angular blocky structure (PPL), (g) granostriated b-fabric (XPL), (h) frost-shattered grain of glaucony in a sub-angular blocky structure (PPL), (i) partly accommodated planar voids in a sub-angular blocky structure (PPL), (j) amorphous organic matter dispersed in the soil and deformed organic material, (k) Planar voids cutting through a channel infilling (PPL), (l) Irregular Fe/mn nodules (PPL), (m) Burnt fibers of organic matter in orthic/disorthic rubified soil aggregate (IL), (n) disorthic nodules of burnt material displaced on a low distance by biological activity (IL), (o) vuggy structure with numerous planar voids in washed sediments.

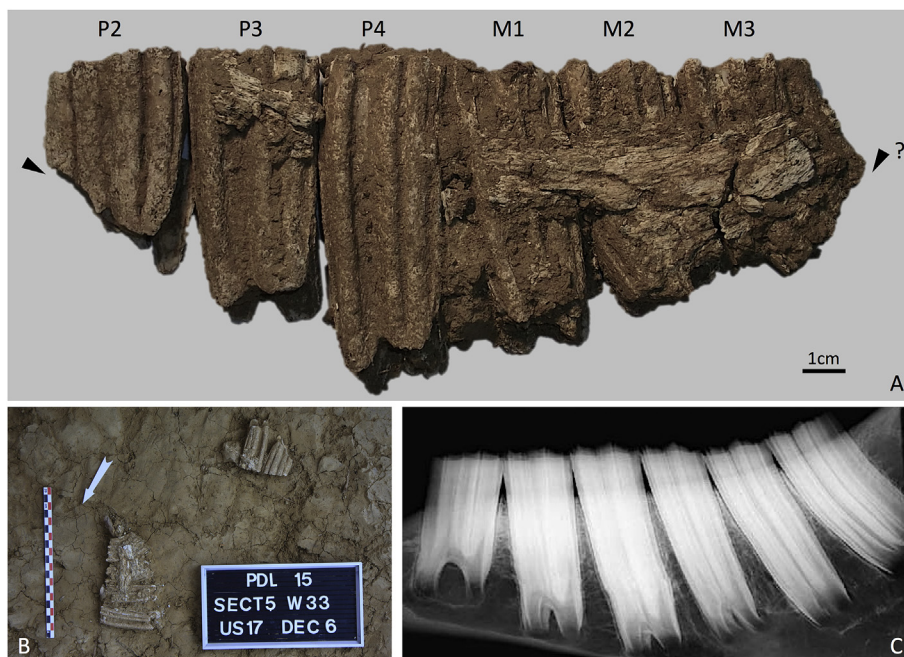


Fig. 5. Lower tooth row from a horse mandible showing damage likely resulting from intentional percussion (A) the arrows indicate the location of the fractures on the P2 and M3 teeth resulting from the possible intentional breakage of the mandibular bone (B) fragments of the same mandible during excavation (C) modern comparative reference of a complete tooth row from an unmodified horse mandible (modified from Hoppe et al., 2004).

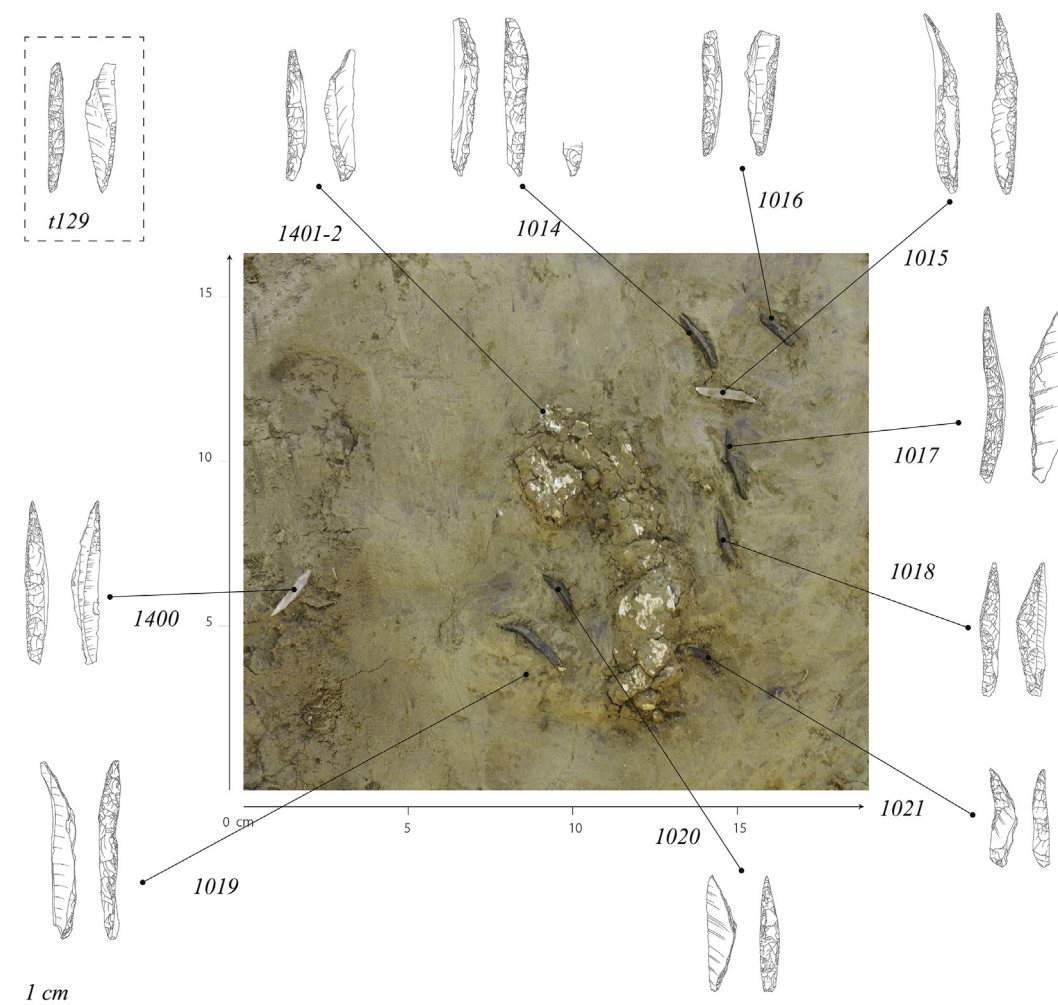


Fig. 6. Find context and details of the backed points found during excavation in close association with an osseous element (SU L17 of Les Prés de Laure).

performed in two phases: an *in-situ* observation of the residues on the stone tool surface followed by an analysis of extracted residues (Cnats and Rots, 2017). *In-situ* observation of residues was performed with a stereomicroscope, a macro-zoom microscope and a reflected-light metallurgical microscope with rotating polarizers and DIC (Rots et al., 2016). Extracted residues were observed using a transmitted light microscope with rotating polarizers and DIC. During use-wear analysis, attention was devoted to all types of traces including fractures, scarring, polish, striations and rounding. All interpretations relied on the combination of different wear traces (e.g., fractures, scarring, striations, rounding, polish) in specific patterns and no interpretation relied on one wear type only (Rots and Plisson, 2014). Specific terms are used for the description of the fractures and to avoid terminological ambiguity (Coppe and Rots, 2017), we define them here. A “spin-off” is defined as a cone-initiated scar starting from an earlier fracture surface and terminating on a ventral or dorsal surface or a lateral edge. A “burination” is defined as an elongated bending initiated fracture starting from one edge and terminating on the opposite edge. “Crushing” is defined as multiple very small scars varying in orientation and initiation and showing abrupt terminations (step, hinge).

3. Results

3.1. The lithic implements

The 11 backed points (Fig. 7) are made from two different types of chert (S6): Valanginian's chert available less than 1 km to the south

($n = 7$) and a tertiary lacustrine chert that can be found in the nearby Jabron River ($n = 3$) (see Tomasso et al., 2016 for identification criteria). Both petrographic *facies* show a very low internal variability, which suggests the backed pieces may originate from only two blocks.

The homogeneity between the 11 backed points is striking and concerns their technology, their morphology and their dimensions (S7). They are all manufactured on bladelets that were detached from the edge of flakes following a unidirectional reduction sequence with, most likely, the use of a soft hammerstone (Fig. 8a). Most bladelets have a twisted morphology ($n = 8$) and a straight ($n = 8$) or slightly curved profile ($n = 3$). The armatures associate a straight backed edge (back) with a distal oblique truncation, resulting in a triangular tool shape. All points share common metric characteristics with regard to: (1) the inflexion point that characterizes the angle between the back and the truncation (average: $149.2 \pm 8.1^\circ$); (2) the point ($26.7 \pm 4.5^\circ$); (3) the thickness (1.9 ± 0.4 mm) and (4) the width (3.5 ± 0.5 mm). Only the length displays some variability (from 12 to 22 mm).

The straight back and the truncation were manufactured by direct percussion (Fig. 8b). The truncation systematically presents regularization by a crossed retouch, which suggests that special attention was paid to its final shaping (Fig. 8c–d). The position of the back on the bladelet (i.e., lateralization) is variable and is situated either to the right ($n = 5$) or to the left ($n = 6$). The bladelets show a twist over their longitudinal axis that is intentional (Fig. 8e) and a correlation seems to exist between the direction of the twist and the position of the back (with one exception). This correlation finds technical reasons, considering that the knappers preferentially shaped the naturally concave

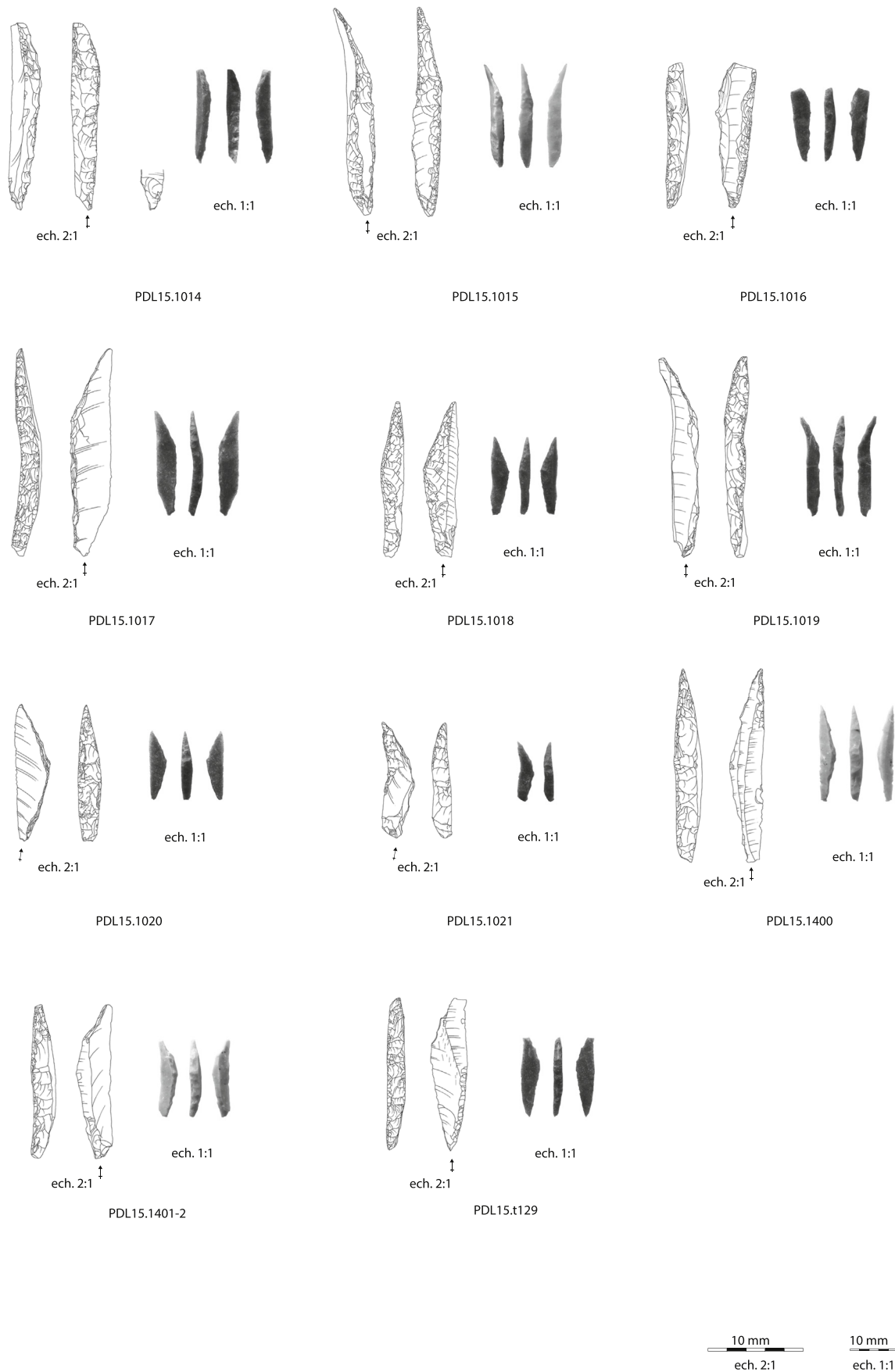


Fig. 7. Drawings (scale 2:1) and pictures (scale 1:1) of the 11 backed points found concentrated in a zone smaller than 500 cm². Noteworthy is their homogeneity in terms of technology, morphology and dimensions.

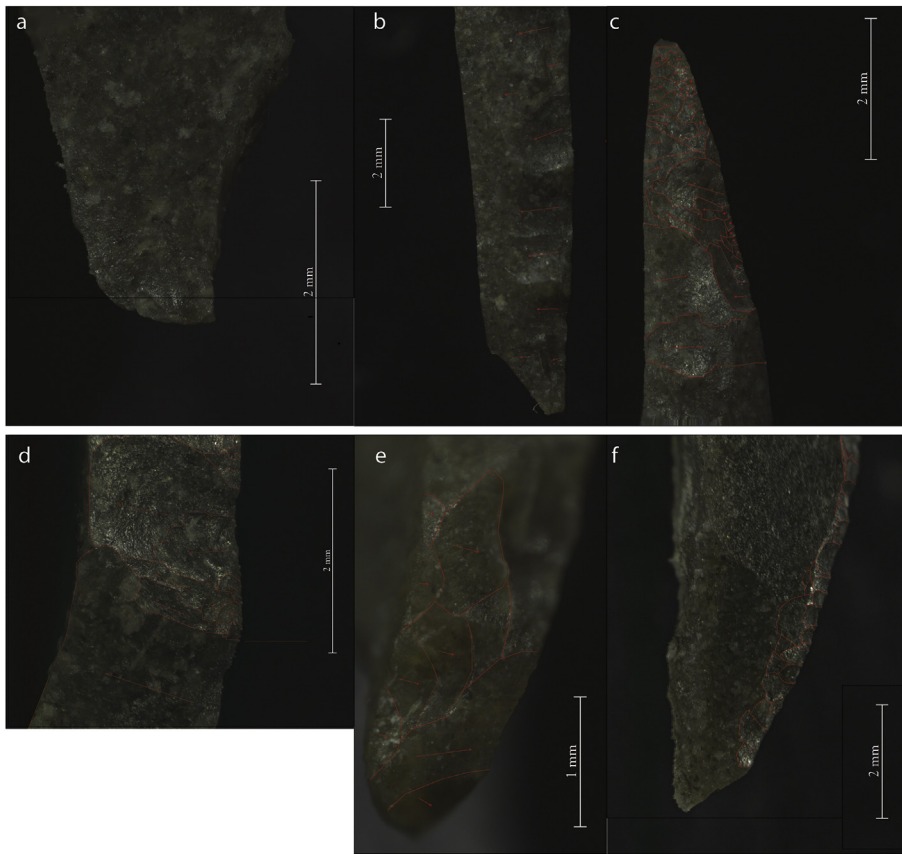


Fig. 8. Production method of the backed points. (a) The hypothesis that a soft hammerstone was used for the production of the blanks is based on the presence of two technical stigmata (a defined contact point and a poorly developed bulb) preserved on the remaining proximal part of the bladelet (PDL15.1016); (b) The backed edge is shaped by direct retouch, which is characterized by the presence of large, deep, and irregular removals (PDL15.1014); (c) The truncation on the distal tip presents a crossed retouch that indicates the use of anvil percussion (PDL15.1018); (d) Detail on the interface between the back (bottom) and the truncation (top), showing a change in the retouch modalities (PDL15.1021); (e) Detail on the remaining removals of a crest visible on the proximal part of the bladelet: the crest shifted the location of the impact-point to the left, which resulted in the production of a twisted blank (PDL15.1019); (f) Marginal direct retouch of the cutting edge (PDL15.t129).

edge to prepare the back. The cutting edge is convex ($n = 5$) or straight ($n = 6$) in plan view and rarely retouched (Fig. 8f). The few modified pieces ($n = 4$) show the application of marginal nibbling (i.e., small and regular) retouch restricted to a portion of the cutting edge.

3.2. The osseous remains

The osseous fragments associated with the backed points are poorly preserved and do not allow direct macroscopic identification or technological observations. Their general morphology can be described as elongated, but only flaky fragments are preserved which are suggestive of either bone or less probably ivory. However taxonomic identification was not possible on the basis of standard macroscopic observations, and so different analyses were required to identify the material.

ZooMS collagen fingerprint analysis (Buckley et al., 2009) allowed the identification of the specimen (Fig. 9) as originating from deer (either *Cervus elaphus* or *Dama dama*). Although ZooMS cannot readily separate some deer species such as *Cervus* from *Dama* (Buckley and Kansa, 2011), the identification of *Cervus elaphus* is favored through known absence of *Dama* in this region at this time and the presence of *Cervus elaphus* in other layers of the site.

However, the ZooMS approach does not typically differentiate between bone and antler and optical microscopy was used to this end. Generally speaking, antler should show a tubular structure that is less dense than bone (Chen et al., 2009). Our samples show a dense, aligned micro-structure that seems more indicative of bone than antler, but diagnostic features that permit to distinguish between bone and antler were obscured by the alteration of the remains (Vercoûtère et al., 2011). To better highlight the structural features, different samples were submitted to SEM-EDS analysis by using a JEOL IT100 SEM equipped with a JEOL EDS (Fig. 10a). This procedure further highlighted the aligned and fibrous microstructure of the remains. Based on comparative archaeological reference samples, the remains proved to

be most similar to bone. In addition, a micro-CT Scan was performed using a Bruker Scanjet (Fig. 10b) to examine the internal structure of the remains in comparison to the archaeological reference samples. Again, the microstructure proved most similar to bone.

3.3. Design and use of the hunting weapon

All backed points were examined for residues and wear traces (Table 1). The terminology that is used is explained in the method (SI3). Some points were intensively damaged by a combination of impact-related fractures, some in association with single spin-offs (e.g. PDL15.1014, PDL15.1021, PDL15.1401) or multiple spin-offs (e.g. PDL15.1016) (Fig. 11a) and dispersed bending initiated step-terminating scars along the cutting edge (Fig. 11b), while other points were less intensively damaged (e.g., PDL15.1015, PDL15.1017, PDL15.t129). Burinations (e.g., 1019) as well as microscopic linear impact traces (MLIT's) (Moss, 1983) (e.g., PDL15.1018, PDL15.1020, PDL15.1021, PDL15.1400, PDL15.1401) (Fig. 11c and d) were identified. Polish formation is rare, but polish from bone contact was observed on some points (e.g., PDL15.1018, PDL15.t129) (Fig. 11c,e), while other points possess a dispersed faint friction polish with some possible bone polish spots (e.g. PDL15.1401) (Fig. 11f).

Explicit evidence for projectile usage was observed on at least 5 points, while suggestive evidence was observed on the remaining ones. The characteristics of the fractures and their organization over the points, including the occurrence of fractures that are laterally initiated and have a twisted profile on one of the extremities (Fig. 11g) and/or the orientation of counter-pressure fracture phenomena (Rots, 2016), indicate the points were used as barbs. The orientation of the barbs is indicated by a few archaeological pieces. Point PDL15.1016 provides important information as the distal fracture (on the truncation) is created by a lateral force (*contra* an axial force) implying that the proximal extremity was oriented towards the apex of the projectile. Point

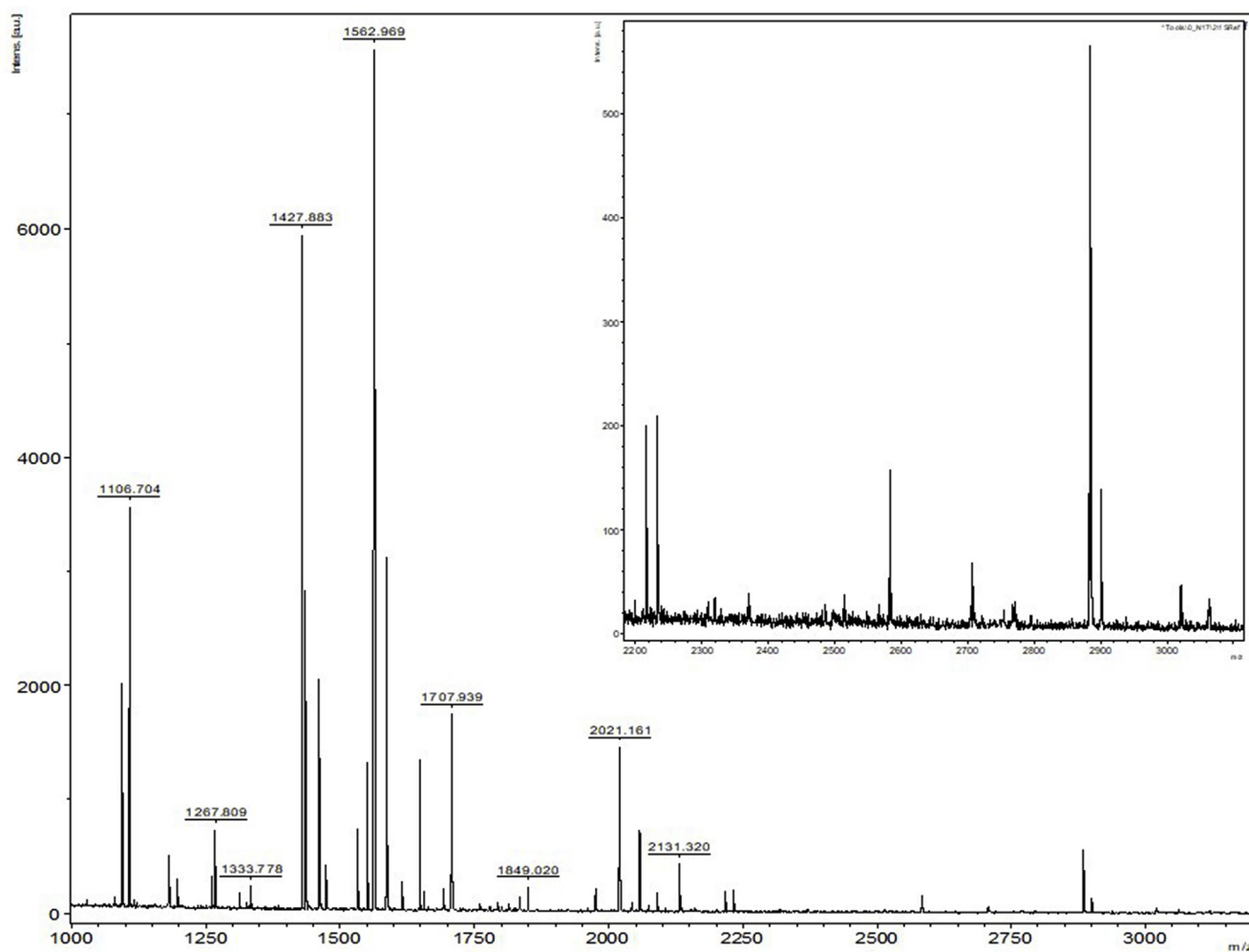


Fig. 9. Results of the ZooMS collagen fingerprint analysis, allowing to identify the osseous remains associated with the backed points as deriving from a deer.

PDL15.1018 presents a similar pattern, with a distal fracture that is initiated from the right edge of the tip toward the back, suggesting that the truncation was not in contact with the osseous point. In nearly all cases, oriented damage was observed on the lateral edge near the base,

while damage with a twisted profile was observed near the truncation. Reliable evidence regarding the orientation was absent on two pieces only. Only one backed point (PDL15.1400) shows evidence that could indicate an inverse orientation (i.e. distal point toward the apex). This

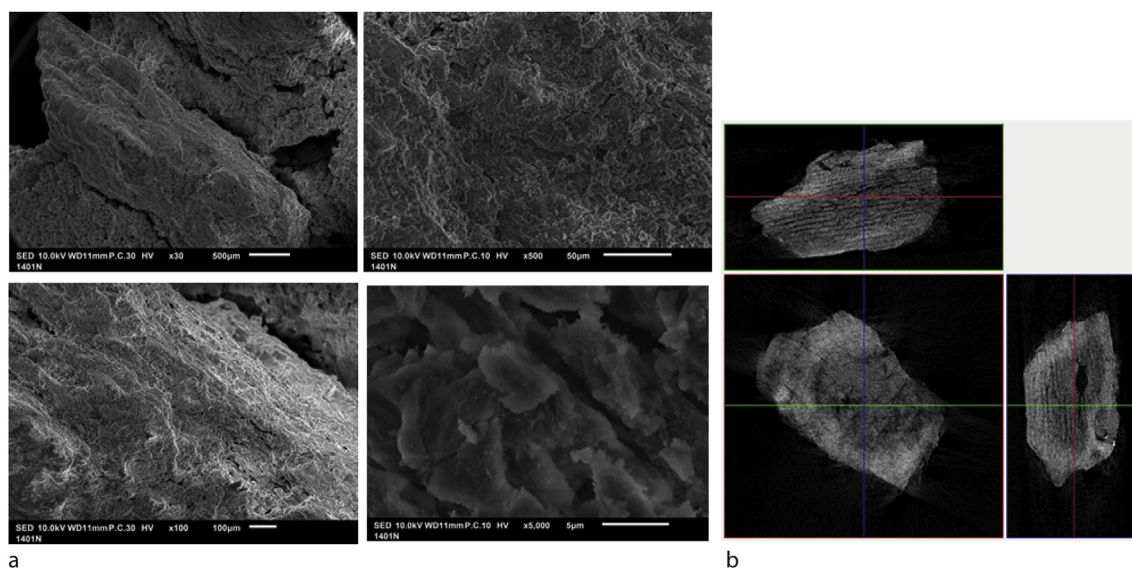
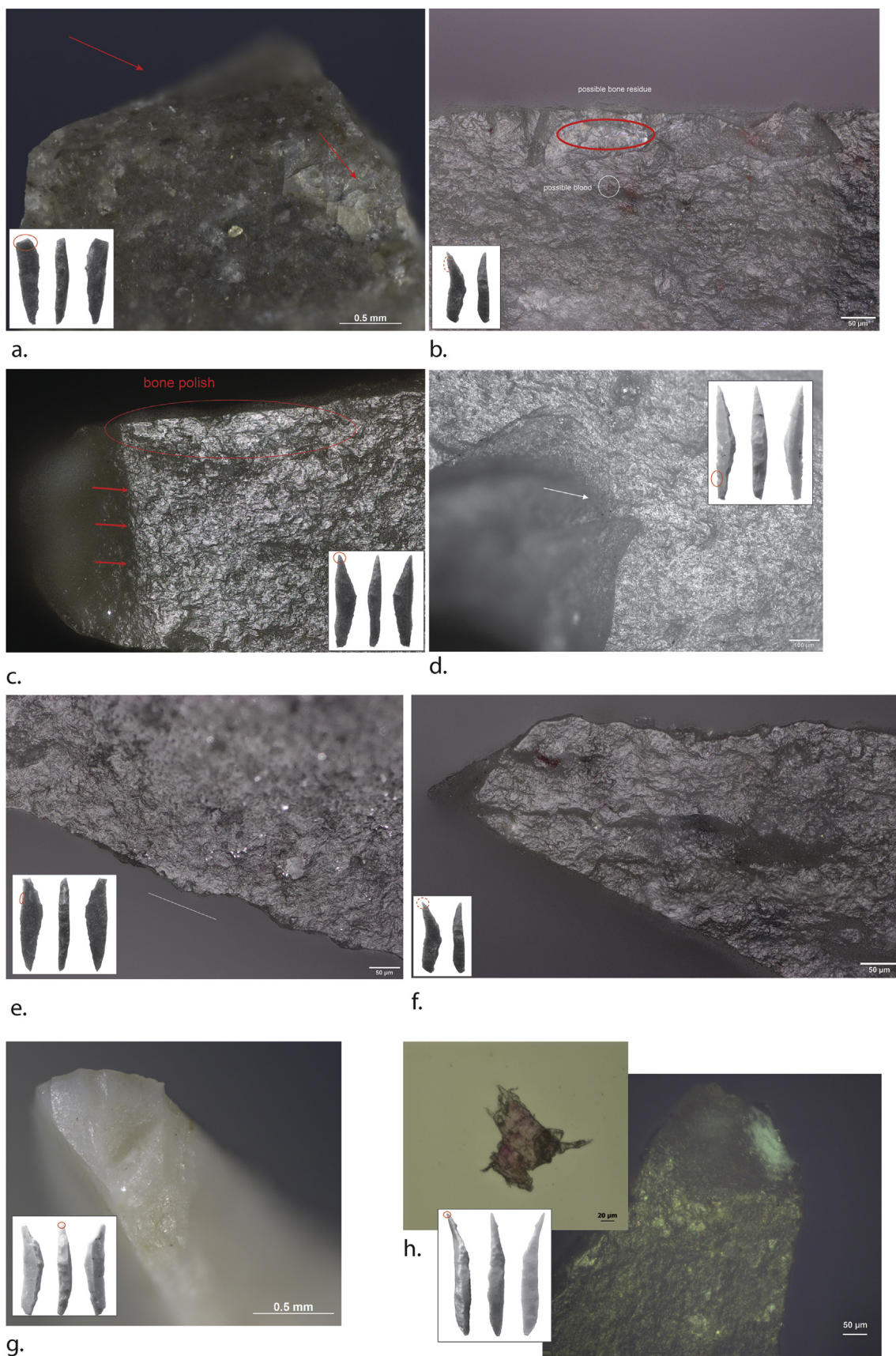


Fig. 10. (a) SEM images and (b) Micro-CT scan of the osseous fragments associated with the set of backed points.

Table 1

Summary of the use-wear and residue observations on the archaeological points. Codes used: Use as armature and use as barb: not diagnostic if find would be isolated/+ poor or moderate confidence if find would be isolated/+ + certain. Part oriented toward apex: (D) possibly distal/P proximal/(P) probably proximal/- unknown. Likely position on point: A apex/I intermediate/I/B intermediate or basal/- unknown. MLIT: microscopic linear impact trace, BS: bright spot (i.e. frictional spot, cf. [Rots, 2002](#)).

#	Summary of the use-wear analysis	Overall trace intensity	Use as armature	Use as barb	Part oriented toward apex	Likely position on point
1014	Proximal part: Small snap fracture on outer tip. Series of bending-initiated step-terminating scars with twisted profile on ventral tip. Small step- and feather-terminating scars with twisted profiles on dorsal face. Dispersed residues (possible blood, modern human hair fragment, rootlet contamination, conidia). Distal part: bending-initiated step-terminating fracture with associated fissure and spin-off. Striations associated with edge damage on ventral edge. Possibly blood, modern rootlet contamination, smeared animal tissue, conidia. Edge: Bending-initiated step-terminating scars, abrasion of outer edge.	3	+	+	P	A
1015	Proximal part: intrusive bifacial bending-initiated scar with step-into-step termination on backed edge. Conidia. Distal part: tiny bending-initiated step-terminating fracture with tiny spin-off, sliced scars on lateral edge. Smeared bone on tip.	2	-	-	-	-
1016	Proximal part: blackish residue, hyphae. Distal part: large transversal fracture with twisted profile: bending-initiated, snap-terminating, associated with multiple superposing step-terminating spin-offs including a non-detached one. Possibly blood, probable hair fragment, smeared red residue, elongated large starch grain (possibly from tuber).	3	+	+	P	A
1017	Proximal part: sliced scars on ventral face. Non-intrusive bending-initiated step-terminating scarring on dorsal face. Distal part: small bending-initiated step-terminating scar; impact striations, residues pushed in damage on distal tip. Some bone residue, brown amorphous residue, orange iron oxide, elongated large starch grain (possibly from tuber).	2	+	+	P	I
1018	Proximal part: Intense bifacial fracturing (oblique initiation), associated with MLITs, bending-initiated scars with step termination and twisted profile on edge. Animal tissue, bone residue, possible blood cells in various locations, dark brown/black blobs (perhaps resin). Distal part: small bending-initiated step-terminating fracture with strongly curved profile. Small bone polish on dorsal ridge, some abrasion from bone contact on ventral right edge, superficial step-terminating scars. Modern human hair, possible blood. Edge: linear friction features; dispersed bone-like polish spots and linear features.	3	+	+	P	A
1019	Proximal part: conidia, possible blood cells. Distal part: small bending-initiated feather-terminating fracture with twisted profile. Thick film of red substance (blood?), linear features, unidentified broken hair.	1	-	-	P	-
1020	Proximal part: compression-related fracture, possible bone. Distal part: bending-initiated hinge-terminating scars associated with MLITs on dorsal face, dispersed scars. Edge: sliced scars, feather- and step-terminating, some alternating; associated with faint MLITs. Possible bone	2	+	+	P	I/B
1021	Proximal part: step-terminating elongated removal, spin-offs associated with deep crushing, faint MLITs. Distal part: possible blood and bone residue within scar on ventral left edge, possible resin, possible bone residue. Edge: small sliced and nibbling scars, superpose retouch on dorsal medial left edge.	2	+	+	P	-
1400	Proximal part: bending-initiated feather-terminating fracture with twisted profile. Presence of manganese. Distal part: tiny snap fracture with superficial small step-terminating scar on ventral surface; short MLIT on ventral tip, MLITs in BS form on dorsal tip (right), bending-initiated step-terminating scar. Edge: deep hinge-terminating scalar scars on dorsal left edge associated with faint MLITs parallel to edge, sliced step-terminating scars along right lateral edge. Possible bone.	3	+	+	(D)	A
1401-2	Proximal part: deep edge damage on ventral face associated with a small step-terminating spin-off and faint MLITs. Distal part: different feather- and step-terminating removals initiated obliquely on dorsal tip with nibbling damage on left edge. Possible bone residue in scar on tip. Edge: dispersed faint friction polish with possible bone spots.	2	+	+	(P)	-
t129	Proximal part: bending-initiated hinge-terminating fracture, hinge is crushed. Distal part: bending-initiated feather-terminating fracture. Step-terminating removal associated with fracture on ventral surface. Bone polish associated with fracture on ventral edge	1	-	-	-	-



(caption on next page)

Fig. 11. Use-wear analysis of the backed points. (a) Fracture with associated spin-off (x55; reflected light, point PDL15.1016). (b) Ventral distal edge, dispersed bending-initiated, step-terminating scars. Possible bone residue is circled in red (x200; reflected light, point PDL15.1021). (c) Ventral distal tip. Bone polish spot and MLITs (x200; reflected light, point PDL15.1015). (d) Ventral proximal edge. MLITs associated with edge damage (x100; reflected light, point PDL15.1400). (e) Ventral distal edge. Bone polish (x200; reflected light, point PDL15.1129). (f) Ventral distal tip. Light friction polish and possible blood residue (x200; reflected light, point PDL15.1021). (g) Distal tip. Feather- and step-terminating removals, slightly oblique, photographed end-on (x59; reflected light, point PDL15.1401–2). (h) Bone pushed into fracture on distal tip (x200, bright field, reflected light, point PDL15.1015) and bone residue extracted from distal tip and stained with Acid Fuchsin (x400, bright field, transmitted light). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

backed point is more symmetrical in morphology than the others, due to which its orientation does not significantly modify its functional parameters.

The damage on the proximal extremity of two points (PDL15.1020, PDL15.1021) witnesses a compression-related aspect that may be due to contact with another barb upon impact, which would suggest a hafting in a row (Rots, 2016). Hafting in a row is further suggested by the occurrence of intensively damaged points and less intensively damaged points. Our experimental evidence and reference material available at TraceoLab is quite compelling in terms of the fact that the first and last barbs in a series are more heavily damaged than the intermediate one (s). However, also the fact whether and how a barb detached upon impact plays a non-negligible role.

An *in situ* analysis of the residues allowed identifying various residues, such as bone fragments, animal tissue, possible blood, hair fragments, smeared red residue, and possible resin. Bone pressed into impact fractures was observed on several pieces (e.g., PDL15.1015, PDL15.1021). After extraction, residues were examined under transmitted light in order to reveal more of their internal structure and confirm initial identifications (Fig. 11h). In addition, linear smearing of residues, indicative of a use-related origin, is abundant. To further strengthen the residue identification, some pieces were subjected to an SEM-EDS analysis (Fig. 12). This confirmed the organic nature of the residues that were compacted within the fractures.

3.4. Experimental testing

To evaluate our hypotheses on the design and functioning of the weapon and to complement the use-wear analysis, we conducted an exploratory experiment. The goal was to produce reference material that further supports typical damage patterns for barbs (as already identified in other experiments of our reference) (Rots, 2016) and which would permit the proposition of the most likely design for the barbed osseous point. Given the multiple potential variables involved in the case of the design and manufacture of hunting weapons (Hughes, 1978; Rots and Plisson, 2014), we limited the parameters to test. Exact copies of the backed points were reproduced. Four possible hafting designs were tested, involving differences in the distribution and orientation of the backed points on the osseous point (Fig. 13). In the first design (a), we secured the truncation on the osseous point. The proximal part of the backed point was therefore oriented toward the base. For the three other designs (b, c and d) we secured the back on the osseous point with the proximal part of the backed point oriented toward the apex. Barbs were placed in two rows of three barbs (design b); three rows of three barbs (design c) or randomly around the osseous point (design d).

Two natural glues (a resin-based mixture and protein glue) were tested. To guarantee comparability and eliminate variation that may result from specific conditions at the moment of impact, each glue type was used to secure one row of barbs on a single osseous point for design types (a) and (b). Only resin-based glue was used for design type (c) and (d) given the absence of symmetry in these designs. One artificial target was used consisting of a real animal skeleton (pony) incorporated in a ballistic gel casing that is covered by a stretched pony hide (for details on the target configuration see method and Coppe and Rots, 2017). Finally, two projecting modes were tested, the spear-thrower and the bow following on-going debate regarding projecting modes of hunting

weapons during the Upper Paleolithic (Coppe and Rots, 2017). Both options share the fact that they are projected from a distance; this choice does not exclude the possibility that the weapon was thrust or thrown by hand. The spear-thrower allows less control over the propulsion than the bow, which implies that there is a higher risk of not successfully hitting the target. Therefore, the test included twice the number of spearheads in comparison to arrowheads, in order to guarantee that the experiment would produce a sufficient number of spearheads that successfully hit the target in comparison to the arrowheads for which a successful hit was more certain. Detailed results are provided in the supplementary material (S8); only a summary is presented in Table 2.

We prepared 16 points, all of which were used for a single shot, four missed the target (one for each design), leaving a total of 12 composite points. In total, 10 barbs were lost upon impact, while 83 barbs were recovered in total. For each hit, at least one barb de-hafted. A relatively high number of barbs did not show relevant traces ($n = 41$), while the 42 remaining ones showed at least one or several fractures.

The barbs of the “design (a)” point have very specific impact traces. Scars along the cutting edge occur frequently (Fig. 14a,d,e). The distal point (i.e. the truncation) shows damage related with an axial force (Fig. 14b and c), while the proximal part often shows scars related to a counter-pressure (Fig. 14f). A single fracture identified in the proximal part of one backed point indicates a twisted force.

The three other point designs show comparable damage patterns. The proximal point frequently has damage caused by an axial force, consisting of large scars (Fig. 15a) and/or transverse fractures associated with a spin-off (Fig. 15b). Scars occur frequently on both faces of the cutting edges (Fig. 15c,d,e). The distal point (i.e. the truncation) frequently shows a twisted fracture that is initiated from the cutting edge (Fig. 15f).

Our experimental results are consistent with previous studies (Chesnaux, 2014; Yaroshevich et al., 2013) and support the use-wear interpretations proposed for the archaeological lithic backed points. The use-wear traces on barbs that are secured on an osseous point with their proximal point facing the apex are recurring and consist of two principal areas of trace production: one near the apex of the lithic point consisting of oriented and often deep uni- or bifacial scarring and another one near the truncation characterized by a strong bending force resulting in scars with twisted profiles occurring potentially on both the cutting edge and the truncation. The organization of these two damage concentrations proves to be indicative for the orientation of the barb on the putative bone point. Indeed, the organization of the microscopic use-wear traces for design (a) is opposite to the one observed on the archaeological pieces. The experimental results therefore confirm that the orientation of the barbs can be reliably based on the damage pattern and that the archaeological barbs were hafted with their truncation toward the base of the projectile.

4. Identification of a composite barbed point

Field data and laboratory analyses converge to hypothesize that the 11 lithic armatures found together with the remains of an osseous element were part of a single composite barbed point. Use-wear analysis demonstrates that the backed points were used as barbs on a projectile. Particularly striking is their great homogeneity in all categories: petrographically, technologically and typologically.

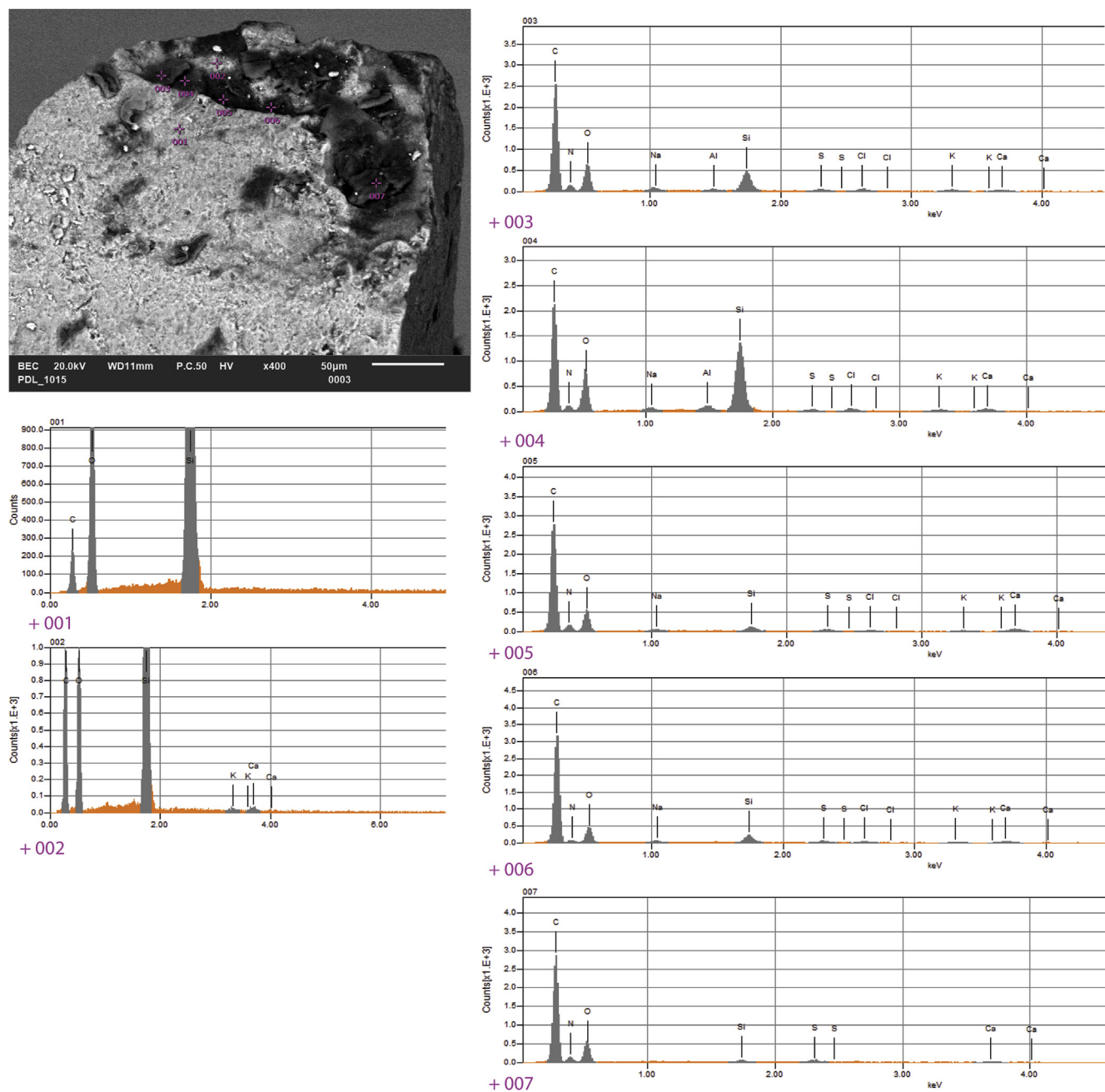


Fig. 12. Results of the SEM-EDS analysis of a residue identified within the impact-related damage on the distal tip of backed point PDL15.1015. It confirms the organic nature of the residue: 001 & 002: reference measurement on chert surface - note characteristic Si and O signal; 003–007: measurements within residue - note the high C content combined with low Si values as the residue covered the chert surface.

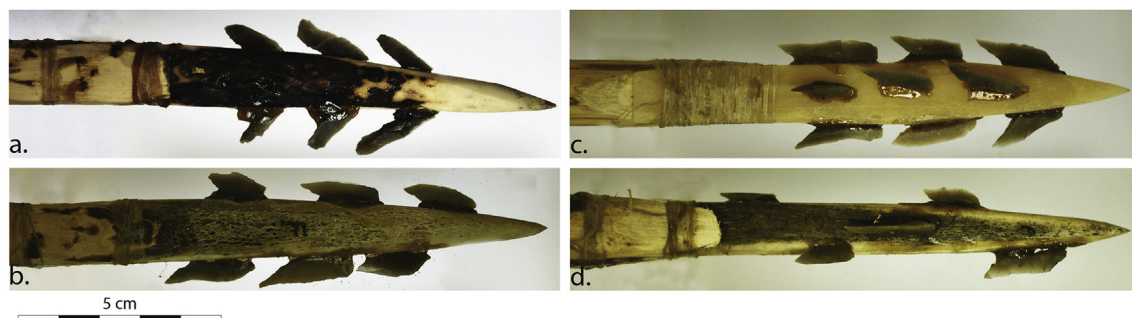


Fig. 13. Design (a, b, c and d) of the experimental hafted barbed points.

Table 2
Results of the experiment with documented wear patterns.

Design	Points	Barbs	No relevant damage	Relevant damage			Main wear traces identified
				Proximal	Distal	Cutting edge	
a	4	21	10	1	4	12	Proximal part: in a single case, sliced into scalar fracture. Distal part: fractures caused by axial pressure. Cutting edge: Dispersed uni- or bifacial scars, bending initiation, feather and step termination. Oriented toward the proximal part. A transverse fracture.
b	4	21	12	3	1	3	Proximal part: fractures related with an axial pressure. Distal part: In a single case, sliced into scalar fracture. Cutting edge: Dispersed unifacial bending-initiated, feather- or step-terminating scars oriented toward the distal end. Two transverse fractures, one associated with a spin-off.
c	2	16	13	3	2	3	Proximal part: fractures related with an axial pressure. Distal part: In a single case, long twisted burination along the cutting edge initiated on the truncation. Probably related with counter-pressure. Cutting edge: Dispersed unifacial bending-initiated, feather- or step-terminating scars oriented toward the distal end. Sliced scars on the distal part of the cutting edge. Two transverse fractures, one associated with a spin-off.
d	2	10	9	0	2	1	Distal part: In a single case, bending-initiated step-terminating fracture with spin-off. Cutting edge: Dispersed unifacial bending-initiated, feather- or step-terminating scars oriented toward the distal end.

Demonstrating that the osseous element was initially a bone point is hindered by the important alteration of the remains not permitting a technical and morphological description. Several lines of evidence support such an interpretation. The association with the armatures is remarkable and it has to be noted that the osseous remains originate from a red deer bone, which contrasts with all other bones from the excavated area that were all identified as being horse remains. In addition, spatial and micromorphological analysis both support the limited disturbance of the archaeological layer and the good preservation of the initial repartition of the artefacts. Considering these facts, we consider that the distribution of the backed points is representative of the position and organization of the remains before burial. The four longest armatures were symmetrically distributed on both sides of the deer osseous remains, while two barbs were found directly in contact with the putative bone point. Finally, the distribution of the backed points along the elongated osseous element, together with their functional orientation as inferred from use-wear analysis (Fig. 16a), allows identifying a composite barbed point that decomposed in-situ.

While an exact reconstruction of the composite point remains hypothetical, a likely design may be proposed on the basis of our analytical results and existing knowledge on European Upper Paleolithic projectile points. All currently known composite points, such as osseous barbed points, have one or two opposing rows of lithic insets. In our case, considering the high number of barbs and their specific distribution around the bone remains, we concur that the evidence best supports the hypothesis of a design with two rows of barbs on the putative

bone point (Fig. 16b), but other designs cannot be firmly excluded (e.g., three rows or dispersed positions of the barbs). The length of the complete projectile point cannot be confidently established given the preservation state of the osseous remains and the length of these remains ($L = 11,6$ cm) therefore only provides a minimal estimate. It is presently impossible to propose a propulsion mode or to infer whether or not the weapon was projected from a distance based on the available evidence.

5. Discussion

The recent discovery and excavation of the open-air site Les Prés de Laure offers new insights into the way Gravettian groups organized their technologies and how they occupied the Liguro-Provençal arc at ca. 25–23.5 ka cal BP. Thanks to rapid burial by fine alluvial deposits, it was possible to expose a 9 m² archaeological surface in a well-preserved context with a low density of organic and inorganic artefacts, documenting human occupations oriented towards the exploitation of horses. Of particular importance is the discovery of 11 lithic armatures associated with osseous fragments interpreted as a composite barbed point.

The two radiocarbon dates, together with the results from the micromorphological and techno-economic analyses, suggest that the archaeological unit under study represents several occupation events. Further excavation, spatial analyses and new radiocarbon dates will have to secure the exact chronology of the techno-economic events

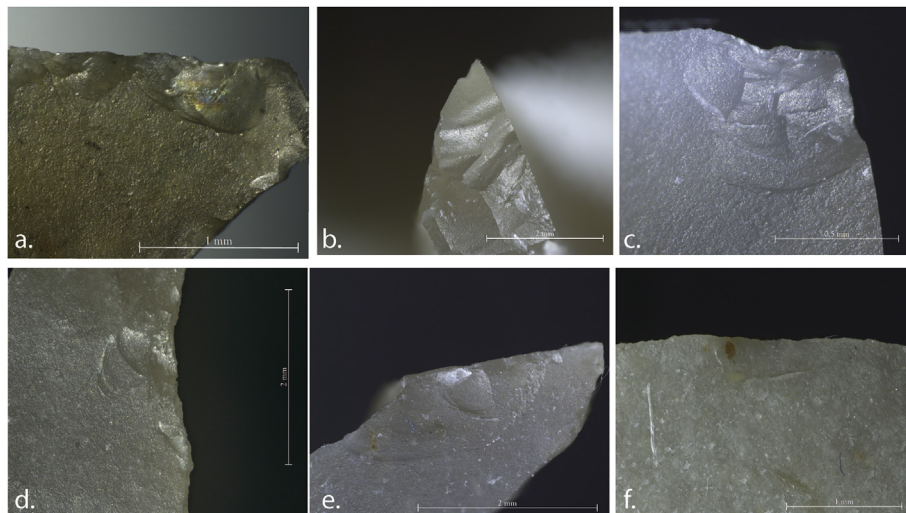


Fig. 14. Impact damage on barbs of the “design (a)” points. (a) Distal right ventral edge: scarring with bending initiation, feather and step termination, oriented obliquely toward the proximal extremity (89N06, x75). (b) Distal tip: bending-initiated fracture with hinge termination (89N104, x42.5). (c) Dorsal distal tip: scars with cone initiation and step termination (89N104, x75). (d) Ventral distal right edge: lateral scarring, predominantly hinge-terminating (89N101, x75). (e) Ventral distal right edge: step-terminating scars (89G72, x64). (f) Dorsal proximal right edge: large bending-initiated and step-terminating scar (89G72, x58).

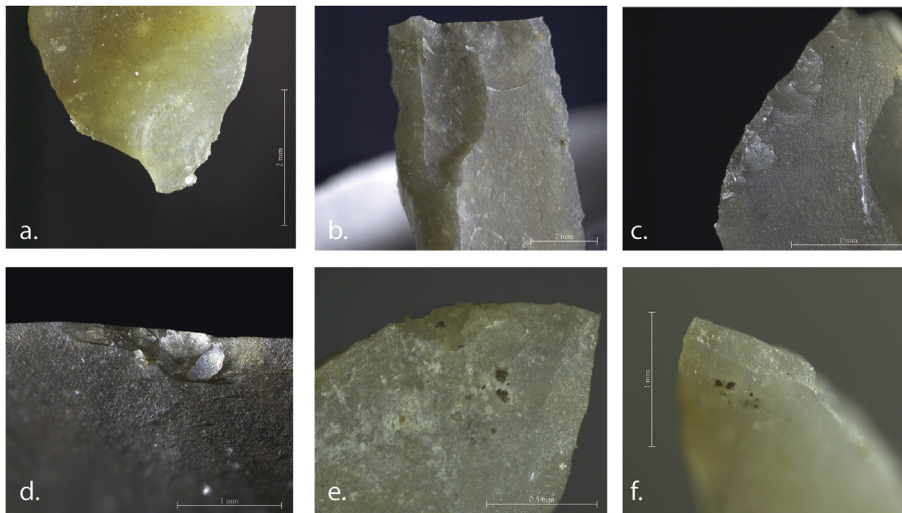


Fig. 15. Impact damage on barbs of the point “design (b)”. (a) Ventral proximal tip: scar with bending initiation, feather termination and curved profile (89E10, x24.5). (b) Spin-off initiated from a proximal transverse fracture caused by impact (89F14, x24.5). (c) Dorsal proximal left edge: bending-initiated and feather-terminating scars (89F89, x24.5). (d) Ventral mesial left edge: concentration of superposing step-terminating scars (89E10, x24.5). (e) Distal ventral tip: bending-initiated and feather-terminating scars (89A26, x160). (f) Distal tip: burination initiated on the cutting edge, twisted profile (89A26, x117).

found at Les Près de Laure. With regard to the dating of the composite barbed point, we presently favor the date of 23.5 ka cal BP considering that the dated specimen originates from the same depth and excavation square as the weapon.

The find in combination with the analytical results have several implications for our knowledge about Upper Paleolithic hunting weaponry. First of all, it pushes back the date of barbed composite projectile points to ca. 23.5 ka cal BP. Such points were previously only known to have existed in the Mesolithic period. Lithic barbs had already been identified for the Upper Paleolithic period (Yaroshevich et al., 2013), but without the factual demonstration that they were hafted on an osseous point in a composite projectile arrangement. However, other evidence from the post-LGM period does support the existence of (1) composite points with backed bladelets as cutting edges (Pétillon et al., 2011) and (2) barbed osseous (not composite) points (Pétillon, 2016). Our study thus confirms what had been assumed up to now: barbed composite projectile points predate the Mesolithic and are anchored in the Upper Paleolithic. Other similar evidence for the use of barbed composite points may be revealed in the future. Indeed, the *lamelles scalènes* of the middle Magdalenian (Langlais, 2004) show a remarkable morphological convergence with the barbs identified here and appear highly relevant to be considered in this perspective.

Another striking element is the nature of the possible osseous point itself, which would be manufactured out of red deer bone, while most of other Upper Paleolithic examples are manufactured out of reindeer antler. Nevertheless, the use of bone is consistent with evidence from Eurasia. For example, points made of bone and antler are present in the archaeological record of the bison kill and camp sites of Amvrosievka (ca. 23–21 ka cal. BP) in Eastern Ukraine, some of which present a single longitudinal groove (Julien and Krotova, 2008; Krotova and Belan, 1993). These osseous points were interpreted as possible bases of composite weapons with laterally hafted backed microliths, even though no direct evidence for such an association was recovered (Boriskovsky, 1953; Nuzhnyi, 1990). Besides, deer bone projectile points (not antler points) are typical raw material in some European Mesolithic contexts, and were support for the insert of microliths (David, 2006). Additional raw materials suitable for manufacturing weapon points is also demonstrated by other evidence from Eurasian Palaeolithic contexts, such as the ones made out of mammoth ivory or even rhinoceros horn (Nikolskiy and Pitulko, 2013).

Finally, the fact that also two apical fragments of microgravette points were found in the same SU is interesting as their wear pattern appears to diverge from the barbs associated with the putative bone point. Evidence on the apical fragments is limited, but the damage and fractures indeed appear to suggest an axial impact, which would imply

that they were used as tips and not as barbs. This is consistent with previous propositions (Nuzhnyj, 2007; Soriano, 1998). Though this hypothesis needs to be further tested with a larger sample and further discussed in terms of its functional association, our preliminary data suggest that stone-tipped weapons and composite barbed weapons co-existed during the Gravettian occupations at Les Près de Laure. Various explanations could be proposed for this purported coexistence, such as the combination of close-range and long-range weapons, the pursuit of different types of prey and variation in hunting strategies.

Evidence for the use of hunting weapons increases throughout the Upper Pleistocene, but the archaeological record still remains very incomplete, hampering the construction of solid models on the design of hunting weapons and their functional and cultural parameters. Hunting weapons play a key role in the evolution of hominin subsistence and in the history of techniques and the discovery made at the site of Les Près de Laure contributes significant new data to their understanding. The find also emphasizes the importance of integrating osseous and lithic data as a precondition for comprehending prehistoric hunting weapons. The discovery triggers reflection on the design and evolution of prehistoric weaponry and sheds new light on how to interpret the occurrence and variability of microlithic backed tools.

List

GP, LP and AT conducted the field research. AT performed the petrographic and technological study; VR and SB the use-wear analysis; VR and DC the residue analysis. LP studied the geomorphology and stratigraphy. MAJ performed the taphonomical and zooarchaeological analysis. SS performed the photogrammetry and 3D scanning. MM conducted the spatial analysis. PS performed the granulometric analysis; MB the ZooMs analysis. VR directed the SEM-EDS and CT-scan. MG made the drawings of the lithic implements. CC prepared the graphic reconstruction of the weapon. VR, JC, AT and CL designed and conducted the experiments. AT, GP, VR, and LP wrote the paper.

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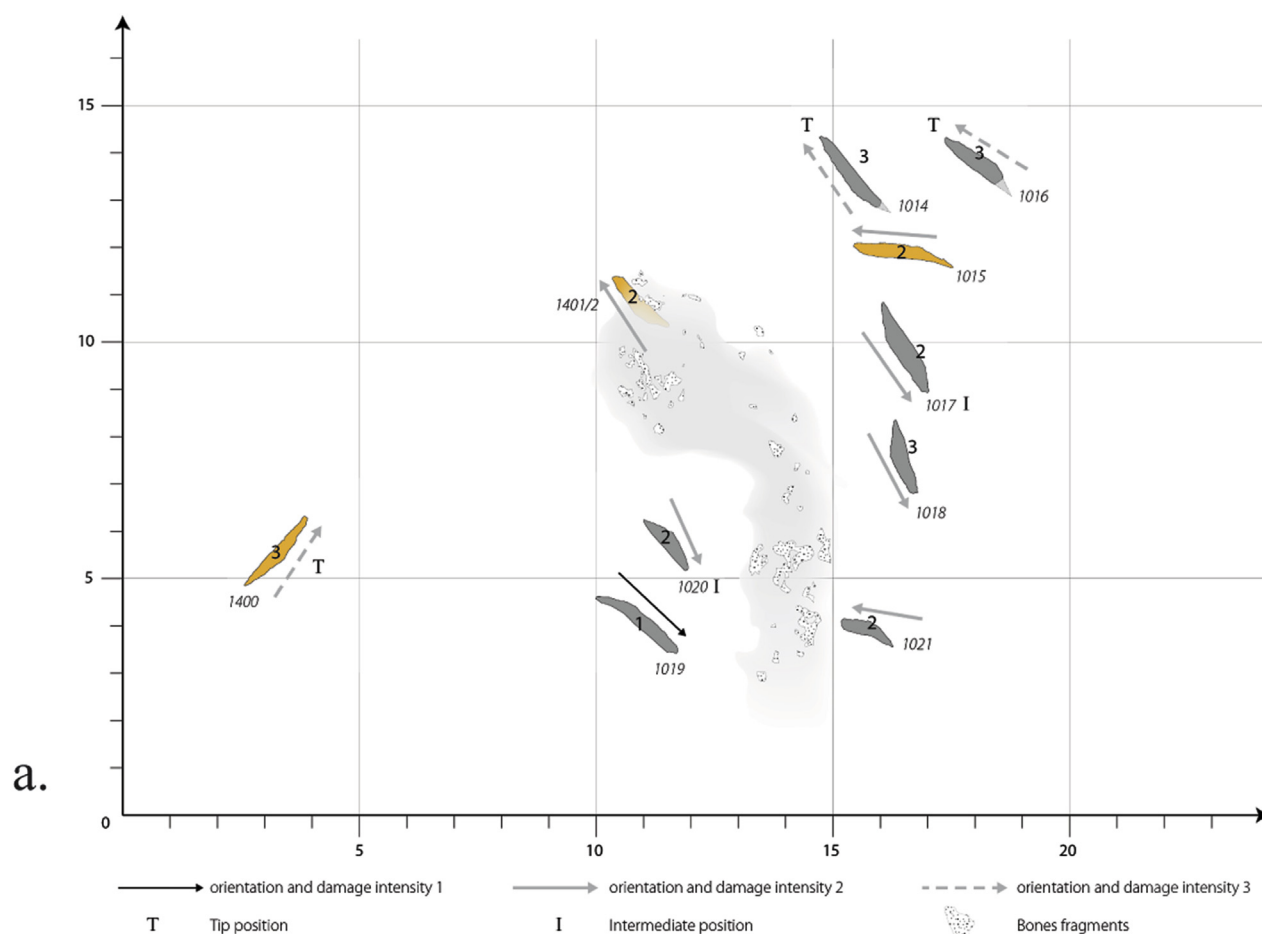


Fig. 16. (a) spatial distribution of the lithic backed points with their use-wear evidence and (b) hypothesized design of the Gravettian composite point of Les Prés de Laure (the proposed reconstruction is based on spatial, functional and experimental data). Colors indicate the raw material of the recovered archaeological barbs: yellow for those made out of tertiary chert, black for those made out of the Valanginian chert. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jas.2018.05.003>.

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