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SHIFTING TECHNIQUES IN PERFORATING ANIMAL TEETH AND METAL OBJECTS. SOME EXAMPLES FROM EARLY BRONZE AGE CONTEXTS

ABSTRACT

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This paper addresses shifting techniques between manufacturing two types of raw materials. On the one hand, they are copper-based alloys that were processed in the Early Bronze Age (c. 2300-1600 BCE) only by a few craftspersons, and, on the other hand, well-known and commonly processed animal hard tissues. At least one technique we observed on the metal objects originates from those of working with animal hard tissues, while the other one can be found in already published evidence. Application of techniques known from bone and antler processing in metallurgy indicates cross-craft communication and learning processes.

Keywords: Animal teeth, metallurgy, daggers, halberds, Early Bronze Age
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1. INTRODUCTION

The first metal objects in today's Poland were made primarily of copper and are dated to the 5th millennium BCE (recently Mozgała-Swach 2019, with further references therein). In the Central European Bronze Age, starting around 2300 BCE, we observe increased evidence of metallurgy, primarily based on processing copper-based alloy. Although in the Early Bronze Age (the EBA), the applied technology seems to have continued Neolithic and Eneolithic traditions (*e.g.*, Kienlin 2013, 415, 516), after that period, the copper-based metallurgy became commonly known in many communities, in particular in today's western Poland. To process mostly imported raw materials used in metallurgy, a specific toolkit, knowledge, and designed devices were necessary, and they were operated by individuals, some of whom may be called specialists (*e.g.*, Costin 1991). Manufacturing similar objects was based on successful communication and efficient knowledge transmission among makers (Jordan 2015, 4) about technological requirements and choices (Hosler 1994, 3). Similar shapes and patterns also occurred in multiple types of raw materials (*e.g.*, Biehl and Rassamakin 2008). Danish flint swords and daggers imitating the metal weapons or formally matching ceramic and wooden vessels from the Alpine lake sites can illustrate the shifting of shapes and functions between available and/or desirable raw materials. That, however, required knowledge of both of them or communication between specialists in various crafts. This phenomenon – the inter-craft communication (*e.g.,* Choyke 2008) – occurred locally and globally.

This paper addresses shifting techniques between manufacturing two types of raw materials. On the one hand, they are copper-based alloys that were processed in the EBA (c. 2300-1600 BCE) only by a few craftpersons, and, on the other hand, well-known and commonly processed animal osseous tissues. We argue these two types of raw material were processed by makers familiar with working hard materials, and when needed, they applied already-known techniques to the new material. In this case, learning was based on their own experience or as a result of inter-craft, intra-site communication. For the sake of the study, we focused on only one technique, perforating.

A perforation is a hole in a solid material made by various techniques, such as scraping and grooving, drilling, piercing, or punching (Gwinnett and Gorelick 1998). Such artefacts have been common in archaeological evidence since the Palaeolithic (*e.g.,* Wilczyński *et al.* 2014). Objects of various raw materials have been perforated to be hung, hafted, or attached. Perforations enable the manufacturing of composed items or musical instruments. Perforated ceramic strainers were used in cheese manufacturing. Depending on the hardness of the processed material, the holes were made with different tools and techniques at various operational chain stages, from punching holes in soft clay vessels to drilling through nearly finished stone axes.

2. MATERIALS AND METHODS

To analyse perforating techniques, we examined seven objects: three made of metal and four made of animal teeth. They come from EBA contexts in Western Poland: a metal hoard from Muszkowo, a settlement pit from Bytomin (today Bytnik), and two graves from Grębocice and Milejowice (Fig. 1).

Two objects made of wild boar tusks were found in a grave of six individuals (three adults, three children) furnished with four vessels of the EBA chronology (Łesiuk 2013). One specimen was complete, and the other was broken at both ends (Fig. 2: a). The perforated object is 88 mm long, 20 mm wide, and 2 mm thick.

A plate made of a wild boar tusk comes from an EBA settlement pit at Bytomin (Markiewicz 2016). The specimen is 63 mm long and 19 mm wide (Fig. 2: c) and, according to the results of use-wear analysis, was attached to a leather object: a costume or a helmet (Markiewicz and Diakowski 2016).

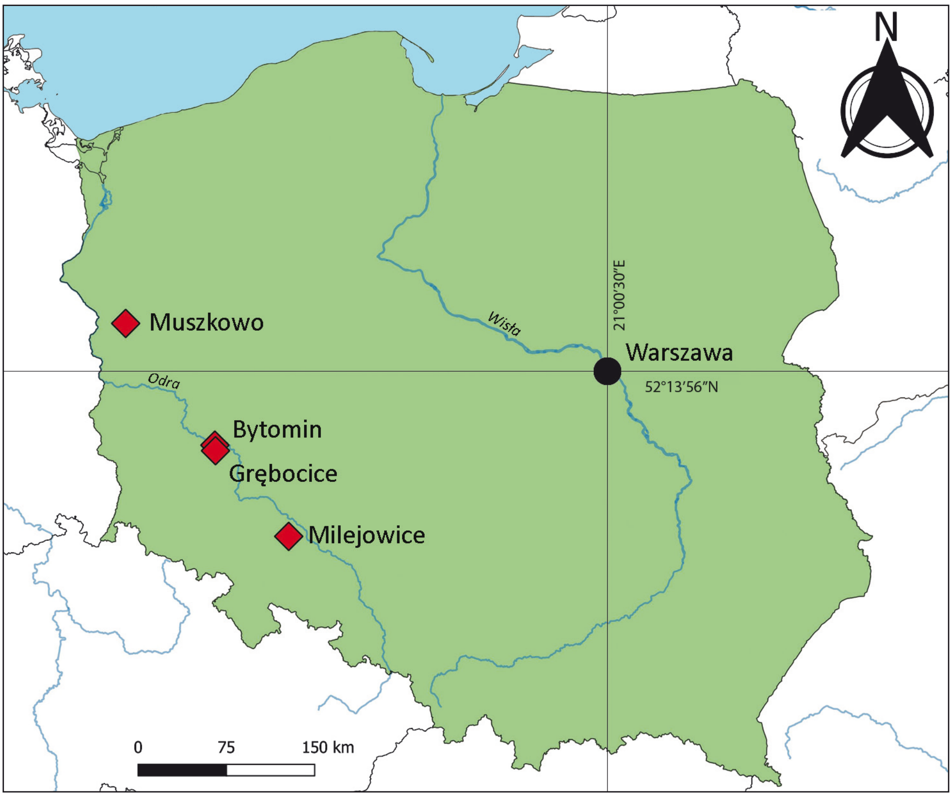

Fig. 1. Map showing locations mentioned in the text.
Source: GUGiK https://www.gov.pl/ and https://dane.gov.pl/

Fig. 2. Perforated objects made of animal teeth;
a, b – Grębocice; c, d – Bytomin (today's Bytnik); e-g – Milejowice. Source: a – Łesiuk 2013, c – Markiewicz, Diakowski 2016, e – Kopiasz 2004, with modifications. All microscopic photos by J. Baron

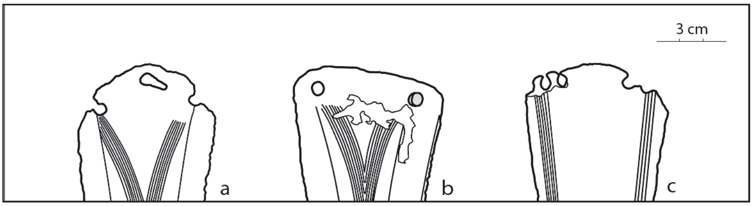

Fig. 3. Perforated metal objects from the hoard at Muszkowo;
a, c – daggers (inv. no. 4 and 6), b – halberd blade (inv. no. 5). Drawn by J. Baron

In an adult woman's grave at Milejowice in SW Poland, a necklace of 14 dog canines was found. It was the only grave good, so no direct indicators of chronology are present, but the burial was situated in an EBA cemetery, so we may assume a similar chronology (Kopiasz 2004, 40, 41). The necklace was placed on her neck; today, 12 teeth are preserved enough to be analyzed (Fig. 2: e).

The metal specimens we examined are two daggers and one halberd blade from an EBA deposit found in 2022. The collection is the subject of a detailed study that has not yet been published, and we decided not to share the full images. The first item (inventory no. 4) is a decorated dagger that is 236 mm long and 59 mm wide at the butt (Fig. 3: a). Its weight is 203.1 g. The second object (inventory no. 5) is a blade with an oblique terminated butt initially part of a halberd (Fig. 3: b). The extent and shape of the halberd's original hilt is represented by a different patina and reaches 17 mm from the blade base. The object is 214 mm long and 64 mm wide and weighs 200.6 g. The last specimen (inventory no. 6) is a fragment of a dagger decorated with grooves along the edges (Fig. 3: c). This part is 81 mm long and 59 mm wide and weighs 110.7 g.

All the artefacts studied here come from contexts representing the Únětice tradition, supported by the style of pottery and metalwork (Muszkowo, Grębocice, and Milejowice), supplemented in one case by the ^{14}C dating (Bytomin: Markiewicz and Diakowski 2016).

Microscopic observations and documentation were made using a Nikon ShuttlePix P-400R digital microscope at the Laboratory of Conservation and Archaeometry, Institute of Archaeology, University of Wrocław in Poland. The surfaces of metal objects were not subject to any conservation work or cleaning before analysis.

3. RESULTS

The tusk from the grave at Grębocice was 2 mm thick and perforated with a flint tool, leaving deep, semi-spiral marks (Fig. 2: b). They are not parallel to the surface, so the perforation was made with short rotational movements, suggesting free-hand drilling.

The plate from Bytomin was also drilled with a flint tool from both sides, making an hourglass-like cross-cut (Markiewicz and Diakowski 2016, fig. 9). Most of the drilling was

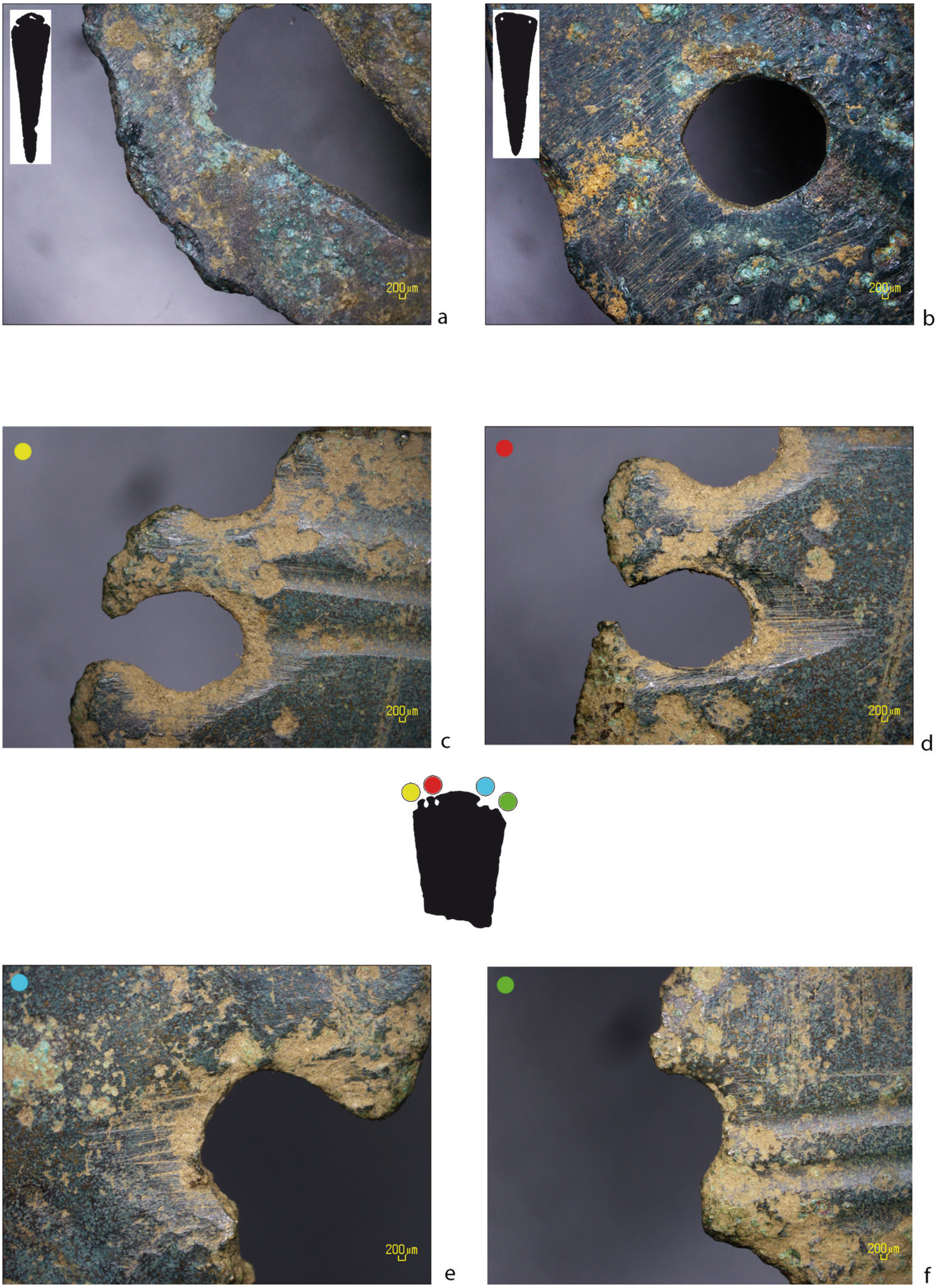

Fig. 4. Perforated metal objects from the hoard at Muszkowo;
a – a keyhole-shaped miscast in dagger no. 4; b – traces of polishing on halberd blade no. 5; c-f – abraded spots around the perforations on dagger no. 6. Photos and drawings by J. Baron

done from the ventral side (Fig. 2: c). The perforation mouth is much wider on that side and has characteristic steps, although most were smoothed by intense use (Fig. 2: d).

Among all 12 teeth from the necklace, we focused on two teeth representing different techniques of perforation. One tooth was perforated with a drilling tool and sand, which left deep spiral traces on the cylindrical hole's walls (Fig. 2: f). The other specimen was prepared before perforation (Fig. 2: g). Its surface was first abraded to less than 1 mm and then polished. The perforation wall is, therefore, less than 1 mm high, and no traces of drilling techniques were observed.

Dagger no. 4 has one central rivet hole and two side holes spaced evenly at two edges (Fig. 3: a). The central opening is fully preserved (*i.e.*, closed) and has the shape of a 5 mm wide and 12 mm long keyhole. Most likely, it was initially designed to be a round perforation with a diameter of c. 5 mm, and the long elongated shape is a miscast. The two side holes were round, partially open, with original diameters of c. 5 mm. Most of the surface was covered with a thick patina, and only some traces at the central hole were visible (Fig. 4: a). There are traces of polishing along the object's longer axis. The miscast of the central rivet hole shows the openings were cast.

The next object (no. 5) has two rivet holes placed at the two sides of the blade base, 6 mm from the edge (Fig. 3: b). Both are of a regular round shape of c. 5 mm in diameter, and a metal rivet is still present in one of them. The shape and smooth edges of both openings suggest they were cast. The multidirectional striations prove the surface around the hole was carefully polished, probably to remove casting defects such as flashes (Fig. 4: b). The upper left part of the opening bears traces of modification with a small and sharp tool.

In object no. 6, five holes were made in two groups of two and three located at both edges of the dagger base (Fig. 3: c). They are broken off, and we assume that initially, there were three holes in each group. Their shapes and surface treatment suggest a different perforation technique than in objects 4 and 5. Two holes on the left side were oval-shaped, 4 mm wide and 5 mm long (Fig. 4: c-d). The openings are situated in centres of lentil-shaped spots abraded with a stone tool, leaving a series of parallel striations. They suggest deliberate thinning of the object before perforation by punching, proved by a thin protrusion of extruded metal forming a lip along the hole edge (Fig. 4: d). In the second group, one of the holes is of quadrilateral shape with a protrusion on the edge, also suggesting a punching technique (Fig. 4: e).

4. DISCUSSION

The four tooth items we studied are made of similar raw materials but represent different perforation techniques observed even in the items composing the same necklace from Milejowice.

The perforations of two teeth of various thicknesses, 2 mm (Grębocice, Fig. 2: b) and 5 mm (Milejowice, Fig. 2: f), have cylindrical walls. Objects with tubular openings have been evidenced since the Stone Age (*e.g*., Gál 2011; Pratsch 2011; Orłowska and Osipowicz 2021), and experiments show that such shapes do not necessarily indicate the use of metal drills, as sometimes suggested (Diakowski 2019, 365). Metal drill bits are absent in EBA assemblages, and similar openings can be made by bone, wooden, and flint drill bits (Orłowska 2015; Gurova and Bonsall 2017, fig. 12.7). The circular striations on the walls of the holes are made by sand applied to make the drilling more efficient (Orłowska 2015, 3). Irregularly spaced short traces on the tusk from Grębocice also suggest using a hand tool instead of a bow drill (Venditti *et al*. 2023, 13, 14).

The plate from Bytomin represents a typical example of cross-drilling with a flint borer known from many prehistoric sites of various chronologies (*e.g*., Diakowski 2019, fig. 6; Osipowicz *et al*. 2019, fig. 5: g; Gál and Bondár 2022). The perforation has an hourglass cross-section and a wide opening on the ventral side. That may reflect the shape of the drilling bit and/or the operating angles. It also can suggest deliberately widening the mouth from one side to make operating a drilling tool easier. Widening of openings by scraping off part of the compacta layer, although originated from the Stone Age, is also standard in the EBA evidence (*e.g*., Kneisel 2010, Taf. 4: 22; Przybyła and Jędrysik 2018, fig. 8; Diakowski 2019, ryc. 6: a, b; Baron *et al*. 2024).

The last tooth was thinned before the perforation to obtain a flat, thin surface before making the hole. Perforating thin and flat surfaces enabled more significant control over a drilling tool and increased the risk of breaking the whole object if the pressure was too heavy. This mixed technique of scraping and drilling is considered typical for the Stone Age (*e.g*., Wilczyński *et al*. 2014, fig. 4; Fontana *et al*. 2020; Osipowicz *et al*. 2020, fig. 3).

Making rivet holes in daggers and swords was done in different ways. As pointed out by Schwenzer, they were either manufactured during casting or in the post-cast process (Schwenzer 2004, 172). Interestingly, in the case of dagger casting moulds (*e.g*., from Skočice, Czech Republic: Novák 2011, 132, Taf. 407: 706), the rivets' location is not marked, and the upper part of the blade is smooth. In casting rivet holes, the metallurgists used small ceramic cores carefully mounted in the casting mould (Armbruster 2000, 108). When pouring the mould with metal, they limited the metal flow and allowed the hole to form. Finds of this type of casting moulds with the cores are scarce; however, the use of this method may be evidenced by holes preserved in the negatives of sword casting moulds (*e.g*., Wennungen, Germany: Jarecki and Volker 2000, Abb. 7), in which the ends of the cores were stabilized in an appropriate position.

As indicated by observations of sword-casting moulds and specimens preserved in their raw state without traces of further processing, the manufacturing of rivet holes could also have taken place differently. One possibility was to cast a full sword tang without marked holes. Holes were then made in the solid metal in the post-production process. In this case, the casting moulds do not have marked spots for future rivet holes (*e.g*., Heilbronn-Nekckargartach, Germany; Piverone, Italy: Overbeck 2018, 104, 105, Taf. 11-13; Bianco Peroni 1970, 72, Taf. 25), and raw casts are characterized by a solid handle without holes (*e.g.*, Bingen, Germany: Schauer 1971, 215, Taf. 106: 659, 660). This solution is analogous to the early bronze daggers discussed above.

Another method of producing rivet holes was to mark the rivet holes' location in the casting mould's negative. The casting moulds are characterized by protrusions in place of the handles, corresponding to later rivet holes.

During casting, bulges in the mould's negative resulted in corresponding recesses in the handle. This technological solution allowed for obtaining places of smaller thickness – dimples, which could then be drilled or punched out more quickly. This technique was most likely used in the case of most Late Bronze Age swords from Ireland and is identified, for example, on raw sword casts from Ballycroghan, Ireland (Ó Faoláin 2004, 86; fig. 5: 7A).

The metal items we studied were perforated to be hafted: objects 4 and 6 as daggers and object no. 5 as a halberd. Based on the archaeological and iconographic evidence (*e.g.*, Horn 2014), there were two different types of hafts for daggers and halberds, but the number and distribution of rivets varied considerably even within objects of similar sizes and morphology (Branigan 1967, graph B). The daggers were hafted with their long axes parallel to the usually short handles. The halberd blades were usually hafted to a much longer handle at a right angle. To ensure durable hafting, the rivet holes must have been placed at some distance from the blade butts; otherwise, they would easily break off even at moderate pressure. This distance can also be estimated by the extent of variant patina as in object no. 5 or from examples cited in the literature (*e.g.,* Horn 2014, Abb. 132: f). Breaking off the rivets is the typical damage observed on bronze tools and weapons that could not be easily repaired (*e.g.*, Jones and Quinnell 2013; Horn 2014, 182-184, Abb. 111; 2017; Horn and von Holstein 2017). Even in this small collection, the rivet holes were preserved on the daggers and the halberd blade in different ways, indicating different pressure directions during the use.

Although obtained from the same context of the exact same chronology, the metal blades represent different perforation techniques. They vary in distribution, number, shape, and size of rivet holes. In objects 4 and 5, the holes have regular circular shapes and similar sizes of c. 5 mm in diameter. At least in the case of object 4, we know the rivet hole was cast, proved by the miscast. They occur frequently at rivet holes in many types of tools and weapons (*e.g.*, Baron *et al.* 2019, Pl. 13, 17; Petriščáková *et al.* 2020, fig. 3/3; Mittermair 2022, fig. 5: a).

The distribution and morphology of the openings were, therefore, designed before casting. Some recent experiments showed that both copper and bronze objects could have been drilled probably with a pump- or bow-drill and with a flint-tipped drill-bit (Bell 2016, 27). Both strategies reflect the makers' knowledge about and skills in hafting finished objects, even if this was not done by metallurgists but other craftspersons, as evidenced in ethnography (Rowlands 1971, 211).

In the case of dagger no. 6, the holes vary in shape and distribution. All the perforations are located right at the dagger base and prove that the rivets were broken off. One group consists of oval and the other one of possibly rectangular holes. Protrusions along the openings' edges suggest they were punched out of the already cast object. The surface was prepared by abrasion, probably done by a stone tool to improve perforation control. Punching the rivet holes instead of casting indicates repair and secondary riveting, as can be noticed elsewhere (*e.g.*, Horn 2014, Abb. 127; Perucchetti *et al.* 2020, fig. 3). The new holes were punched probably too close to the base edge, and during the use, the rivets broke off again.

After the rivet holes were ready, the next stage was attaching a perforated haft. The main impact in this case would be directed to a rivet head and a metal or organic haft (*e.g.*, Nowak 2020, fig. 4). Traces of hammering or imprints of the rivet heads would not be observed on the blades because they had no direct contact with rivet heads. We argue, therefore, that widened mouths of openings noted in the literature are not rivet-derived wear (*e.g.*, Tarbay 2019, fig. 18.1) but a post-cast treatment of the cast holes or traces of drilling (Bell 2016). Some extra material, casting seams, or irregular edges must have been removed to fit the blade with rivets. The technique of widening the opening (*e.g.*, Tarbay 2019, fig. 10.1; Mittermair 2022, 7b) would, therefore, be similar to what we observe on the plate from Bytomin and on other published items made of bone and antler (*e.g.*, Diakowski 2019, fig. 6).

At least one technique we observed on the metal objects originates from working animal hard tissues. The widening of the openings by rotational movements to finish the rivet holes was not observed in our collection of metal objects. However, in the literature, there are many analogies of application similar technique to what we observed on the plate from Bytomin. Scrape-and-drill techniques have been standard in manufacturing tooth pendants since the Stone Age and were applied as a secondary riveting of repaired blade no 6. The metal dagger need not necessarily have been renewed by the metallurgist. It could have been manufactured elsewhere and brought to the place of use. It seems that it was fixed by someone skilled in working with other materials, and his/her knowledge was applied to repair a broken metal item.

CONCLUSIONS

This short study shows that the manufacturing of objects that we consider similar can involve a variety of technical solutions. If they were composite items and hafting was required, it could have been done in different ways depending on the craftsperson's skills, experience, and knowledge of processing other raw materials. Making the rivet holes in metal objects could have been both planned before casting and performed in already cast or broken items.

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References

Armbruster B. R. 2000. *Goldschmiedekunst und Bronzetechnik. Studien zum Metallhandwerk der Atlantischen Bronzezeit auf der Iberischen Halbinsel* (= *Monographies instrumentum* 15). Montagnac: Mergoil.

Baron J., Diakowski M., Kufel-Diakowska B., Nowak K. and Sych D. 2024. From flint to metal? Techniques of bone and antler processing in the early Bronze Age Poland. In J. A López Padilla and N. Provënzano (eds), *Metal And Worked Bone Materials In Prehistoric Europe. From Iberia to the Carpathians*. Alicante: MARQ Museo Arqueológico de Alicante, 143-165.

Baron J., Maciejewski M., Jarys, R., Kuźbik R., Łaciak D., Łucejko J. J., Mackiewicz M., Miazga B., Nowak K. and Sych D. 2019. *Phenomenon of Repetition: Deposits from Karmin*. Wrocław: Uniwersytet Wrocławski.

Bell D. 2016. Rivet-hole production in the Bronze Age. *The Journal of Irish Archaeology* 25, 17-30.

Bianco Peroni V. 1970. *Die Schwerter in Italien. Le spade nell'Italia continentale* (= *Prähistorische Bronzefunde* IV/1). München: C. H. Beck.

Biehl P. F. and Rassamakin Y. Ya. (eds) 2008. *Import and Imitation in Archaeology* (= *Schriften des Zentrums für Archäologie Undkulturgeschichte des Schwarzmeerraumes* 11). Langenweißbach: Beier&Beran.

Branigan K. 1967. The Early Bronze Age Daggers of Crete. *The Annual of the British School at Athens* 62, 211-239.

Choyke A. M. 2008. Shifting Meaning and Value through Imitation in the European Late Neolithic. In P. F. Biehl and Rassamakin Y. Ya (eds), *Import and Imitation in Archaeology* (= *Schriften des Zentrums für Archäologie Undkulturgeschichte des Schwarzmeerraumes* 11). Langenweißbach: Beier&Beran, 5-21.

Costin C. L. 1991. Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Production. *Archaeological Method and Theory* 3, 1-56.

Diakowski M 2019. Badania technologiczno-funkcjonalne neolitycznych i wczesnobrązowych przedmiotów kościanych. In M. Furmanek (ed.), *Pierwsi rolnicy i hodowcy na Śląsku. Dialog interdyscyplinarny*. Wrocław: Instytut Archeologii Uniwersytetu Wrocławskiego, 357-373.

Fontana F., Cristiani E., Bertola S., Briois F., Guerreschi A. and Ziggiotti S. 2020. A snapshot of Late Mesolithic life through death: An appraisal of the lithic and osseous grave goods from the Castelnovian burial of Mondeval de Sora (Dolomites, Italy). *PLoS ONE* 15/8: e0237573.

Gál E. 2011. Prehistoric antler- and bone tools from Kaposújlak-Várdomb (South-Western Hungary) with special regard to the Early Bronze Age implements. In J. Baron and B. Kufel-Diakowska (eds), *Written in Bones. Studies on technological and social contexts of past faunal skeletal remains*. Wrocław: Institute of Archaeology, University of Wrocław, 137-164.

Gál E. and Bondár M. 2022. Drilled canine ornaments from a special Late Copper Age Grave / Kutya-szemfogból Készült Díszek Egy Különleges Késő Rézkori Sírból. *Archaeometriai Műhely* 19/1, 43-56.

Gurova M. and Bonsall C. 2017. Experimental Replication of Stone, Bone and Shell Beads from Early Neolithic Sites in Southeast Europe. In D. E. Bar-Yosef Mayer, C. Bonsall and A. M. Choyke (eds), *Not just for show. The Archaeology of Beads, Beadwork and Personal Ornaments*. Oxford & Philadelphia: Oxbow Books, 159-167.

Gwinnett A. J. and Gorelick L. 1998. A Brief History of Drills and Drilling. *BEADS: Journal of the Society of Bead Researchers* 10, 49-56.

Horn Ch. 2014. *Studien zu den europäischen Stabdolchen. Teil 1* (= *Universitätsforschungen zur prähistorischen Archäologie 246*). Bonn: Dr. Rudolf Habelt GmbH.

Horn Ch. 2017. Combat and ritual — Wear analysis on metal halberds from the Danish Isles and the Cimbrian Peninsula. *Journal of Archaeological Science: Reports* 14, 515-529.

Horn Ch. and von Holstein I. C. C. 2017. Dents in our confidence: The interaction of damage and material properties in interpreting use-wear on copper-alloy weaponry. *Journal of Archaeological Science: Reports* 81, 90-100.

Hosler D. 1994. *The Sounds and Colors of Power. The Sacred Metallurgical Technology of Ancient West Mexico*. Cambridge: The MIT Press.

Jarecki H. and Volker A. R. 2000. Die Erkundung der spätbronze- bis früheisenzeitlichen Grabenanlage von Wennungen, Ldkr. Burgenlandkreis. *Jahresschrift für mitteldeutsche Vorgeschichte* 83, 109-124.

Jones A. M. and Quinnell H. 2013. Daggers in the West: Early Bronze Age Daggers and Knives in the South-west Peninsula. *Proceedings of the Prehistoric Society* 79, 165-191.

Jordan P. 2015. *Technology as Human Social Tradition Cultural Transmission among Hunter-Gatherers* (= *Origins of Human Behavior and Culture* 7). Oakland, California: University of California Press.

Kienlin T. L. 2013. Copper and Bronze: Bronze Age Metalworking in Context. In H. Fokkens and A. Harding (eds), *The Oxford Handbook of the European Bronze Age*. Oxford: Oxford University Press, 414-436.

Kneisel J. 2010. Wyroby z kości i poroża z wykopów 14-17. In J. Müller, J. Czebreszuk and J. Kneisel (eds), *Bruszczewo II. Ausgrabungen und Forschungen in einer prähistorischen Siedlungskammer Großpolens. Badania mikroregionu osadniczego z terenu Wielkopolski* (= *Studien zur Archäologie in Ostmitteleuropa, Studia nad Pradziejami Europy Środkowej* 6/1). Bonn: Dr. Rudolf Habelt GmbH, 663-850.

Kopiasz J. 2004. Cmentarzysko kultury unietyckiej na stanowisku Milejowice 19, powiat Wrocław, woj. dolnośląskie. *Archeologiczne Zeszyty Autostradowe Instytutu Archeologii i Etnologii PAN* 3/2, 31-59.

Łesiuk M. 2013. *Sprawozdanie i opracowanie z ratowniczych badań archeologicznych związanych z budową gimnazjum w Grębocicach, pow. polkowicki. Stan. Grębocice 24.* Unpublished excavation report.

Markiewicz J. E. 2016. Osada z młodszego okresu przedrzymskiego na stanowisku Bytomin (Bytnik) 6 gm. Głogów. In J. E. Markiewicz and A. Błażejewski (eds), *Osada i cmentarzysko z epoki żelaza na stanowiskach Bytomin (Bytnik) 1 i 6*. Wrocław: Instytut Archeologii Uniwersytetu Wrocławskiego, 67-145.

Markiewicz J. E. and Diakowski M. 2016. The wild boar at the Oder shore: on a boar's tusk ivory plate from the early Bronze Age found in Bytomin (woj. dolnośląskie/PL). *Archäologisches Korrespondenzblatt* 46/1, 43-56.

Mittermair N. 2022. Take it to the grave. Traces of Production, Post-Casting Treatment and Use of Metal Objects from Urnfield Cemeteries in Lower Austria. *Archaeologia Austriaca* 106, 65-115.

Mozgała-Swach M. 2019. Kiedy pojawiły się pierwsze metale… In M. Furmanek (ed.), *Pierwsi rolnicy i hodowcy na Śląsku. Dialog interdyscyplinarny*. Wrocław: Instytut Archeologii Uniwersytetu Wrocławskiego, 375-386.

Novák P. 2011. *Die Dolche in Tschechien* (= *Prähistorische Bronzefunde* VI/13). Stuttgart: Franz Steiner Verlag.

Nowak K. 2020. Badania śladów produkcji oraz śladów użytkowania zachowanych na przedmiotach ze skarbu z Marcinowic. In A. Michalak and E. Przechrzta (eds), *Marcinowice. Skarb przedmiotów metalowych z wczesnej epoki brązu*. Zielona Góra: Stowarzyszenie Przyjaciół Muzeum Archeologicznego Środkowego Nadodrza oraz Muzeum Archeologiczne Środkowego Nadodrza w Zielonej Górze, 75-99.

Ó Faoláin S. 2004. Bronze Artefact Production in Late Bronze Age Ireland. A survey (= *BAR British Series* 382). Oxford: Archaeopress.

Orłowska J. 2015. How Did They Drill That? – A Few Observations on the Possible Methods for Making Large-sized Holes in Antler. *EXARC Journal* 2015/2, 1-15.

Orłowska J. and Osipowicz G. 2021. Mesolithic bone adzes and mattock heads from Poland. Some suggestions on their technology and function. In S. Beyries, C. Hamon and Y. Maigrot (eds), *Beyond Use-Wear Traces: Going from tools to people by means of archaeological wear and residue analyses*. Leiden: Sidestone Press, 143-154.

Osipowicz G., Orłowska J., Piličiauskas G., Piličiauskienė G. and Bosiak M. 2019. Osseous Points and Harpoon Heads From Đventoji Subneolithic Sites, Coastal Lithuania. First Traceological Insight into The Way They Were Produced And Used. *Lietuvos Archeologija* 46, 147-169.

Osipowicz G., Piličiauskienė G., Orłowska J. and Piličiauskas G. 2020. An occasional ornament, part of clothes or just a gift for ancestors? The results of traceological studies of teeth pendants from the Subneolithic sites in Šventoji, Lithuania. *Journal of Archaeological Science: Reports* 29: 102130.

Overbeck M. 2018. *Die Gießformen in West- und Süddeutschland (Saarland, Rheinland-Pfalz, Hessen, Baden- Württemberg, Bayern) mit einem Beitrag von A. Jockenhövel, Alteuropäische Gräber der Kupferzeit, Bronzezeit und Älteren Eisenzeit mit Beigaben aus dem Gießereiwesen (Gießformen, Düsen, Tiegel)* (= *Prähistorische Bronzefunde* XIX/3). Stuttgart: Franz Steiner Verlag.

Perucchetti L., Northover J. P. and David-Elbiali M. 2020. What is a dagger? A metallurgical interpretation of three metal daggers from western Switzerland dated from the Late Neolithic to the Early Bronze Age. *Journal of Archaeological Science: Reports* 30, 102251.

Petriščáková K., Verčík M., Pavúk P., Limburský P., Daněček D. and Ernée M. 2020. Od nástrojov a zbraní k symbolom: analýza pracovných stôp na kovových dýkach staršej doby bronzovej v Čechách: Pilotná štúdia. *Slovenská archeológia* 68 (Suppl. 1), 459-469.

Pratsch S. 2011. Mesolithic antler artefacts in the North European Plain. In J. Baron and B. Kufel-Diakowska (eds), *Written in Bones. Studies on technological and social contexts of past faunal skeletal remains*. Wrocław: Institute of Archaeology, University of Wrocław, 79-92.

Przybyła M. S. and Jędrysik J. 2018. A classification of objects made of bone, antler, tooth and horn from the Early Bronze Age fortified settlement in Maszkowice. *Sprawozdania Archeologiczne* 70, 269-296.

Rowlands M. 1971. The Archaeological Interpretation of Prehistoric Metalworking. *World Archaeology* 3/2, 210-224.

Schauer P. 1971. *Die Schwerter in Süddeutschland, Österreich und der Schweiz I (Griffplatten-, Griffangel- und Griffzungenschwerter)* (= *Prähistorische Bronzefunde* IV/2). München: C. H. Beck.

Schwenzer S. 2004. *Frühbronzezeitliche Vollgriffdolche. Typologische, chronologische und technische Studien auf der Grundlage einer Materialaufnahme von Hans-Jürgen Hundt* (= *Kataloge vor- und frühgeschichtlicher Altertümer* 36). Mainz-Bonn: RGZM.

Tarbay J. G. 2019. Moulds for large daggers. Unique finds from the Bronze Age Hatvan-Strázsa-Hegy Tell. *Acta Archaeologica Academiae Scientiarum Hungaricae* 70, 5-39.

Venditti F., McCartin M. J., Ostermann M.-L., Nicholas J., Conard N. J. and Wolf S. 2023. Foxes in Retrospect – Unraveling Human-Fox Relationships through Fox Tooth Ornaments in the Swabian Jura. *Quaternary* 2023, 6, 50.

Wilczyński J., Szczepanek A., Wojdal P., Diakowski M., Wojenka M. and Sobieraj D. 2014. A Mid Upper Palaeolithic Child Burial from Borsuka Cave (Southern Poland). *International Journal of Osteoarchaeology* 26, 151-162.