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Stone Age imitation of a slotted bone point from Pärnu River (south-western Estonia)

Tõnno Jonuks
tonno.jonuks@folklore.ee

Department of Folkloristics, Estonian Literary Museum, Vanemuise 42, 51003 Tartu / Centre of History, Archaeology and Art History, Tallinn University, Narva mnt 25, 10120 Tallinn, Estonia

Shidong Chen
shidong.chen@ut.ee

Chair of Analytical Chemistry, Institute of Chemistry, University of Tartu, Ravila 14A, 50411 Tartu, Estonia

Aivar Kriiska
aivar.kriiska@ut.ee

Chair of Laboratory Archaeology, Institute of History and Archaeology, University of Tartu, Jakobi 2, 51005 Tartu, Estonia

Ester Oras
ester.oras@ut.ee

Chair of Analytical Chemistry, Institute of Chemistry, University of Tartu, Ravila 14A, 50411 Tartu, Estonia / Chair of Laboratory Archaeology, Institute of History and Archaeology, University of Tartu, Jakobi 2, 51005 Tartu, Estonia

Samantha Presslee
sam.presslee@york.ac.uk

BioArCh, Department of Archaeology, University of York, York, YO10 5DD, UK

Andres Uueni
andres@archaeovision.eu

Co-Founder and Co-Manager, Archaeovision LLC, Tööstuse 48a, 10416 Tallinn, Estonia / Laboratory MUKOLA, Department of Cultural Heritage and Conservation, Estonian Academy of Arts, Põhja 7, 10412 Tallinn, Estonia

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ABSTRACT

This is an in-depth study of a mimicked slotted point, carved from a cervid longbone, found in the lower reaches of the Pärnu River. The 3D digital model, created during this study, provides an interactive and innovative tool for studying the object in detail. The AMS dating places the artefact at the very beginning of human habitation in the present-day territory of Estonia. SEM-EDS, ATR-FT-IR and GC-FID/MS analyses demonstrate that this unique object was probably originally partially covered with a mixture of red ochre and some coniferous resin, possibly as hafting adhesive. As this is a detailed replica of a slotted point, it also demonstrates how people themselves saw slotted points in the Early Mesolithic, also raising the question of the purpose of this replica – was it an ordinary arrowhead or rather a ritual object?

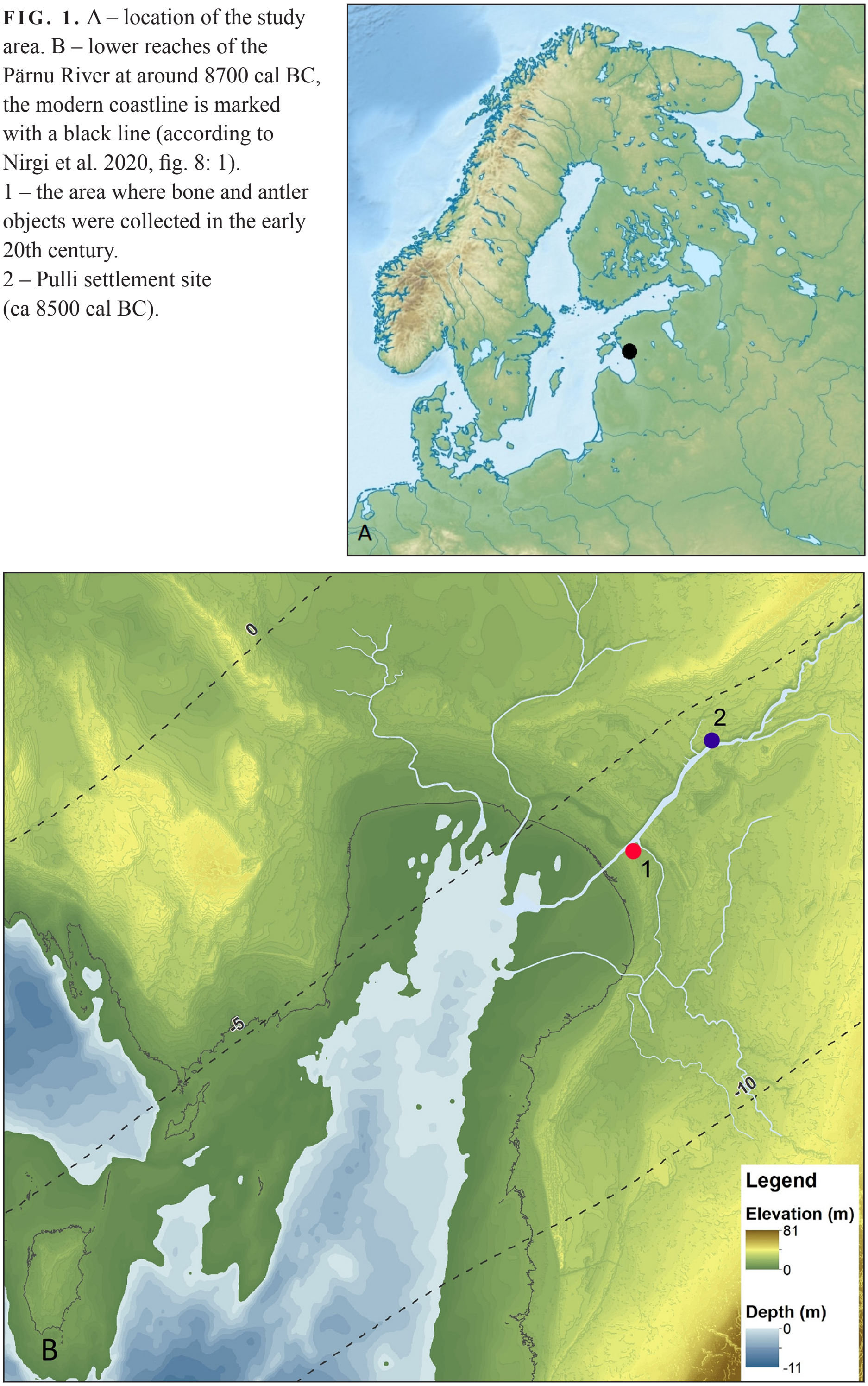
KEYWORDS
Mesolithic, skeuomorph, slotted point, 3D visualisation, residue analysis.

Introduction

In the early 20th century, a unique bone point was found in the Pärnu River, south-western Estonia (see Fig. 1: A). The point finally came into a private collection of Friedrich Rambach, a one-time consul in the municipality of Pärnu. As a man with antiquarian interests, he owned more than 500 objects, mostly bone and antler, collected from the lower reaches of the Pärnu River (Indreko 1926). Unfortunately, no details have preserved about the exact provenance of the objects in his collection. During a couple of decades in the early 20th century, a rich collection of nearly 2000 archaeological finds, mostly of bone and antler objects, was formed in the course of digging sand and gravel from the Pärnu River (Glück 1906; Bliebernicht 1924; Indreko 1926; Kriiska 1997). Despite such a rich selection of finds, no *in situ* objects or occupation layers have been reported. Even the exact find locations are unknown, and most of the finds were reportedly found in a 1.5 km long reach of the Pärnu River, downstream from the estuary of the Reiu River (see Jonuks 2016 for details). Four objects of this assembly have been directly dated to the 8th–7th millennium (see Table 1) and by using typological characteristics, the rest of the finds in this collection belong to a wide timespan in the Stone Age from ca 9000 until 2000 cal BC, while the youngest finds already date to the 2nd millennium AD. Several Stone Age sites are located at the estuary of the Reiu and upstream, including currently one of the earliest known settlement sites in Estonia – the Pulli site from the beginning of human habitation about 9100–8300 cal BC (Kriiska & Lõugas 2009; see Fig. 1: B).

Consul Rambach's collection was first published after it had been transferred to the Pärnu Museum in 1925, among others, also this point as object No. 54 (Indreko 1926). Richard Indreko, the leading archaeologist of the Stone Age in Estonia at the time, noticed the uniqueness of the object and described it as an arrowhead, which has 'thin, protruding strips with teeth or notches on both edges' (Indreko 1926, 293). This peculiarity is also marked on the drawing of the object (Indreko 1926; Fig. 2: B), where the central part of the point is depicted as any other bone object, but the serrated narrower sides are depicted blank, as they were made of a different material.

FIG. 1. A – location of the study area. B – lower reaches of the Pärnu River at around 8700 cal BC, the modern coastline is marked with a black line (according to Nirgi et al. 2020, fig. 8: 1).
1 – the area where bone and antler objects were collected in the early 20th century.
2 – Pulli settlement site (ca 8500 cal BC).



Description of the point

The 153 mm long bone point, made of a plate split from a tubular bone, has an even, 6–7 mm wide higher central part with an oval cross-section.This forms the core of the object, on which 2 mm thick and 1–2 mm wide serration was carved on both sides (see Figs 2: A; 3). This serration, mimicking slotted point flint insets, is the characteristic that makes this point unique (see Fig. 4). No marks of 'insets' can be found on the very top of the point where both edges are sharpened. There are several slotted objects, either arrowheads, knives, etc., found across eastern and northern Europe, the tip of which is similarly formed of sharpened bone or antler core, followed by flint insets (e.g. Indreko 1948, fig. 74; Oshibkina 1997, fig. 54, table XIII; Vankina 1999, figs XXVII, XXIX; Zhilin 2015, fig. 4). The 'insets' of the Pärnu River point do not reach the same distance, measuring 78 mm on one side and 72 mm on the other, suggesting that the symmetry of the carved 'insets' was not even aimed at. As this layout apparently demonstrates how insets were set on real slotted points, this uneven reach was probably intentional to make the point more similar to a real slotted point.

During the use-wear studies, no particular details were recorded suggesting its usage as a projectile weapon, as the surface of the object is partly eroded. The broken and missing tip, however, is a sign that the point could have been used. Similar damage appears on many other projectiles (Pétillon 2005; Pétillon et al. 2016) and the colour of the cross-section of this fraction indicates that the fracture is old and did not happen after the point was found in the early 20th century. Also, the carved 'insets', which are barely visible on the upper half of the object, suggest as if the artefact has been used as a projectile and the 'insets', which were carved thinner, are degraded. On the one side, a series of sharp, diagonal lines cover the core of the object, indicating some kind of usage, but these scratches may also have appeared in the post-deposition phase in the sand (Gambier 2000; Fernández-Jalvo & Andrews 2016).

FIG. 2. A – bone point R 54 PäMu 1/A 41 in the collection of the Pärnu Museum. B – drawing of the same object according to Indreko (1926). Note the marking of thinner edges on both sides. Photo by Tõnno Jonuks.

No morphological signs of hafting were detected – neither crosswise lines indicating bonds to secure the haft or lengthwise grooves.

The point has been broken and glued together. Most probably, the breaking occurred soon after the finding, as the fracture is depicted already on the very first drawing of the object (Indreko 1926, plate I: 54). The glue in the fracture was analysed by Attenuated Total Reflection Fourier Transform Infrared spectroscopy (ATR-FT-IR) using a Thermo Scientific Nicolet 6700 FT-IR spectrometer with a Smart Orbit diamond micro-ATR accessory. A protein-based adhesive (e.g. bone glue, etc.) was identified, suggesting a pre-WWII treatment. There is also another partial fracture, visible only on one side. Both fractures probably appeared in the collection of Friedrich Rambach or later in Pärnu Museum, where the bone object was stored in a dry environment, causing internal stresses. The current, slightly convex shape of the point is probably also due to the dry conditions of the collections.

FIG. 3. Interactive 3D model of the bone point, URL: https://3d.archaeovision.eu/3D-mesh/nooleots-KirMus/. To record and visualise the exact geometry and surface features of the point, laser scanning, 3D modelling and WebGL conversion were used. With an accurate Nikon ModelMaker MMDx50 laser scan head paired with a portable articulated co-ordinate measuring arm, the artefact's dimensions were recorded with minimum differences in geometry. The laser scanner produces a low-noise laser stripe that consists of approximately 1000 measured points. This was used to acquire the entire surface of the bone point, mounted in foam in a nearly vertical position. As a next step, a total of 50 photographs were captured and processed by the reflectance transformation imaging (RTI) method (Earl et al. 2010). High-resolution images were combined with the scanned model. To enable more efficient access and smooth visualisation, the number of the faces of the 3D model was optimised for web presentation. For the high-resolution detail view, the images captured during the RTI processing were combined and used to build the texture. For interactive visualisation of the 3D model directly inside a standard web page, the open-source framework 3D Heritage Online Presenter (3DHOP) was used (Potenziani et al. 2015). The result is an interactive 3D model that allows the artefact to be observed under different lighting angles, giving an RTI-like experience, but also to measure its details.

FIG 4. Close-up photographs of the carved 'insets'. The idea of flint insets is most clearly expressed in the lower third of the serrated area, where rectangular or trapezoid protrusions are carefully carved. Microscopic analyses demonstrate that different carving techniques have been used on different edges – on one side, there are three crosswise cuts to separate the 'insets' (B), while the contours of the 'insets' on the other edge are marked by smooth triangular carving (A). Photos by Tõnno Jonuks.

Analogies and dating

The typological features of the point from the Pärnu River are scarce and difficult to associate with other objects from well-dated contexts. The largest number of slotted points in Estonia, more than thirty items, have been collected in and around the Kunda Lammasmägi settlement site (Indreko 1948, 210–296). As the settlement was repeatedly inhabited during the Stone Age, it is impossible to determine the age of each individual item without direct ^{14}C dating. Some slotted points from Kunda are directly dated to the 8th–7th millennium BC (see Manninen et al. 2021, table 2), but these examples do not provide a morphological analogy to the point from the Pärnu River. The closest analogy is presented by another slotted point, also found in the lower reaches of the Pärnu River (PäMu 4A 812; Fig. 5: 3). It has similar morphological characteristics, such as a sharpened tip without slots and a narrowing stem. The bilateral slots are deep and carefully carved, no flint insets are preserved. The broken tip indicates heavy usage of the point. Unfortunately, this point is not directly dated and, since this is also a strayfind from the Pärnu River, its location does not provide any date.

The narrowing stem and the tipmost quarter, carved of bone and sharpened, is associated with slotted arrowheads from multiple sites across eastern Europe (e.g. Ivanovskoye VII; Stanovoye 4; Veretye 1; Aziarnoye 2B; see Fig. 5: 1) dated from the middle of the 10th millennium to the middle of the 7th millennium BC (Oshibkina 1997, table XVIII; Zhilin et al. 2002, fig. 8; Zhilin 2015, 37, 41; Manninen et al. 2021, table 2). Slotted arrowheads with narrowing stems have also been found in Kunda, northern Estonia, and at Lake Lubāna, eastern Latvia (e.g. Vankina 1999, figs XXVIII, XXIX), but they are not directly dated.

As contextual and typological dating did not provide any results, a sample of 1 g was separated from the point for direct AMS-dating. A cut was made below the 'insets' to preserve the diagnostic features, the serrated edges and the narrowing stem. This section was carefully documented beforehand, but no remains of use-wear or pigment were recorded. The age of the sample was measured to be 8800–8550 cal BC (see Table 1), which corresponds to the earliest ^{14}C dates from the Pulli and Kunda Lammasmägi sites and refers to the earliest human habitation in Estonia (e.g. Kriiska & Lõugas 2009, fig. 26.3; Sander & Kriiska 2018, table 4). A fragment of a slotted arrowhead from the Pulli site serves temporarily as the closest example. The tradition of using composite technology was nevertheless quite common, as indicated by about 80 flint insets from the site (Jaanits et al. 1982, 30; Jaanits & Ilomets 1988, table 2). Thus, this unique replica of a slotted point belongs to a broader tradition of composite objects, also utilised by the very first known settlers in the early 9th millennium BC in what is now Estonia, but for some reason it is expressed by mimicking methods.

TABLE 1. Directly dated objects from the lower reaches of the Pärnu River. Dates modelled in OxCal v.4.4.4 using IntCal 20 calibration curve (Reimer et al. 2020; Bronk Ramsey 2021)

Artefact ID	Artefact type	Sample material	Age BP	Age cal BC 95.4%	$^{13}C/^{12}C$	Lab ID	Reference
AI 2761: 5	Slotted point	Bone	8252+/–41	7461–7082		AAR-26573	Manninen et al. 2021, table 2
AI 2761: 6	Slotted point	Bone	8018+/–49	7070–6701		AAR-26572	Manninen et al. 2021, table 2
PäMu 4/A 944	Ornitomorphic sculpture	Antler	7040+/–40	6000–5840	–22.7	Beta-286994	Jonuks 2013
PäMu 1/A 501	Antrhopomorphic sculpture	Antler	7180+/–40	6220–6020	–21.4	Beta-317861	Jonuks 2016
PäMu 1/A 41	Point	Bone	9397+/–47	8800–8550		UBA-44292	This study

FIG. 5. 1–2 – slotted points from Aziarnoye II-B (1: KP 5773:VP373; 2: KP 5788:VP399). 3 – a slotted point from the Pärnu River (PäMu 4A 812). Photos 1 and 2 by Aliaksandr Vashanau, photo 3 by Tõnno Jonuks.

This carved slotted point from the very beginning of human habitation in Estonia is the only dated object from outside the Pulli and Kunda Lammasmägi sites. At the time of manufacturing this object, the sea level was lower than it is nowadays, and the find location remained some kilometres inland (see Fig. 1: B). Soon after this artefact was produced, rapidly rising Ancylus Lake covered the area where it was found with sediments (see Rosentau et al. 2011; Nirgi et al. 2020). At that time, the Pärnu River had a riverbed leading directly to the sea, this was filled and diverted only during the next phase of the Baltic Sea, the Litorina transgression around 5700–5600 cal BC (Nirgi et al. 2020, 13). The rich selection of artefacts found in the lower reaches of the Pärnu River, some of which are directly dated (see Table 1), covers all these millennia, suggesting multiple Mesolithic sites at the shores of the original Pärnu River, which was inundated and buried under sediments by the rising transgressive phases of the Baltic Sea, with culminations around 8200 and 5300 BC (Veski et al. 2005; Rosentau et al. 2011; Nirgi et al. 2020).

ZooMS analysis

Two samples were taken for ZooMS (Zooarchaeology through Mass Spectrometry) analysis– one using the forced bag as described in McGrath et al. (2019) and the other using the eraser method as described in Fiddyment et al. (2015; see the Supplementary material for details). Table 2 shows the ZooMS results of both methods. Neither method produced high-quality mass spectra, and the *m/z* values of higher molecular weight markers were not present, but a potential identification was possible.

TABLE 2. Collagen markers are labelled according to Brown et al. (2021)

	ZooMS collagen *m/z* markers											
	α1 508	α2 978	α2 978 (+16)	α2 484	α2 502	α2 292	α2 793	α2 454	α1 586	α1 586 (+16)	α2 757	α2 757 (+16)
Forced bag method	1105.6	1180.6	1196.6	1427.7		1648.8	2131.1	–		–	–	–
Eraser method	1105.6	1180.6	–	1427.7		1648.8	2131.1	–	–	–	3017.4	3033.4

Using these results, the identification of the bone point was a match to various species of Bovidae or Cervidae. Of these, several could be dismissed due to geographical restrictions and this further narrowed down the possibilities to red deer or elk. Unfortunately, we cannot differentiate between these species without further proteomic analysis (Jensen et al. 2020), and thus, both species act as possible source material for this point. Both species were hunted during the Early Mesolithic and are among the animal bones found in the contemporary Pulli settlement site (Lõugas & Maldre 2000, 90; Veski et al. 2005, table 3). Red deer and elk antler have also been found in the sand and gravel at the bottom of the Pärnu River.

Pigment and binder

During the optical microscope analysis, multiple small reddish and brownish spots and particles were detected on both sides of the point, on the core as well as on the 'insets'. The spots were not visible on the tang and on the tipmost parts. To determine the composition of these coloured spots, a scanning electron microscopy (SEM) with energy dispersive spectrometry (EDS) analysis using a Zeiss EVO MA15 SEM equipped with an Oxford X-MAX 80 EDS detector (including Aztec software for element analysis) was carried out. Altogether, measurements in 25 spots and one larger area were performed with SEM-EDS (Fig. 6), and the following elements were detected: C, O, Fe, Mn, Si, Al, K, Mg, Na, Ca, P, Cl, S, Ba, Zn. The elements Ca and P belong to the calcium phosphate (i.e. bone) composition. The presence of Fe, Al, Si, Mg, K indicates that the reddish spots may derive from red ochre; the presence of the small amount of Mn shows that the brownish colour tone may come from umber. In the EDS spectra, also Ba and S were detected, which may belong to barium sulphate. Other elements may be impurities.

The different colours detected during the microscopic study suggest that the object has been covered with different paints. The one-time carver may have used various ochres (maybe a mixture of raw materials from different locations), and thus, the original look was reddish-yellowish-brownish, while the detail view with the optical microscope shows randomly separated colour tones. No traces of red ochre were found at the stem, supporting the hypothesis that the point had been shafted. There are no remains of pigment on the very tip of the point either. It is possible that the one-time paint could have covered the object only partially, but the pigment could also have been eroded, either because of natural reasons or due to using it as a projectile.

It is, however, open to debate whether the remains of the ochre suggest a deliberately painted object or whether the ochre was bedded on the point by natural causes during the post-deposition centuries. The find location, the riverbed of the Pärnu River, does not support natural bedding. The riverbed lies in the clays of the Baltic Ice Lake, and its shores are formed and covered with sand-based sediments from various Baltic Sea stages (see Nirgi et al. 2020). None of these geological contexts is suitable for ochre-bedding for natural reasons. To confirm the hypothesis that the red ochre paint has been used deliberately on this artefact, the following studies focused on determining the binder in the possible paint. There is a wide variety of different sticky substances, from grease and milk to wax and resin, used throughout history to fix powdered ochre to an object. Unfortunately, none of these preserve well.

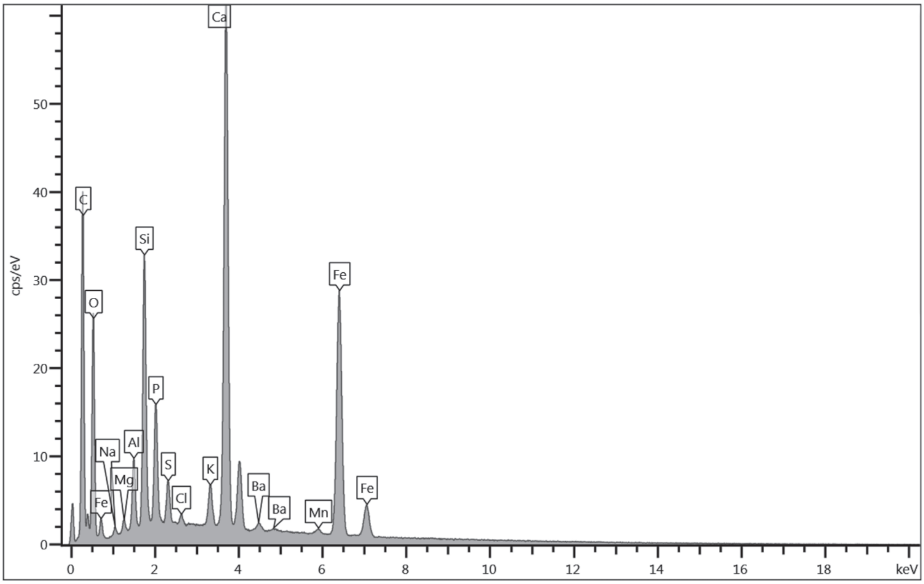


FIG. 6. SEM-EDS spectrum of reddish-brownish traces on the point.

GC-FID/MS analysis

After the point was cut and a sample was separated for AMS-dating, potential organic residues were removed from the artefact using a modified solvent extraction approach with a dichloromethane (DCM) and methanol (MeOH) (2:1) solvent mixture, widely used in the analysis of organic residues, especially resins and tar (Aveling & Heron 1998; Regert et al. 2006; Chen et al. 2021). The lower part of the 'insets' section was dipped into the solvent mixture at a height of around 2 cm and sonicated in an ultrasonic bath for 15 minutes. After three consecutive extractions, the lipid extract was collected from the object and dried under a gentle stream of nitrogen (see Supplementary material for sample preparation details). The total lipid extract (TLE) was then derivatised by N,O-bis(trimethylsilyl)trifluoroacetamide (BSTFA) with a 1% trimethylchlorosilane (TMCS) reagent and reconstituted by 90 µL of DCM with 10 µL of a C36 alkane internal standard before Gas Chromatography-Flame Ionisation Detector/Mass Spectrometry (GC-FID/MS) analysis (see Supplementary material).

Small amounts of diterpenes from abietane families were detected in the sample, denoting the presence of Pinaceae resins and tars in the coating material (see Fig. 7). Among them was dehydroabietic acid as a significant biomarker for coniferous resins (Evershed et al. 1985; Regert & Rolando 2002; Rageot et al. 2021) along with some other degradation biomarkers for coniferous tars, such as phenanthrene derivatives (dehydroabietane), 7-oxodehydroabietic acid and methyl 6-dehydrodehydroabietate (Egenberg et al. 2002; Hjulström et al. 2006). Such oxidised diterpenes were generated by isomerisation, decarboxylation and partial aromatisation of abietic acid during the production of tars, when wood and resins were heated (Egenberg & Glastrup 1999). The presence of anhydrosugars (e.g. levoglucosan), which are pyrolysis products of wood cellulose or starch, supports the exploitation of wood tars from Pinaceae (Bailly et al. 2016). A small amount of cholesterol and its degradation products (e.g. cholestan-3-ol, 7-ketocholesterol and 5,6-epoxycholestan-3-yl acetate) were detected, though these are most likely the result of later human contamination during artefact handling (Schrack et al. 2016; Hammann et al. 2018; Whelton et al. 2021). The high peaks of phthalates as indicators of plasticisers detected in the chromatogram probably derive from the forced bag method at ZooMS sampling described above or from some other pollutant of unknown origin.

A small amount of degraded compounds indicating coniferous resin together with markers of Pinaceae tars suggest that these substances have preserved from the original object. None of these could have been applied to the object during post-deposition processes, nor has any of these been used for conservation. Eduard Bliebernicht, curator of the archaeology collection at Pärnu Museum in the 1930s, was well-educated and preferred shellac-based solvents (Saluäär et al. 2002). Nothing is known about the conservation of bone and antler objects in this museum during the second half of the 20th century. Generally, synthetic conservation materials were preferred at the time, but most likely, bone and antler objects were stored without

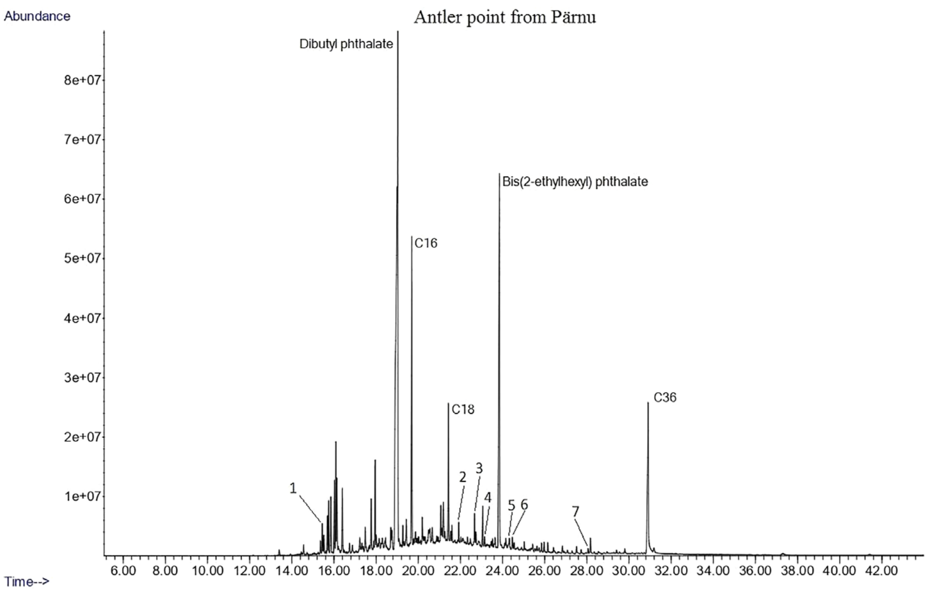


FIG. 7. Total Ion Chromatogram (TIC) of the TLE from the Pärnu Point (time in minutes), the possible biomarkers and internal standard are labelled as follows:
1 – tripropylene glycol mono-n-butyl ether, trimethylsilyl (TMS) derivative;
2–7 – isopropyl-1,1,4a-trimethyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene;
3 – dehydroabietic acid, TMS derivative; 4 –stigmasterol; 5–7 – oxodehydroabietic acid, methyl ester; 6 – sucrose, 8TMS derivative; 7 – cholesterol, TMS derivative;
C16 – palmitic acid, TMS derivative; C18 – stearic acid, TMS derivative;
C36 – hexatriacontane (internal standard).

any special treatment. The presence of a small amount of Pinaceae and coniferous tars and resins can thus be related to the original manufacturing, e.g. coating of the object, and it is most likely that this coat also contained red ochre.

Such coating and painting with ochre-containing mixtures has only rarely been reported from the eastern Baltic, such as an amber disc from Daktariškė 5, Lithuania, the engraved ornament of which was probably highlighted by a mixture of resins and mineral pigment (Butrimas et al. 2018). On the other hand, only very few objects have been analysed by the analytical techniques and this is the first study to use mass spectrometry approaches on Mesolithic bone/antler objects from this region. A similar mixture, where red ochre is mixed with spruce and pine resins, has been detected on detached stone points collected from the Yukon Territory in northwestern Canada (Helwig et al. 2014). In this case, the mixture was interpreted as adhesive for hafting and not as a coat to cover the entire object. The red ochre was interpreted as being added for 'symbolic or decorative reasons' (Helwig et al. 2014, 664), although it may also have had technological purposes. There are more examples of using red ochre as part of adhesive from South Africa, Australia (Wadley 2010 and references therein) and southern Europe (Sano et al. 2019), where red ochre is interpreted in technological terms – ochre was an agent to make adhesive, either plant gum, beeswax or anything else, less sticky, less brittle, easier to work with and also more cement-like. Fine sand would have been a viable alternative to red ochre as well (Wadley 2010, 114), although powdered ochre produces a finer substance and the selection of ochre might add a decorative and symbolic characteristic.

Imitation, mimicry or skeuomorph: towards interpreting the object

The most intriguing feature of this point is undoubtedly its form, where the bone-carved object is mimicking slotted point technology. This specific composite object technology, where flint insets are attached to a bone or antler core to form sharp edges, appeared in the eastern part of Europe no later than the middle of the 14th millennium BC (Manninen et al. 2021, table 2) and was used in eastern and northern Europe until the beginning or even middle of the 5th millennium cal BC, as demonstrated by the youngest sites with slotted points from the Moscow region in Russia and from Estonia (Jaanits et al. 1982, fig. 40; Lozovskaya & Lozovski 2015). Sharp insets were attached to various objects from projectiles to cutters by using side slots. Considering the form and size of this slotted point, it is most likely that it was used as an arrowhead, and this interpretation is also considered in the following discussion.

Skeuomorphs, where the physical design of an object represents some other material or technique, can be found widely across the globe. Skeuomorphism in archaeology is primarily understood in terms of technology and innovation (e.g. Wengrow 2001; see Frieman 2010 for a comprehensive overview), and thus skeuomorphic objects are interpreted as having been made because of the desire to create innovative objects, but for which the material or technology was unavailable; out of nostalgia, preserving old techniques and know-how in using new materials; or because necessary raw materials for common objects were not available due to natural or social restrictions. Fishtail flint daggers, mimicking bronze metal-hilted daggers, represent the spatially closest and most well-known example from the eastern Baltic (Frieman 2010), but skeuomorphic objects can be found throughout history. Skeuomorphism has also been used on symbolic objects, such as tooth pendants. In some instances, bone replicas of tooth pendants are used in the same manner and contexts as real objects (Wood 1957), but in many cases, the special value and meaning are emphasised in discussions about tooth pendant like objects (e.g. Taussig 1993; Gell 1998; Knappett 2002; Choyke 2010).

Many technological reasons can be left aside for the bone point originating from the Pärnu River. According to the AMS-dating, the Pärnu point was made at a time when slotted point technology was widely used (Manninen et al. 2021) and it was neither a novel nor disappearing technology. The main raw materials – bone for the core, flint for the insets and birch to produce tar for attaching insets – were also locally available. Moreover, the carving of such a fine and detailed object required skills and good-quality flint, and thus the one-time craftsman must have had access to resources. Therefore, it is difficult to see technological reasons for creating such an object, and rather it seems reasonable to label this point as an image or mimicry of a slotted projectile.

The point from the Pärnu River is not the only object from the eastern Baltic mimicking the elements of slotted object technology. Two Stone Age bone arrowheads from Lake Lubāna in Latvia, probably from the beginning of the 9th millennium to the middle of the 6th millennium (Berg-Hansen et al. 2019), provide close analogies. Both are interpreted as skeuomorphs of slotted points by Lūcija

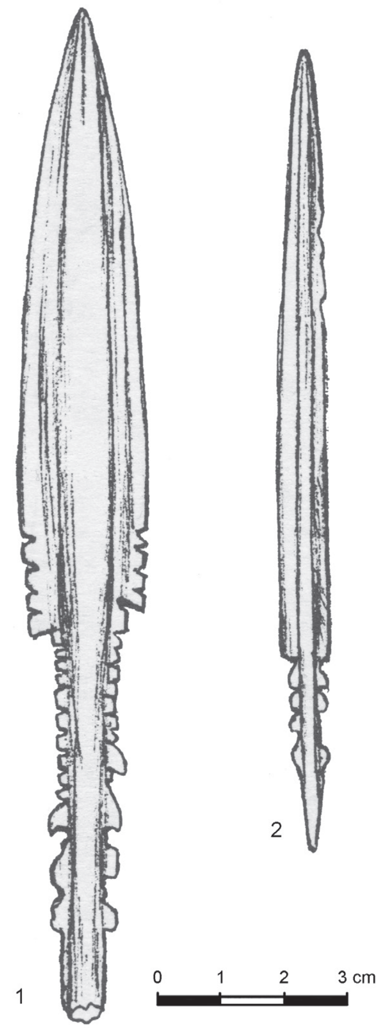


FIG. 8. Bone points from the settlements of Lake Lubāna, Latvia (according to Vankina 1999, XXIX: 3, 4). Note the serration in the lower part of the blade (1) and on the stem (2), partly mimicking the slotted technology.

Vankina (1999: 80, table XXIX: 3, 4; Fig. 8). The serration of one of them (see Fig. 8: 1) on the lower part of the arrowhead blade most certainly looks like mimicking flint insets, while most of the serration on both objects is marked on the stem and could thus be interpreted rather as aids of hafting. There is also a good example of a point from Russia, from the upper Mesolithic layer of Zamostye 2 (dated to the end of the 7th millennium and the beginning of the 6th millennium BC according to Lozovskaya & Lozovskiy 2015). The bone point has a slot for insets on one side and a thinner carved edge on the other side, thus resembling insets (Lozovskaya 2001, fig. 1: 9). The latter example especially suggests that such thin carved edges may have functioned in a similar way to real flint insets. The Pärnu point, however, is a detailed copy of a slotted point, following the prototype exactly in every detail, even carving the individual 'insets' that would have been unnecessary for only sharpening the edge.

Ritual or ordinary object?

The previous analysis has demonstrated that the point from the lower reaches of the Pärnu River is an unusual object, carved out of bone and mimicking in great detail the slotted point technology of the time and region where the composite object technology was commonly used. In addition, it was originally, at least partially, covered with coniferous and Pinaceae resins, possibly mixed with red ochre. Even if the resin was first used as an adhesive for hafting the point, remains of resin and red ochre were also detected on the other parts of the object which should not have been influenced by hafting activity. Such a cover gave the object originally a shining reddish-yellowish-brownish tone, quite different from what a natural and untreated, white bone projectile could have looked like. Until now, we have not found any artefact analogous to this point. However, the most crucial question for interpretation seems to be whether the mimicking nature of the object adds extra meanings to it or whether it is comparable to any other carved bone projectiles and the image of a slotted point is only incidental.

As a result, we propose two different interpretations for this unusual projectile. According to the first, this is an ordinary bone arrowhead, the edges of which were carved thinner, and the point was attached to a haft by using conifer resins mixed with powdered red ochre to make the resin more suitable for adhesive purposes. This interpretation is also supported by the broken tip and upper part of the 'insets', which seem to be worn out due to usage. Such a broken tip appears on many other bone points and seems to be a characteristic sign of use-wear for projectiles. The rare documentation of the use of coniferous resins and red ochre may be due to the fact that only very few projectiles in the eastern Baltic have been studied so explicitly and neither the red ochre nor the resins were visible with the bare eye. The unique form of the object, copying a slotted point in great detail, may be a single artistic attempt. As demonstrated by the examples from Lubāna and Zamostye, the thinner-carved edges, resembling flint insets, probably functioned also as cutting edges and were used as such. As a result, despite being an accurate replica in an unusual colour, extraordinary in our eyes, it could have served as an ordinary projectile. The high symbolical value of red ochre may be ascribed to it only by us, modern scholars, but powdered red ochre might have been the most suitable ingredient for the resin-based adhesive for Mesolithic people. It is also possible that after detailed studies, more such objects may appear from collections.

On the other hand, covering such an accurate, time- and energy-consuming replica of a one-time high-tech edged tool with red paint also suggests its symbolic (and possibly magical?) meaning. In the anthropology of art, in debates over replicas, it has often been stated that the knowledge of what the replica depicts is more important than the detailed copy itself (Taussig 1993 and references therein). Carl Knappett (2002, 110) has suggested that skeuomorphs could have denoted powerful objects, while others, Michael Taussig in particular (1993, 2), have emphasised the connection between replicas and sympathetic magic, a point later elaborated by Katherine Frieman (2010, 42) by noting that a skeuomorph is not merely a copy: 'it is a nuanced and meaningful copy'. According to such interpretation, this unusual arrowhead is a symbol of a real arrowhead with some extra semantics. The symbolic interpretation is further supported by the distribution of spots of red ochre, which were detected all over the object. Thus, the painting or covering of the arrowhead with a shiny reddish-yellowish-brownish coat seems to be deliberate, not only a 'misplaced' hafting adhesive. The signals of coniferous resin were detected in the lower part of the 'insets', which did not have to be covered with adhesive for hafting purposes. It is also important to recognise that covering the whole object with resin adhesive probably made the sharpened edges blunt, rendering such detailed carving useless.

The red paint certainly directs interpretations towards hunting magic, where a replica of an arrow-head symbolises a blood-covered weapon. It can also be associated with the interpretation that early shaman-like specialists used the bow and arrows as ritual equipment during their soul wanderings (Diószegi 1978, 144; Devlet 2001, 49; Mikhailova 2006, 188). The broken tip and worn-out 'insets' certainly suggest that it was not only a symbol of an arrowhead but an object that was used in actual shooting. However, the possibility cannot be excluded that such a cover was simply meant to make the object beautiful. As an analogy, beads were covered with pine resin in the Iberian Peninsula in the 3rd–2nd millennium BC, interpreted as a method to give otherwise ordinary beads a luxurious and appreciated amber-look (Odriozola et al. 2019), and similarly red ochre was used to decorate ceramic vessels, e.g. in Poland (Borowski 2017) but also in Estonia (Kriiska 1995, 55). In summary, this bone-carved artefact seems to be an object suitable for use as a projectile, and was probably used as such, but had probably some extra meanings as well, whether associated with magical thinking or with the desire for luxurious and unusual objects.

Conclusions

The study of the unique point reveals that several unusual methods are combined in the very same object. On the one hand, all these techniques were applied in an ordinary context, such as sharpening of edges or the use of various resins and ochre. On the other hand, it is only this particular object where all such unusual methods were used simultaneously, making it unique. As neither the presence of resin nor ochre is visible with the bare eye, a more detailed laboratory analysis by means of different analytical techniques, including ATR-FT-IR, SEM-EDS, GC-FID/MS and others, focusing on possible paint and coating, is a potential field for future research. It is also likely that such systematic studies will change our concepts of what hunter-gatherer bones and antler points looked like. And most importantly – the imitation of a slotted point from the Pärnu River may not be such a unique object in the future when bone and antler objects are carefully studied and such a skeuomorphic approach is specifically addressed.

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Supplementary material

FIG. S1. Section of the bone point R 54 PäMu 1/A 41, selected for total lipid extraction.

Total lipid extraction

The 'insets' section (see Fig. S1) was dipped in DCM and MeOH (2:1) solvent at a height of around 2 cm and sonificated in an ultrasonic bath for 15 minutes. The dissolved sample material was collected into a single sample tube, following the same procedure three times, followed by 10 minutes of centrifugation at 3000 rpm to separate the solvent from any solid particles. The lipid extract was transferred to a clean glass tube and evaporated to around 2 mL under an N2 stream at 40 °C. The TLE was then transferred to a small vial, where the solvent was continually evaporated to dryness.

The TLE was derivatised by adding 100 µL of BSTFA with a 1% TMCS reagent, and the mixture was heated at 60 °C for 60 min. The reagent was evaporated under an N2 stream at 40 °C. The sample was redissolved in 90 µL of DCM and transferred to an auto-sampling vial with 10 µL of a C36 alkane internal standard (1µg/mL).

Instrumental set up of GC-FID/MS analysis

A hybrid GC-FID/MS analysis was carried out using simultaneously a FID and an MS detector at the Institute of Chemistry, University of Tartu. An Agilent 7890A Series gas chromatograph with Agilent Silica Fuse Column DB5-MS, (5%-phenyl)-methylpolysiloxane column (30 m × 0.25 mm × 0.25 µm), was connected to an Agilent 5975C Inert XL mass selective detector. The injection volume was 1 µL.

The split injector (1/10 for FID/MS detector accordingly) was kept at 300 °C using helium as carrier gas with a constant flow rate at 3 mL/min (31.3 psi). The temperature program was set from 50 to 325 °C with a total run time of 44.5 minutes: the temperature was maintained at 50 °C for 2 minutes and raised with a gradient of 10 °C/min, then kept constant for 15 minutes after reaching 325 °C. The GC column was connected directly to the ion source of the mass spectrometer, using electron ionisation at 70 eV with a full scan from *m/z* 50 to 800. The FID was kept at 300 °C with a hydrogen flow at 30 mL/min, an air flow at 400 mL/min, and a makeup gas (nitrogen) flow at 25 mL/min. Compounds were identified using Agilent Chemstation software, which was compared with the NIST mass spectral library.

ZooMS analysis method

In brief, the method of the forced bag was used: the artefact was placed in an unused sample bag, the sample was gently rubbed in the bag for several minutes and then the artefact was removed. 2 mL of 50 mM ammonium bicarbonate buffer (AmBic pH8) was added to the sample bag. It was heated at 65 °C for 4 hours to gelatinise any collagen present in the bag before the AmBic was transferred to a microfuge tube and spun to dryness. The sample was resuspended in 50 uL AmBic, ready for digestion.

To collect the eraser sample, a new piece of PVC eraser was used to rub several times over the unmarked side of the tang (see Fig. 2: A). The lower part of the unmarked side was used to avoid removing the remains of possible paint and other substances during sampling, also to avoid possible contamination with glue from the large fracture in the middle of the point. The eraser rubbings were collected in a microfuge tube and 100 µL of 50 mM AmBic was added before the sample was heated at 65 °C for 1 hour. The 50 µL was then pipetted into a new microfuge tube for digestion, while the remaining 50 µL was stored at –20 °C for further analysis, if needed.

The digestion and subsequent analysis of both samples were the same. 1 µL of 0.4 µg trypsin (Promega UK) was added to each sample, and they were digested overnight (approx. 18 hours) at 37 °C. Digestion was stopped by the addition of 1 µL of 5% TFA, and the collagen-containing peptides were extracted using 100 µL of C18 resin ZipTip pipette tips (van Doorn et al. 2011). The samples were spotted in triplicate onto a Bruker MALDI plate, mixing 1 µL of the sample with 1 µL of matrix solution (α-cyano-hydroxycinnamic acid) on the plate. MALDI-ToF MS analysis (see Fig. S2) was carried out using a Bruker Ultraflex III mass spectrometer, and the mass spectra were analysed using the open-access software mMass (Strohalm et al. 2010). An averaged mass spectrum was created from the three replicates, peaks were selected using a signal to noise ratio set at 6, and the mass spectra were cropped between the *m/z* range of 800–3500. The resulting *m/z* values were compared to published markers (Buckley et al 2009; Welker et al 2016; Culley et al 2021).

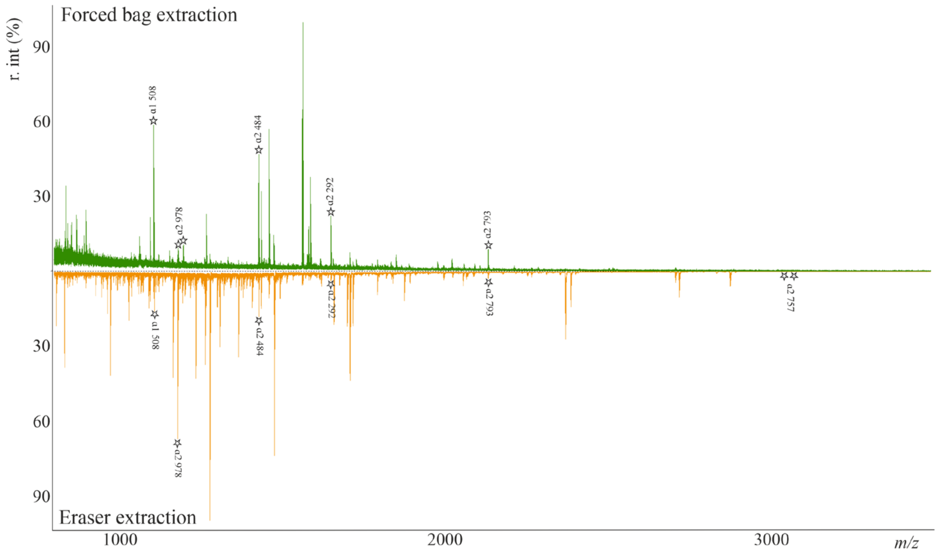

FIG. S2. MALDI-ToF MS spectra of the bone point, showing the results of both the forced bag extraction and the eraser extraction. Both extraction methods produced *m/z* values that could be used for creating an ID. r. int – relative intensity.

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Kiviaegse pistikteradega otsiku imitatsioon Pärnu jõest

Tõnno Jonuks, Shidong Chen, Aivar Kriiska, Ester Oras, Samantha Presslee ja Andres Uueni

RESÜMEE

Artiklis esitatakse algselt Pärnu kollektsionääri Friedrich Rambachi erakogusse ja alates 1925. aastast Pärnu muuseumi kogusse kuulunud luust otsiku uuringute tulemused. Otsik leiti Pärnu jõest liiva ja kruusa kaevandamisel 20. sajandi algul. Eripäraseks muudab otsiku tõik, et see on üleni lõigatud välja luust, kuid imiteerib pistikterade tehnoloogiat – mõlemal küljel on välja nikerdatud ilmselt tulekivist pistikterasid tähistavad trapetsjad või kolmnurksed moodustised ning lisaks on teradega serv voolitud õhemaks. Vormi ja suuruse järgi otsustades oli tegemist kõige tõenäolisemalt nooleotsaga. Otsiku tipp on murdunud moel, mis on tavaline viskerelvadele ning on tõenäoline, et seda on ka päriselt nooleotsana kasutatud. Kuna tegemist on ainulaadse esemega, siis valmistati sellest enne detailsemaid uuringuid kasutajate poolt kergesti hallatav 3D mudel, millele on lisatud mõõtmisvõimalus ning RTI-fotograafia efektid. Nii on võimalik eset suure detailsusega mudeli abil uurida ka distantsilt.

Otsiku rootsult võetud luuproovi AMS-dateering andis proovi vanuseks 8800–8550 kal eKr. Nõnda on see väljaspool Kunda Lammasmäe ja Pulli asulaid kolmas dateering teadaolevast inimasustuse esimesest etapist Eestis. Otsiku pinnalt võetud luuproovide ZooMS analüüsi järgi on luu pärit põdralt või punahirvelt, kelle mõlema luid on leitud nii Eesti varamesoliitikumi asulatest kui kogutud ka Pärnu jõe alamjooksult veekogu põhjast. Nooleotsa pinnalt leiti ookermullaga värvimisele viitavaid punakaid laigukesi. Uurimaks, millega võimalik ookervärv nooleotsale kinnitatud oli, analüüsiti otsikut GC-MS meetodil. Tulemusena eristati väheses koguses ja tugevasti lagunenud okaspuude vaigule ning männitõrvale viitavaid ühendeid. Kuna need olid tugevasti lagunenud ja esindatud vaid väikeses koguses, on tõenäoline, et need pärinevad eseme algsest viimistlusest. Seda enam, et teadaolevalt ei ole luu- ja sarvesemeid Pärnu muuseumis kas üldse konserveeritud või kui, siis üksnes šellak-lakiga. Analüüside tulemusel tekkis kaks võimalikku tõlgendust: kas nooleots oli algselt kaetud ookervärviga, mis oli kinnitatud eseme pinnale okaspuuvaiguga, või nooleots oli varretatud okaspuuvaiguga, millele oli parema liimumise tekitamiseks juurde segatud peenikest ookermulda.

Samalaadseid esemeid, kus luust või sarvest on nikerdatud pistikteradega esemete laadseid otsikuid, on enamgi. Paraku on need seni veel haruldased üksikobjektid ja nii on neid ka keeruline tõlgendada. Skeuomorfe, esemeid, kus üht materjali või tehnoloogilist viisi on imiteeritud teiste materjalide või tehnoloogiatega, on tuntud

üle maailma. Tavaliselt on neid valmistatud ajal, mil algsed materjalid ei ole olnud kättesaadavad, mõni tehnoloogia oli kadumas või oli tekkinud innovaatiline meetod. Käesolev nooleots, valminud pistikterade tehnoloogia kõrgajal, mil kunagisele meistrile olid kättesaadavad kõik pistikteradeks vajalikud oskused ja materjalid, ei sobi hästi skeuomorfi definitsiooni alla. Pigem on tegemist imitatsiooniga, mille põhjust me ei oska arvata. Et tegemist ei ole tehnoloogilistel või materjali kättesaadavusest tingitud lahendusega, osutavad ka näited Läänemere idakaldalt ning Loode-Venemaalt, kus mõnel esemel on kombineeritud nii tulekivist pistikteradega loodud lõikeserv kui luust nikerdatud „pistikterad".

Selline luust nikerdatud pistikterade imitatsiooniga otsik, mis vaigu ja ookermullaga kaetud, võis olla kasutusel nooleotsana nagu osutab viskerelvale tavaline murdunud ots. Teisalt ei saa välistada, et säärase kunstipärase koopiaga võis kaasneda suurem sümboolne tähendus, mida rõhutas ookrist tulenev punakas värvus ning otsiku pinnale vaiguga lisatud helk.