Primljeno 21. 3. 2024. godine
Prihvaćeno 4. 11. 2024. godine

Godišnjak/Jahrbuch 2024,53:71–79
DOI: 10.5644/Godisnjak.CBI.ANUBiH.53-186

Mysterious sceptre-"stilettos" of the Late Bronze Age (manufacturing technology, experimental works)

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Abstract: This article highlights and discusses the challenges associated with reconstructing the manufacture of a mysterious object from a woman's burial in a Late Bronze Age (1400–1300 BC) mound in Ukraine.
The deceased was buried with a number of jewellery items. These included bronze spiral bracelets on her arms and legs, two pins on her chest, four gold spiral pendants near her head and a rich amber necklace. At his side, in a wooden case, were two massive bronze objects originally called stilettos. Later most researchers came to the conclusion that these objects were hyperlong pins. The clothing reconstructors positioned them on the chest. The term "stilettos" is proposed by the author to refer to them, and the reason for this name is discussed. However, the most intriguing aspect of these products is their deep internal cavities. Remnants of wood and charred organic matter were discovered within. It is suggested that wooden cores were used to create the cavity in the casting.
An experiment was conducted to investigate the use of wood in bronze production, a technique that is often viewed with scepticism. Experiments have confirmed that it is possible to cast hollow products using lost wax technology and a wooden core. To protect the wood from fire, it must be treated with a fire retardant. This technology is unique and unknown for the Bronze Age.

Keywords: Late Bronze Age, experiment, unique casting technologies.

Introduction and Research Questions

Only two pairs of bronze items are currently known. One of these pairs was discovered in the burial of mound 16 at the Hordiivka kurgan burial ground and dates back to 1300–1100 BC.[1]

The origin of the other similar pair cannot be established. It is kept in the National Museum of History of Ukraine (hereinafter referred to as NMHU). It is assumed that these originated from the territory on the right bank of the Dnipro River.[2]

All items are adorned with engraved decorations (Fig. 1).

The product surface analysis showed that the objects were cast using individual wax models. There are glued seams on the projections of the cross-guard. They are duplicated in metal from the wax model (Fig. 2).

There is no doubt that these wares are very similar in appearance to the pins of the Noua culture, but they are much more massive. However, these objects have hilt. As the name suggests, the hilt is the part of the sword that is held in the hand. It is the part of a sword, rapier, dagger or stiletto that is comfortable to hold in your hand. The hilt consists of the pommel, grip and cross-guard. The pommel was located at the end of the handle. It counterbalanced the blade and allowed the weapon to be held comfortably. Cross-guard prevents the opponent's sword from slipping off the blade and injuring the owner's hand, hence the term "hilt". The cross-guard helps prevent the wearer's hand from getting injured. Our product's hand guard has four protrusions, two of which are mushroom-shaped and two are tubular. A through hole passes through the tubular protrusions.

Today, a group of researchers believe that these objects combine power and sacred functions.[3]

[1] Beresanskaja / Kločhko 1998, taf. 27, 1–2.
[2] Hoshko 2005; Lysenko / Lysenko / Yakubenko 2006.
[3] Klochko 1998, 335; 2008, 149–150; Hoshko 2005, 237; Lysenko / Lysenko / Yakubenko 2006.

Fig. 1. *Sceptre-"stilettos": 1–2 – Hordiivka; 3–4 – National Museum of History of Ukraine.*

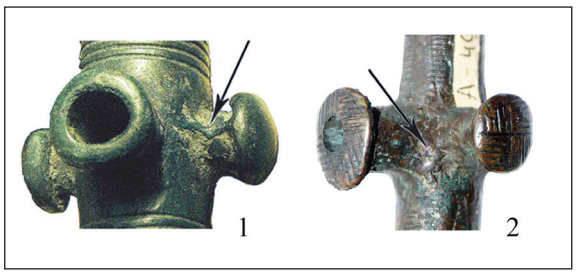

Fig. 2. *Macro photographs of the cross-guard of a sceptre-"stilettos", showing traces of wax modelling which was duplicated in bronze: 1 – NMHU; 2 – Hordiivka.*

However, some colleagues argue that these are hyper-long pins, citing evidence of similar decorations found in Western Europe.[4] However, hyper-long pins have been discovered in female burials in Germany. These pins were placed on the shoulders of the deceased, with the point facing up or down.[5] Slightly shorter ones could be placed across the chest. And what is important, regardless of the shape of the head, all stems are straight, without any protruding parts. That is, such pins were intended to secure clothes on the shoulders (Fig. 3). The "pins", referred to as sceptre-"stilettos" in this context, were discovered in a wooden case near the hands of the deceased (due to the poor preservation of the skeleton, the sex was determined solely by the large number of amber beads scattered on and around the skeleton, as well as two long pins). They have a well-defined hilt with a cross-guard (Fig. 4). Pins were also found in the burial, positioned on the chest of the deceased.[6]

This suggests that our items were not merely accessories like pins in a costume. So these objects were designed to be held in the hands, and hilts were made for that purpose. Why else would one refer to it as "stilettos"? Because they were deliberately sharpened by forging.

It is important to note that objects found in burials or treasures are always paired. For instance, a pair (Fig. 5, 1–2) from a hoard found during excavations near the village of Öpalyi in eastern Hungary in 1952.[7]

They have a hilt: pommel in the form of spherical heads with a wide disc underneath, a cross-guard in the form of four protuberances with spherical ends. There are three rollers with ribs around the grip. One of them has a small loop on the rollers (perhaps for a belt?). The length of the pieces is 908 and 895 mm.[8] The hilt is 147.42 mm long and 16.75 mm thick. The tips are probably broken. No doubt, the items were manufactured using disposable moulds. These products cannot be referred to as "stilettos" due to their size; they are more akin to rapiers. It is interesting to note that the treasure included items of military equipment: a spear, battle axes and a celt.

[4] Berezanska et al. 2011, 56.
[5] Matthews 2004, 6, fig. 1.
[6] Berezanska et al. 2011, 18.
[7] Mozsolics 1963, 65.
[8] Ibid., 67, taf. V, 6

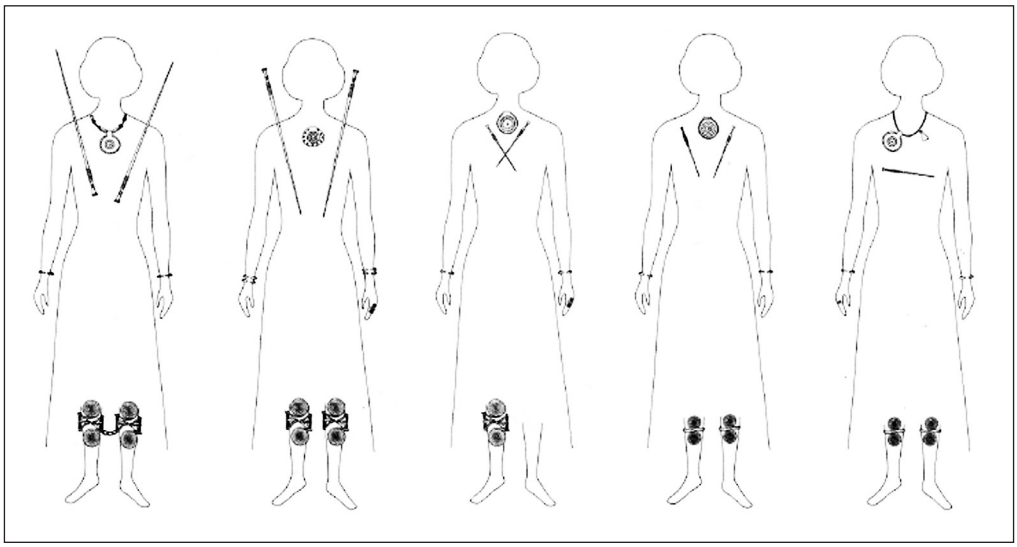

Fig. 3. *Examples of women's jewellery from southern Germany of the Middle Bronze Age (from Wels-Weyrauch 1989, cited in Matthews 2004, 6, fig. 1).*

Fig. 4. *The location of the sceptres in the grave of barrow No. 16 in Hordiivka.*

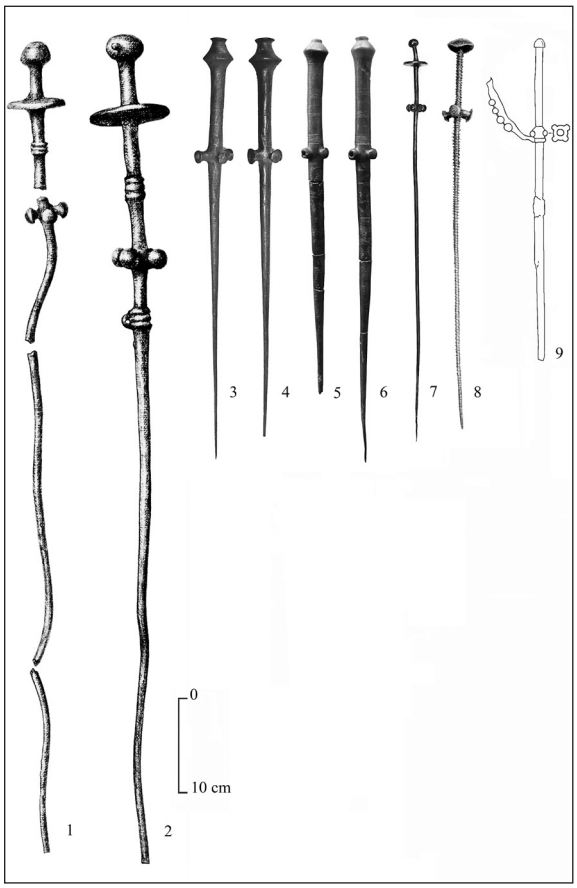

Fig. 5. *Findings of similar products. 1–2 – Öpalyi treasure; 3–4 – Hordiivka; 5–6 – NMHU; 7 – one of the four pins from the Hudlow treasure; 8 – one of the two pins of the Lubny treasure; 9 – a stiletto-dagger from burial 500 of the Senior Akhmyliv cemetery.*

Four "pins" of a similar shape to the artefacts from the Öpalyi hoard, but smaller in size, were found in a hoard found near the village of Khudlov, Uzhhorod district, Transcarpathian region (Fig. 5, 7). Pins like these are frequently found in the area inhabited by the Noua culture. The hoard not only contained pins but also

weapons such as swords, battle axes, and armour spirals.[9] J. Kobal dated the treasure to the older phase of the BD period.

The latest pair of stiletto-like objects comes from the Lubny treasure.[10] The treasure was found near the village of Matskivtsi in the Lubny district of the Poltava region (Fig. 5, 8). Lost wax technology was also used to cast them. The hoard also included weapons. According to the latest updated data, the treasure is dated to the turn of the 9th–8th centuries BC.[11]

As a more distant analogy, we can cite a stiletto-dagger from the burial of a male warrior in the Senior Akhmilov cemetery of the Early Iron Age Ananyin culture.[12] It has a handle decorated with a mushroom-shaped top and a guard. The stiletto is 32 cm long and has a shoulder strap. It has a grip decorated with a mushroom pommel and a guard. The stiletto is 32 cm long and has a sword-belt (fig. 5.9).

According to the size of the hilt, only the Öpalyi, the Hordiivka and the NMHU can be classified as cult objects to be held in the hand. The stiletto dagger from the Akhmyliv cemetery is undoubtedly a weapon. Hudlov and Lubny are jewellery that imitate iconic objects.

Methods

To begin planning and carrying out the experiment, the first step was to study and analyse all the data on the artefacts that could be used to find out how they were made and used. Only on the basis of such knowledge can tasks be set. The more information you have about the object, the faster you can find a solution to the problem. A visual observation of the object under the microscope, a metallographic and spectral analysis and, finally, an experiment were carried out. Because it is only through experimentation that we can not only confirm or refute our assumptions, but also get answers to many questions. During the experimental work, our aim was to use methods and materials similar to those that an ancient master might have used.

A detailed study of the surface of the objects allowed us to conclude that both objects were cast from individual wax models. This technology makes it possible to manufacture a product of complex configuration. The cross section of parts larger than 180° (on a guard) is the main characteristic of the lost wax process. Traces of soldering or gluing of model parts are clearly visible.

This type of casting can be defined as hollow core casting. In their initial publication describing the sceptre-"stilettos", the authors did not give sufficient attention to a crucial technological detail: the depth of the internal cavity.[13]

Since then, all subsequent articles have only depicted the prominences, despite one of them reaching a depth of 23 cm, and in the other, approximately 21.5 cm (Fig. 6, 1). Wood remnants were found within the cavity of one of the sceptre-"stiletto".

How were these artefacts cast? Most of the information about the manufacturing technology has come from artefacts from the NMHU. One of these was broken into 3 fragments, the other into 4. This made it possible to see that their internal cavities are not solid, but in some places completely filled with metal. In addition, it can be seen that the cavities do not run in the centre of the casting, but are slightly offset from the central axis (Fig 6, 2–3). And all the internal surfaces are uneven and bumpy.

In one sceptre, the cavity at the edge of the tip widens sharply and forms a shallow niche along the perimeter (Fig. 6, 2a). It was here that the remains of burnt organic material were found.

I have expressed my hypothesis about their casting technology repeatedly. Based on the findings of wood (Hordiivka) and charred organic matter (NMHU), it strongly suggests the use of cores made of organic material, specifically wood. The core had to function in harsh temperature conditions and its surface was washed with molten metal, causing it to burn out. A. S. Savrasov's experimental work confirmed the feasibility of using a wooden core. He encountered difficulty removing clay cores from the casting, despite being covered with chalky mortar and not sticking to the metal. To address this issue, A. S. Savrasov attempted to use a wooden core. Although the wooden cores were easier to

[9] Kobal 1999, fig. 1–3.
[10] Klochko 2003.
[11] Skoryi / Suprunenko / Sydorenko 2016.
[12] Khalikov 1977, fig. 66.
[13] Beresanskaja / Kločhko 1998, taf. 27, 1–2

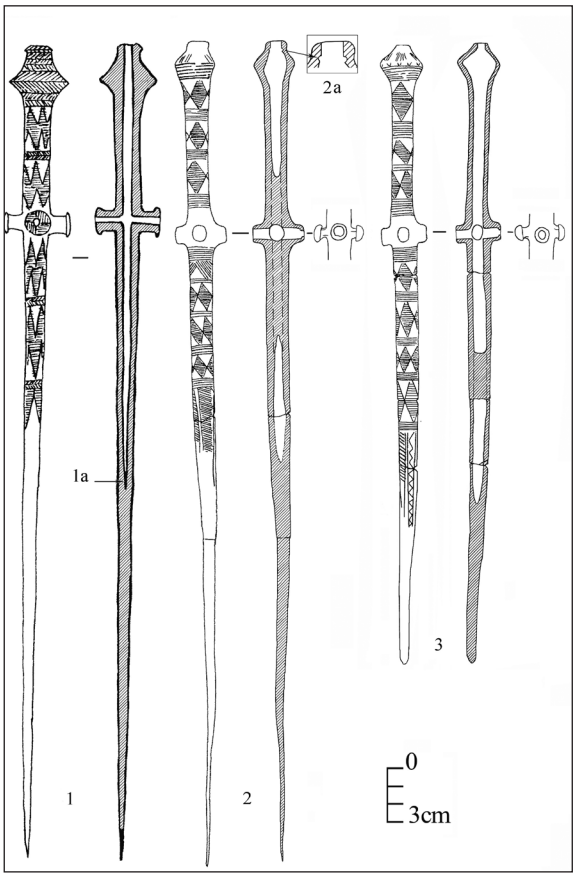

Fig. 6. *Schematic of the location of internal holes in the sceptre-"stilettos". 1 – one of Hordiivka's sceptres (1a – the site of the burnt wood); 2–3 – NMHU (2a – a niche with the remains of burnt organic matter).*

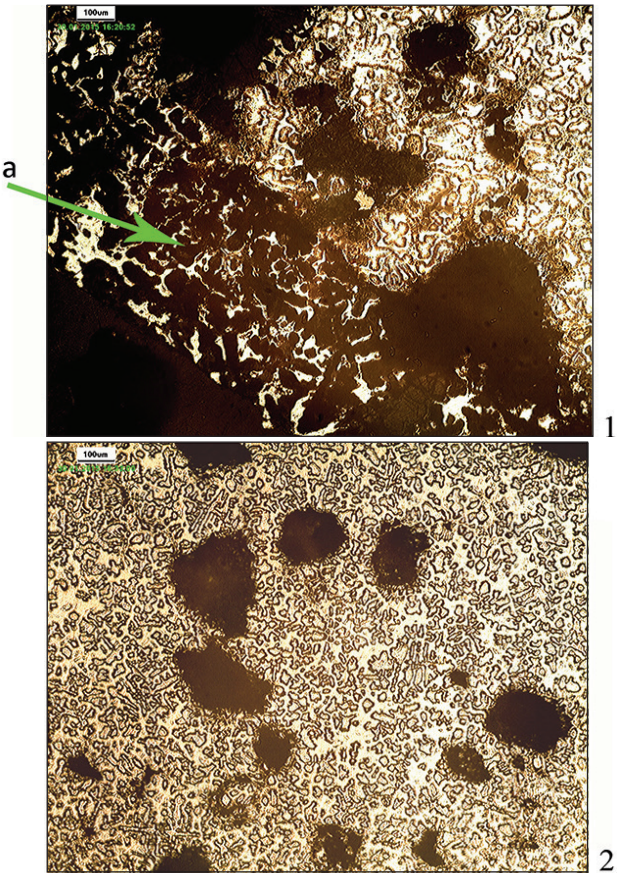

Fig. 7. *Microstructures. 1 – NMHU (a – oxidised metal layer); 2 – high porosity experimental microstructure.*

remove, they emitted a significant amount of gas during casting.[14]

Metallographic studies were conducted on the sharpened point of the sceptre-"stiletto" from Hordiivka and in the middle of the blade on one of the sceptre-"stilettos" from NMHU. The microstructure of the Hordiivka sceptre reveals fully recrystallised grains with twins and a small number of shear bands. The Cu31Sn8 eutectoid is highly elongated in the longitudinal direction. The microstructure suggests that the baton was forged to lengthen and sharpen its point. Shear bands may have formed due to the end of forging on cooled metal or during use, such as piercing hard materials.[15]

The middle section of the NMHU sceptre has a dendritic, undeformed microstructure with a large amount of Cu2O and pores (Fig. 7.1). This confirms the assumption that a wooden core was used, as wood reacts to molten metal by charring and releasing oxygen, which dissolves in the metal during solidification. The presence of oxygen also explains the poor preservation of NMHU products, as the metal's sensitivity to cold brittleness increases. Cu2O particles are located at the grain boundaries, causing brittleness.

Confirmation that a wooden core was used led to further research in this direction. A sprue is an element of a casting mould that creates a cavity in the casting. However, it was unclear whether wood could withstand the temperature of molten bronze, as the core must endure high temperatures and mechanical stresses while inside the molten metal. Therefore, an experiment was necessary.

The experiment aimed to address specific questions about the material used to make the core, including why wood was chosen and whether other materials could have been used.

[14] Savrasov 1996, 150.
[15] Hoshko 2011, 233, fig. 22, 7.

Additionally, the experiment investigated techniques for safeguarding wood against fire. The procedure for securing a core in the mould to prevent movement during the pouring of molten metal was also examined. Furthermore, the optimal location for pouring the metal into the mould was determined. How should the bulges be positioned on the model? Can a hollow product be cast using a wooden core?

Why was wood chosen as the material for the core? We considered several options for the core material, including clay and organic laces, but ultimately chose wood. Clay was not suitable due to its inability to mould a core with a thickness of 5 mm and a length of 215 to 263 mm with a complex configuration. Additionally, pouring molten metal into the clay mould would cause it to break. Further experiments were conducted only with wooden core, as the use of organic materials such as leather straps or ropes impregnated with some kind of refractory solution is unlikely to solve the problem of core stiffness. It should be noted that the use of wood in bronze casting is heavily criticised.[16]

During the experiment, pouring metal into the mould caused the wood to catch fire, resulting in significant misruns in the casting (Fig. 8, 1–3). This raised the question of how ancient people protected wood from high temperatures. One possible method was to coat it with liquid clay or impregnate it with a natural fire retardant. Efforts to cover the core with chalk slurry or liquid clay were unsuccessful, as they cracked and crumbled when wax was applied.

What flame retardants were available to ancient craftsmen? Soda and ash were among the most suitable natural flame retardants. Ancient Egypt used soda extracted from soda lakes to make glass long before Christ. In Europe, there are such lakes in Hungary, while in Ukraine, the largest raw material base for soda is Lake Sivash. Another source of soda production for many centuries until the early 19th century was the ash of certain seaweeds and coastal plants. The most common of these is Salsola Soda, which grows on saline soils on the Black Sea coast.

Wood ash is of interest because it removes heat and displaces oxygen from the burning site. When hot water is poured over the ash, it produces a solution of potash, also known as potassium carbonate. Firefighters previously used this substance to treat wooden structures.

Potash was chosen as the best fire retardant. A pine tree rod (Fig. 9, 1) was soaked in a water-ash solution for a week at a rate of 250 ml of ash per 1000 ml of water, resulting in noticeably stronger wood. After drying the rod, a mixture of wax, oleoresin, and linseed oil was used to create a model of the scepter to come. (Fig. 9, 2). This mixture is commonly used by Ukrainian anthropologists to reconstruct skulls. The material is plastic, allowing for precise work on small details of the model. The metal is poured from the tip into the pouring cup located here (Fig. 9, d).

The next step was to consider how to secure the core in the mould, as this is a crucial aspect that affects the quality of the casting. The core must remain stationary during the melting of the wax and the pouring of the metal. Chaplets are used to support the core in the mould cavity. To keep the core in a vertical position while casting, a chaplet was inserted on the side of the future pommel (Fig. 9, a). Additionally, two lateral horizontal chaplets were inserted into the two projections on the cross-guard, and their free ends were spirally bent to prevent any lateral movement (Fig. 9, b).

Vents are essential for removing gases from the mould cavity and controlling the filling of the mould with molten metal. The correct placement of vents in a mould is critical to ensuring high quality castings. To create vents, wire is used and then removed from the finished mould. In this case, vents were positioned on mushroom-shaped protrusions on the cross-guard and near the bottom chaplet to facilitate better filling of the mould cavity with metal (Fig. 9, c). However, the proposal to add additional vents above the cross-guard was rejected due to the higher risk of igniting the wooden core.

The experiment resulted in hollow castings (Fig. 8, 4), which are similar in quality to NMHU sceptre-"stiletto". These castings have high porosity due to oxygen saturation, especially in the upper part of the mould (Fig. 7, 2).

[16] Minasyan 2014, 187.

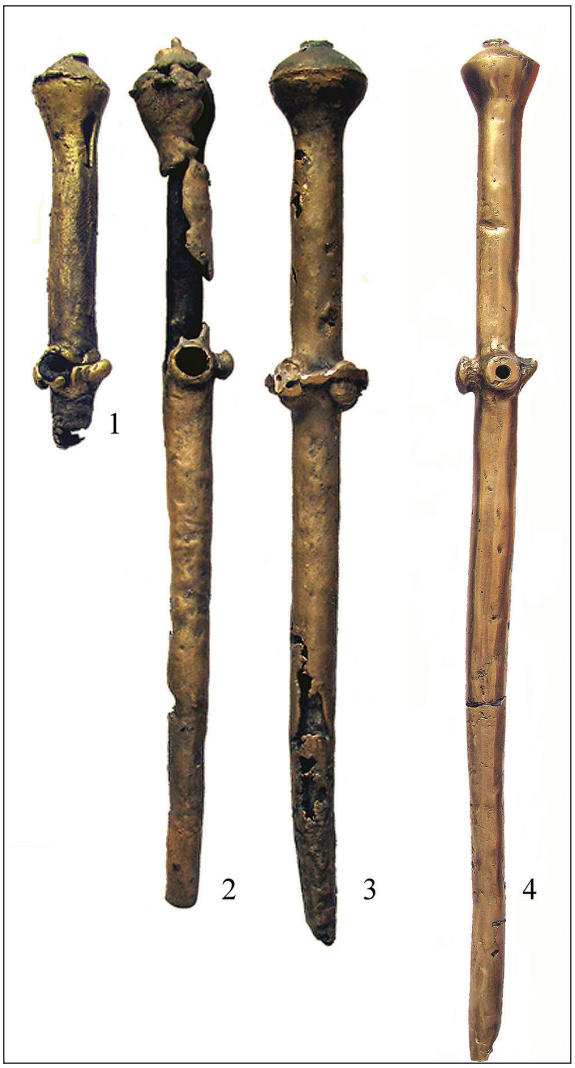

Fig. 8. *Experimental castings. 1–3 – misruns in the casting; 4 – the final hollow casting.*

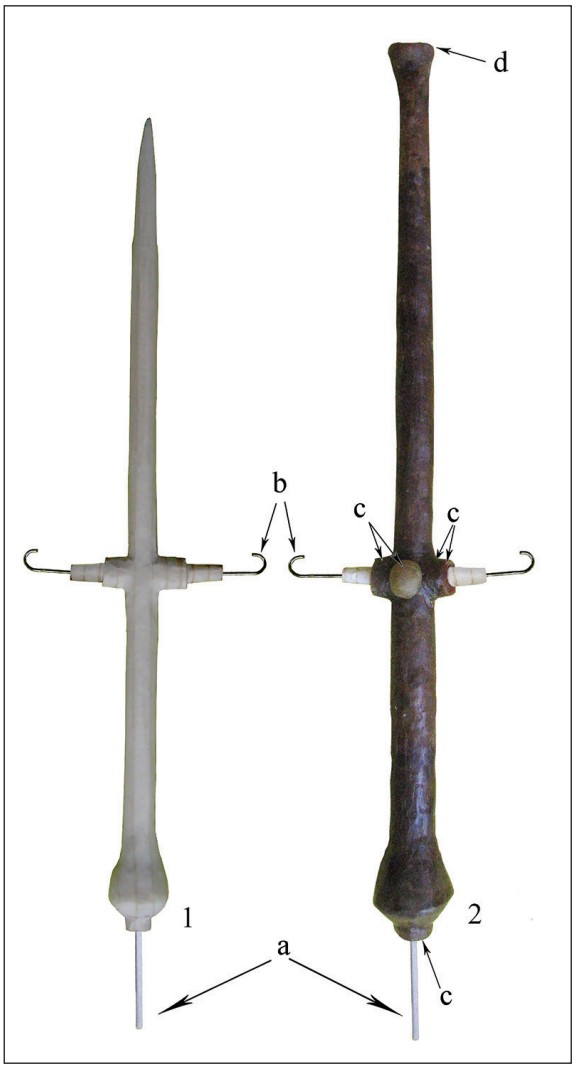

Fig. 9. *Creating a wax model. 1 – wooden rod; 2 – wax model; a – chaplets location; b – horizontal chapels location; c – vents location; d – pouring cup location.*

Conclusions

The experiment produced hollow castings (Fig. 9), which are of similar quality to NMHU sceptre-"stilettos". These castings have high porosity and are highly oxygenated (Fig. 7, 2).

Unfortunately, the clay composition for the mould was not given enough attention, especially when applied to the model. This led to non-compliance with the conditions, causing the vents on one of the protrusions on the cross-guard to shift, resulting in underpouring. Moreover, the casting mould collapsed during the metal pouring, most likely due to its fragile nature. Despite our mistakes, we completed the task. The ability to cast bronze objects using a wooden core has been demonstrated. This technology may have been invented during the Bronze Age. However, it was not widely adopted due to its complexity and the difficulty of producing high-quality castings. The quality of sceptre-"stiletto" castings from Hordiivka is higher than that of the NMHU. It remains a mystery how the craftsmen managed to achieve this quality.

Rezime

Misteriozni skiptri "stileti" iz kasnog bronzanog doba (eksperimentalna provjera tehnike izrade)

U članku se razmatraju izazovi i nedoumice povezane sa rekonstrukcijom načina izrade misterioznih predmeta pronađenih u ženskom grobu iz tumula 16 u Hordiivci u Ukrajini koji je datiran u kasno bronzano doba (1400–1300. p.n.e.). Pokojnica iz ovog groba je bila opremljena raznovrsnim nakitom. Na rukama i nogama je imala spiralne bronzane narukvice i nanogvice, na grudima su bile dvije ukrasne igle, a pored glave su nađena četiri zlatna spiralna privjeska i bogata ogrlica od ćilibara. U drvenom kovčegu pored pokojnice nalazila su se dva masivna bronzana predmeta koja su prvobitno ounačena kao stileti. Većina istraživača je kasnije došla do zaključka da su ovi predmeti zapravo bile izuzetno dugačke igle. Rekonstruktori odjeće su smatrali da su te igle bile na grudima. Autorica smatra prvobitni termin "stileti" ispravnim, dajući u tekstu obrazloženje za takvu interpretaciju.

Najintrigantniji aspekt ovih predmeta su njihove duboke unutrašnje šupljine u kojima su otkriveni ostaci drveta i ugljenisane organske materije. Pretpostavlja se da su to bila drvena jezgra koja su korišteni za stvaranje šupljina tokom livenja. Tehnike upotrebe drveta u proizvodnji bronze se često posmatra sa skepticizmom, pa je u izveden proizvodni eksperiment koji je potvrdio ovu mogućnost. Naime, pokazalo se da je moguće izlivati šuplje proizvode koristeći tehnologiju izgubljenog voska, uz upotrebu drvenog jezgra. Da bi se drvo pri tome zaštitilo od vatre, neophodna je zaštita nekim protivpožarnim sredstvom. Prema tome, nalazi iz Hordiivke su se pokazali kao prva potvrda postojanja ova jedinstvena tehnologije u vrijeme bronzano doba.

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