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MANUFACTURE TECHNOLOGY OF SOCKETED IRON AXES

This study analyses socketed iron axes of the first millennium AD. It was a widespread phenomenon that the first iron axes greatly resembled their Late Bronze Age counterparts. However, in north-east Europe, socketed iron axes continued to be in use far longer than in other parts of Europe. The Kohtla weapon and tool deposit contained about 100 axes, out of which one specimen was selected for invasive metallographic analysis. The axe was made from four separate components: firstly the bulk of the axe that had been made from a rolled tube; then the steel cutting edge; then also a wedge shaped filling in the blade; and a slag-rich filling in the socket. As the axe turned out to have undergone quite a complex forging technique, experimental production of the same type of axe was undertaken to better understand the reasoning behind the ancient smiths decisions. The experiment revealed that the two fillings served several purposes and that the choice of materials by the Iron Age smiths was well suited for the function of these parts. When the Kohtla axe was compared to the other axes, it became evident that the same results could be achieved with different forging patterns. In the future, the manufacturing technology could be the basis for improved typological and chronological characterization.

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Introduction

In August 2013 near Kohtla-Vanaküla (referred to as Kohtla) a remarkable weapon and tool deposit was discovered by a local metal detectorist (Fig. 1: 1). It was subsequently excavated over two consecutive years by a team of archaeologists from the University of Tartu (Oras et al. 2018). Among the hundreds of artefacts deposited there we found around 100 axes. Many finds are dated to the 5th–6th centuries but material under and around the main deposit is dated to the 1st–2nd centuries and 3rd–4th centuries accordingly. The interpretation therefore is that it used to be a long-term sacrificial place, located in a wetland environment during the deposition period (Oras et al. 2018).

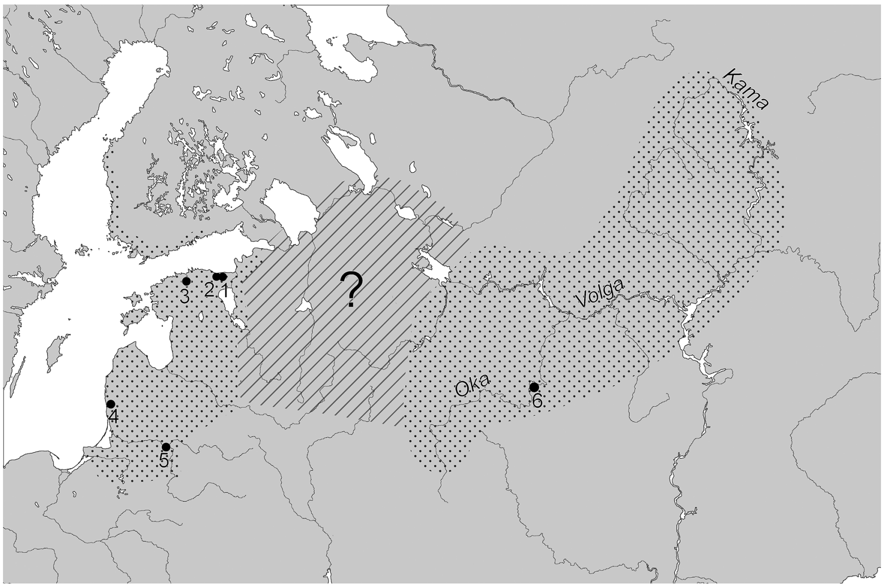

Fig. 1. The confirmed area (dotted pattern) and the uncertain area (striped pattern) of socketed iron axes in the first millennium AD. Sites: 1 – Kohtla, 2 – Alulinn, 3 – Perila, 4 – Mazkatuži, 5 – Marvelė, 6 – Nikitinski.

Socketed axes have been investigated in different countries around the Baltic Sea and Russia. Some of the studies on Latvian (Moora 1938) and Finnish axes (Salo 1968) are quite outdated now, while Lithuanian (Malonaitis 2003) and Russian (Zav´yalov et al. 2009) artefacts have been studied more recently. In addition to typological comparison, socketed iron axes have been metallographically investigated in Latvia (Anteins 1976), Russia (Zav´yalov et al. 2009), Lithuania (Bertašius et al. 2010) and Estonia (Peets 2003). The forging process of socketed iron axes has seen little interest in Estonia before now and they have not previously been looked at from the perspective of experimental archaeology. A case study was subsequently undertaken on the Kohtla axe (TÜ 2309: 203) in order to collect data about the manufacturing process. The objective was to determine the forging method by combining metallographic analysis with experimental forging and then to interpret the results against the wider historical context. In order to achieve this an overview of the historiography was also provided.

Destructive metallographic analysis allows us to answer several questions: What techniques were used during forging? What materials were available to the smith who made it? What skill level was involved in the making of the artefact? How does it compare with other contemporary artefacts?

The investigation of the axe was undertaken in several stages. It began with the visual documentation of the axe before the metallographic analysis. Then the axe was cut longitudinally to provide a cross section that could give the maximum amount of information. The metallographic analysis subsequently provided a hypothetical forging pattern, which was tested out using modelling clay. The forging pattern was then repeated twice using iron and steel and the experimentally produced axes were then also cut longitudinally for comparative analysis.

Socketed axes in the broad picture

Socketed iron axes were used in Central and Western Europe in the Hallstatt and La Tené culture areas during c. 800–1 BC. While the phenomenon of iron axes imitating the Bronze Age axe forms was widespread, the use of socketed axes is especially prevalent around the Baltic Sea, and the Volga and its tributary river areas in Russia (Fig. 1). Two main types of socketed axes are found around the Baltic Sea: looped socketed axes and axes without the loop (Fig. 2).

Looped socketed axes have been found across southern Scandinavia, the Finnish coastal areas (Salo 1968, fig. 102), Estonia and northern Latvia (Moora 1938, 499), and from the Votian areas in north-east Russia (Ryabinin 1988). The easternmost looped socketed axes have been discovered between the Volga and Oka river basins (Jaanits et al. 1982, 191). There are over 20 looped socketed axes from Estonia, which are usually 11–15 cm long with a 2–3 cm wide blade, and are made out of a rolled iron sheet with one particular edge rolled up to make a loop (Jaanits et al. 1982, 190). This design most probably mimics the Late Bronze Age Akozino-Mälar type axes and the first looped socketed iron axes made around 500 BC (Salo 1984, 192). Therefore, this type of axe was not adopted from Central Europe as proposed by Harri Moora (1938, 498), but this is more of an axe type that was developed around the Baltic Sea with the advent of iron-working technology in the region (Salo 1984, 192).

The looped axe design was abandoned during the 1st–2nd centuries and was replaced with a more slender type that lacked the loop (Lang 2007, 140). These axes have been found from the coastal areas of southern Finland (Salo 1968, 162 f.), Estonia (Tvauri 2012, 124), Latvia (Moora 1938, 499 ff.), Lithuania (Malonaitis 2003), Eastern Prussia (Nowakowski 1996, taf. 8: 8; 89: 4; Bitner-Wróblewska 2007, plates VII: 6; LXXIII: 16) and north-west Russia (Khvoshchinskaya 2004, 94, plate CXI: 18–20). The easternmost extent of the socketed axes reaches the river Kama, a tributary of the Volga, where crude and simple socketed axes

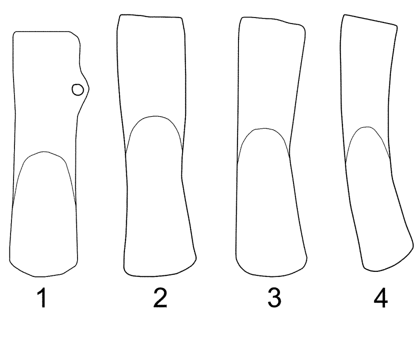

Fig. 2. Socketed axes. 1 – looped axe, 2 – axe with a widened socket and the blade, 3 – axe with a straight back, 4 – curved axe.

were already used in the 5th–3rd centuries BC (Zav´yalov et al. 2009, 82, fig. 25) and remained in use up to the 5th century AD (Zav´yalov et al. 2009, figs 34, 35). In central Russia, they have been found in the Finno-Ugric areas of the Djakovo culture as far as the Oka river valley, where the latest examples belong to the 5th–8th centuries (Zav´yalov et al. 2009, fig. 65). There is an area between the Baltic Sea and the Volga river (Fig. 1), which, to the authors knowledge, lacks sites where socketed axes have been found. This might well be an issue related to the state of research and publishing, but it could also mean, that socketed axes were not commonly used in that area.

In Lithuania socketed axes appear in the archaeological record up until the 11th century, the late Viking age (Malonaitis 2003, 12 f.), which is exceptional as they are no longer used in the other areas by this time. It can be concluded that in the 1st millennium, the socketed axe was mostly used in north-east Europe – in the areas of Baltic and Volga Finns, and Western Balts.

A similar axe type to the socketed axe was the tenon axe, which was spread along the coastal areas of Finland, in Estonia, Latvia, and northern Lithuania in the 1st century BC and 1st century AD (Moora 1938, 508; Lang 2007, 141). Both axe types, the socketed axe and the tenon axe, could also be used as an adze if the axe head was fixed crosswise to the handle (Lang 2007, 140). Subsequently many of the socketed axes (mostly found from the east) could have been used as adzes, which is indicated by the concave blade shape (for example: Ashikhmina 1987, fig. 4: 1, 2; Goldina 2004, figs 100: 16; 107: 3, 4; 183: 23). This is why these axes have sometimes been interpreted as chisels (Kolchin 1953, 108 f.), hoes or other socketed-axe-like objects (in Russian *кельтообразные орудия*) (vt Ashikhmina 1987, 109 ff. with references). The varying shape of the socketed axe and its broad range of uses points to a multi-purpose carpentry tool, which could also have been used as a weapon.

By the 8th or 9th century, the socketed axe developed into the hollowing chisel, which had an open socket and a concave blade. The oldest hollowing chisel originates from the Salme ship burial, dated to the 7th and 8th century (Tvauri 2012, 128). Another hollowing chisel was deposited alongside other grave goods in the Püssi inhumation burial dating from the 9th or early 10th century (Mägi-Lõugas 1995, 523). Therefore, these hollowing chisels were used at the time when the socketed axes had already been replaced by axes with an eye for the haft.

Several typologies have been created for the socketed axe. Before the Kohtla find, there were about 50 socketed axes from Estonia, with no studies devoted to them. In Latvia, the last overview was written by Harri Moora (1938, 499 ff.), who looked at 250 socketed axes and divided them into four groups. These groups were: 1 – looped socketed axes; 2 – short socketed axes; 3 – long and slender socketed axes; 4 – wide bladed axes with the bit tilted towards the handle. Moora dated the first group to the 1st–5th centuries and the last three to the 5th–7th centuries (Moora 1938, 499 ff.). After 80 years of research, these dates have been adjusted substantially: looped axes were used from the 5th century BC up to the 2nd century AD, and socketed axes without the loop appeared around 1st century AD and were used at least up until the 7th century.

The Finnish socketed axe typology originates from half a century ago, when Unto Salo divided the 20 axes from Finland into two groups (1968, 159). The looped axe was divided into two subtypes: type I:1 that features a looped axe with and even shape; and type I:2 which is a looped axe with a widening blade (Salo 1968, 159 ff.; fig. 101). The first subtype has been found from the coastal areas of southern and south-western Finland, but also from Norrland and Skåne in Sweden (Salo 1968, fig. 102). The second subtype is represented by two finds from Finland, but has more examples from southern Sweden, as far as Uppland, including Öland and Gotland (Salo 1968, fig. 104). Salo supposed that the looped axes were introduced in the first century AD. The type II included socketed axes without a loop: type II: 1 has an even shape, while type II: 2 has a widening blade and socket. These have been found in the *tarand* grave areas in the coastal areas of southern Finland from the 1st and 2nd centuries (Salo 1970, 107).

The most recent study of socketed axes comes from Lithuania, where Arvydas Malonaitis divided 824 axes into five groups (2003). The first type had an even or a slightly widening blade, and these were used from the 1st up to the mid-5th century. Types 2, 3 and 4 are all axes with a widening blade, that are dated to a quite long time period, from the 1st to the mid-8th century. The fifth type of axes have a bit that is curved towards the handle (Fig. 2: 4), which date between the 5th and the end of the 11th century (Malonaitis 2003, figs 2 and 7). So in broad terms, the simpler axes are older and the curved axes are younger.

There were a total of 93 intact, socketed axes found at Kohtla, along with one axe blade and nine socket fragments. These axes are dated the 1st to 4th centuries (Oras et al. 2018). They are also very similar in appearance: for most axes the blade and the socket are even in width and the transition from the blade to the socket is slightly narrower (Fig. 2: 2). The metallographically investigated axe is also a member of this very common type. Also about 20 axes have a straight back and a slightly widening blade (Fig. 2: 3). The length of the intact axes range between 14.6–28.3 cm, the blade width between 2.8–5.1, and the socket diameter range from 2.3 to 5 cm. Sockets are mostly 10–14 cm long. The blade length varies the most: from 21 cm (axe TÜ 2309: 202) to only 3 cm (axe TÜ 2309: 221). The former might be a special purpose carpentry axe, which was used when splitting boards from logs. The blade length might have also been reduced by sharpening and wear, but as the metallographic analysis shows, the axe might lose its hardened edge when sharpened too often. In conclusion this overview revealed that socketed axes have few well dated external features, which means that metallographic analysis of their forging pattern might be useful for their further characterization.

Metallographic analysis

The goal of the metallographic analysis was to clarify the forging method and compare the axe to other socketed axes studied in a similar way. The orientation of the longitudinal section (Fig. 3) was chosen to provide a similar section to previous

Fig. 3. The Kohtla axe (TÜ 2309: 203) before cutting. The cutting path is marked on the X-ray. X-ray settings: 50 kV, 4 mA, 8 s, brass filter (X-ray by Kristiina Paavel).

socketed axe studies in Estonia (Peets 2003, fig. 95). The preparation of the samples was undertaken at Tartu University's Archaeological Laboratory using the following procedure: samples were cut using an IsoMet 4000 precision saw; then ground and polished using a Buehler AutoMet 250 grinder-polisher; and finally etched in a 4% nital solution. The microstructures were photographed using a Buehler ViewMet inverted microscope. Micro hardness was measured with a Wilson Tukon 1102 tester on the Vicker scale with 0.1 kg during 10 seconds (from here on referred to as HV0.1) and repeated five times for each structure.

Four different components were recognizable in the cross-section (Fig. 4). The steel cutting edge was heat treated to tempered martensite (Fig. 5: a). In an

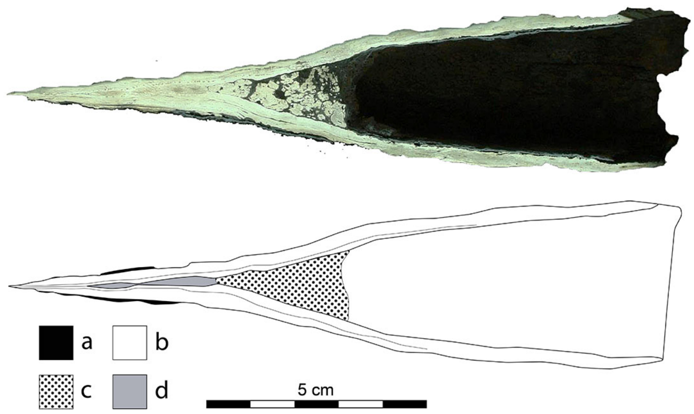

Fig. 4. Etched cross-section of the Kohtla axe (above). Forging pattern (below). a – steel on the axe blade, b – axe body of piled iron, c – slag-rich iron filling in the socket, d – iron filling in the blade core.

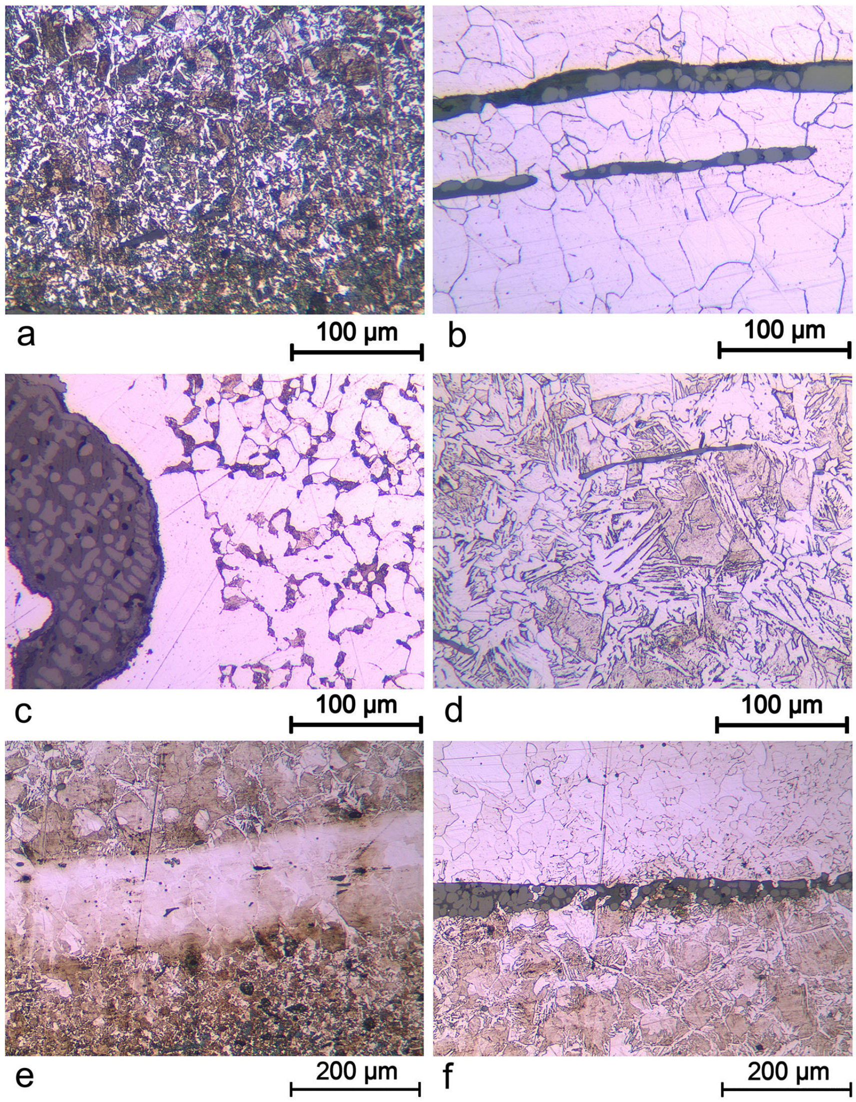

Fig. 5. Micrographs of the Kohtla axe. a – tempered martensite in the steel edge, b – ferrite and elongated slag pockets in the axe body, c – ferrite and pearlite in metal, wüstite (light grey) and fayalite (dark grey) in the slag inclusion (filling in the socket), d – Widmanstätten ferrite and pearlite (filling in the blade core), e – a relatively clean weld in the steel edge, f – a slag-rich weld between the steel edge and the axe body.

experiment performed by Lipiński and Wach (2010) a similar structure was produced when steel was tempered at 200 °C, although in that experiment the steel was harder (430 HV), than in the case of the Kohtla axe (228–352 HV0.1). The main part of the axe is mostly piled iron, with a low carbon-content (133–193 HV0.1). Thin strips of slag are visible throughout the cross section, which originate from piling the raw material (Fig. 5: b). The filling in the socket is ferrite with only a little pearlite (131–166 HV0.1). It also contains large slag inclusions (Fig. 5: c), which shows that very little refining has taken place. The closest comparison in microstructure is a wüstite rich slag from the Lapphyttan smelting site, which originates from the iron refining process (Buchwald 2008, 212). However, the iron filling in the blade core has been purified, removing the slag, and consists of ferrite, Widmanstätten ferrite and pearlite (142–182 HV0.1; Fig. 5: d).

The quality of the welds varied considerably, as there are welds without slag and weld lines displaying continuous slag pockets. The clean welds can be found inside the steel edge (Fig. 5: e), which indicates that the steel was also piled from smaller pieces. The weld between the iron filling (Fig. 4: d) and the main body of the axe (Fig. 4: b) was also neatly done. However, the weld between the steel edge and the main body of the axe has many elongated slag pockets (Fig. 5: f).

Experimental forging of the axe

The forging of the experimental axe was preceded by the making of several prototypes from modelling clay and cutting them longitudinally. In addition to gaining information about the shape of the cross section, the models also helped to predict the size and shape of metal parts needed for the reconstruction, without wasting energy and materials. After a successful model was achieved (Fig. 6: a), the process was taken into the forge.

Low carbon steel was used for the body of the axe. For the mid-part (Fig. 4: d) different scrap steel was chosen. For the socket fill (Fig. 4: c) various scrap iron along with borax for the flux were used. For the steel cutting edge (Fig. 4: a), high-carbon tool steel was selected. The starting size and shape was selected according to the previous experience gained from the modelling-clay test models.

The following hand tools were used in the forging process: hammers, anvil, tongs, and a blunt cone-shaped mandrel. A coal furnace was used for heating, and the hammering was conducted at temperatures between 650–850 °C. Forge-welding took place at approximately 1000–1200 °C, and the scale was cleaned off with an electrical grindstone with lamellar grind discs. The reconstruction was hardened in oil at approximately 850 °C and was not tempered, so as to achieve better contrast after etching.

At first a socket tube was made and flattened at one end. Then the filling of the blade core was added and the blade was then flattened. It was impossible to check if the fill material had reached the bottom of the socket, and later a gap was discovered in the socket, when the reconstruction was cut longitudinally (Fig. 6: b). This could cause the deformation of the tool in practice, which was made of soft iron. Nevertheless, the cross-section of the blade part was similar to the original artefact.

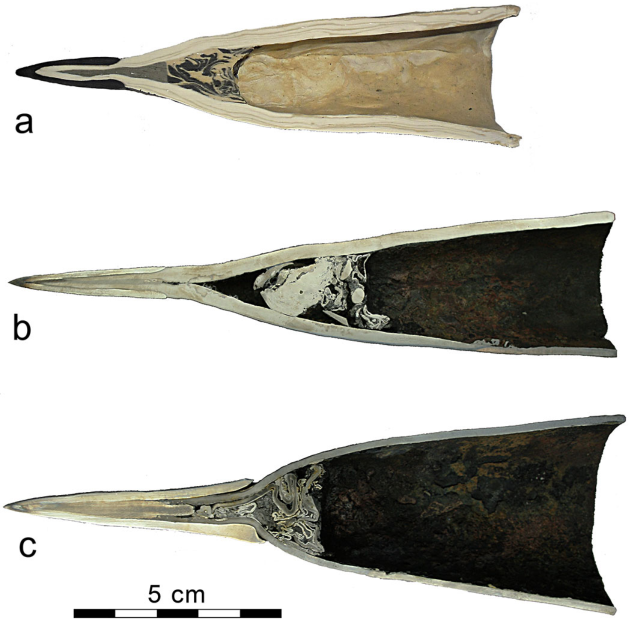

Fig. 6. Experimental forging of the Kohtla axe. a – modelling clay axe, b – axe from experiment 1, c – axe from experiment 2.

While making the second reconstruction, the gap under the socket fill was avoided by adding both the filling components before rolling up the socket (Fig. 7). This way, the filling could be fitted exactly to the right place and could even be compressed while the socket was closed. As the billet to make the steel cutting edge was thicker, the finished axe had a cross-section that resembled the Perila axe more than the Kohtla axe.

Fig. 7. Inserting the blade core filling in experiment 2.

Discussion

The experiments were insightful in several ways. For instance, a 3–10 mm thick iron sheet is suitable to forge the axe's main body (socket and bulk of the blade). The final shape of the axe socket can be achieved in several ways, so the billet's dimensions can vary. The use of slag-rich unprocessed iron may have served several purposes. On the one hand it could be seen as an optimizing decision, as the socket filling does not have to be strong and it does not have any other purpose other than supporting the axe's wedge shape structure and adding mass. However, using a slag-rich filling would also help to prevent a gap in the socket, as noted in the first experiment when a solid filling was used. Adding an extra piece of metal (Fig. 4: d), unseen in any previous studies, helps to shape the axe into a wedge form – out of the initial tubular shape – and ensures a smooth transition between the blade and socket part. It can be assumed therefore that the wedge shape of these axes has been important for aesthetic or functional reasons. During woodworking experiments conducted by archaeologists from the University of Tartu at the Rõuge experimental farm, wedge shaped axes were preferred to axes with concave sides, as they do not get stuck as often.

Little is known about the biography of an axe before it was deposited, and therefore it is also possible that it was subject to heating in a ritual manner, creating a tempered heat treatment. There is evidence for this kind of treatment in the case of the Perila axe, which was heated prior to its deposition and therefore rendered less useful (Peets 2003, 201). But since there are parts of wooden shafts preserved in the sockets of several axes from the site, it is more likely that they were not heated before the deposition and what is seen from the cross section is the original heat treatment. As the axe suffered a lot of impact blows when used for chopping, tempering would have prevented the steel edge from breaking off in small fragments. So the heat treatment observed in the microstructure is functional and well suits the intended use of the object. Other axes from Latvia (Anteins 1976, 11) and Lithuania (Bertašius et al. 2010, 179) investigated metallographically, also have tempered martensite as the cutting edge heat treatment.

Based on the invasive analysis of socketed axes, we can distinguish at least four forging patterns (Fig. 8). The first one, already discussed above, is present in two examples, the Kohtla axe and the Mazkatuži axe. The Mazkatuži axe, dated to the 3rd century CE, is similar to the Kohtla axe in several aspects: it was quenched and tempered, and was produced with a slag-rich core (Anteins 1976, 11). Anteins suggests that the slag-rich core is evidence that the smith who produced the axe also smelted the iron, as even small and low-quality pieces were used in the axe manufacture. It could also mean that the smith only took part in the refining of bloomery iron, which produces many of the smaller slag-rich pieces that fall off during the hammering.

The second pattern is present in one find from Perila in Estonia (Peets 2003, 200 f.) and is similar to the Kohtla axe. An extra layer of material was forge

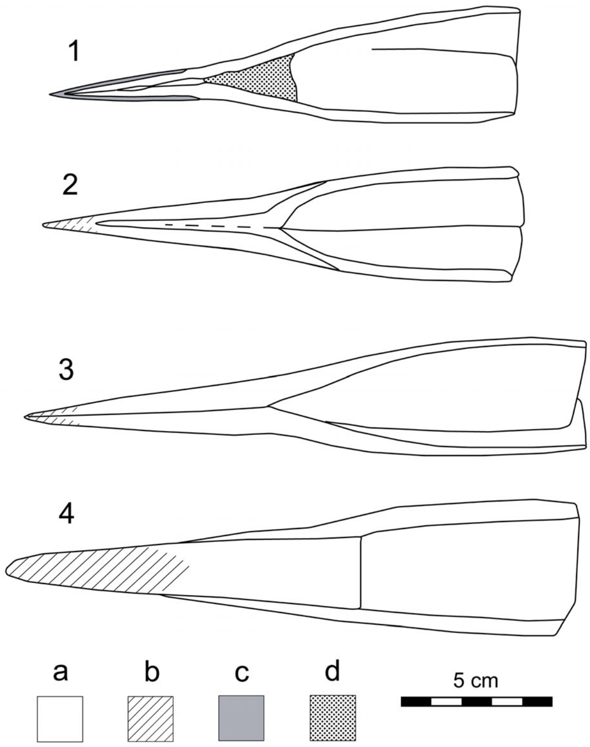

Fig. 8. Forging patterns of socketed axes. 1 – Kohtla, 2 – Perila, 3 – Alulinn, 4 – Marvelė. Legend: a – low carbon iron, b – locally carburized region, c – steel, d – slag-rich filling (2 and 3 after Peets 2003, fig. 95; 4 – after Bertašius et al. 2010, figs 12, 13).

welded on the blade, but no filling was added to the blade core or the socket. The third forging pattern is the most numerous one, found from Alulinn mire in Estonia (Peets 2003, 200) and from Nikitinski burial site in the Oka river valley (Zav´yalov et al. 2009, 174). It is a simple forging pattern, where the axe is first rolled and then the blade is finished without adding extra components.

The fourth pattern comes from the Marvelė burial ground in Lithuania, dated from the 3rd to the 5th century (Bertašius et al. 2010). The iron socket has been welded on either side of the iron core, which has been carburized to heterogeneous steel (ibid., 179). The cutting edge was tempered and is comparable to the Kohtla axe in hardness. The Nikitinski burial site also has axes with the fourth forging pattern (Zav´yalov et al. 2009, 174, fig. 71). However, as they only sectioned the cutting edge of the axe, it is difficult to say what was the starting billet like and how the weld was made between the blade and the socket. The fourth pattern has the blade carburized first and then welded between the socket, while axes made with the second and third pattern are forged out first and then carburized as the last step.

Although not many axes were investigated metallographically, a simple chronology can be provided based on the available data. The simplest form (Fig. 8: 3) was used in the 1st–2nd and 4th–5th centuries in Estonia (Peets 2003, 200) and in the Oka river valley in the 5th and the early 6th century (Zav´yalov et al. 2009, 167). More complex forms appear in the 3rd century Latvia (Fig. 8: 1) and 3rd–5th centuries Lithuania (Fig. 8: 4). The latest pattern (Fig. 8: 2) was used in the 5th–6th centuries Estonia. The Kohtla axe, with its quite broad date range of the 1st to the 4th century, is most likely contemporary with the Mazkatuži axe, which shares its forging pattern. Therefore, the simplest pattern was used the longest, and the more diverse and technologically sophisticated axes appear during the 3rd to the 5th century.

Conclusions

In the first millennium CE, the socketed iron axe was used on the eastern shore of the Baltic Sea and in the Volga, Oka and Kama river basins. If the socketed axe is void of qualitative attributes (e.g. the loop), then the typologies based on appearance are not really helpful for their precise dating. In that light, socketed axes are similar to the primary tools of the smiths (hammer, tongs, anvil, chisels etc.) in that they did not really change much since La Tène period. Metallographic analysis might provide better dating options once the forging patterns have been studied with a sufficiently large sample number. Invasive analysis also provides the possibility to investigate the provenance and production chain of the artefact.

While forging the Kohtla axe, the smith had excellent knowledge of the composition of the chosen materials. Steel has only been used on the cutting edge of the axe, while the rest of the axe is made of relatively low carbon content iron. A large high-slag content iron lump has been placed inside the socket to add weight and for stopping the wooden shaft from tearing the welds apart during use. Based on our experiments, the use of slag-rich material also helps to fill up the socket without leaving a gap, so it might be argued that it is actually a well-suited material for this function.

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RAUAST PUTKKIRVESTE VALMISTAMISE TEHNOLOOGIA

Resümee

Käesolev uurimus kasvas välja Kohtla putkkirve (TÜ 2309: 203) metallograafilisest analüüsist, mille eesmärk oli välja selgitada putke valmistamise tehnoloogia ja kirve tegemiseks kasutatud materjalid, anda hinnang sepa oskustele ning võrrelda seda teiste putkkirvestega. Rauast putkkirved võeti Euroopas kasutusele Kesk- ja Lääne-Euroopas La Tène'i ning Hallstatti kultuuri alal varasel rauaajal. Läänemeremaades oli rauast putkkirveid kaht tüüpi: aasaga ja ilma. Aasaga putkkirveid kasutati pronksiaja lõpust kuni vanema rooma rauaajani. Aasata putkkirveid hakati valmistama rooma rauaajal ja need püsisid Eestis kasutusel vähemalt rahvasterännuaja lõpuni.

Aasaga putkkirved valmistati toruks keeratud raualehest, mille ühte, veidi ülespainutatud äärde tehti varre kinnitamiseks auk. Selliseid kirveid on leitud Lõuna-Skandinaaviast, Soome rannikualalt, Eestist ja Põhja-Lätist ning Ingerimaalt. Kaugeimad idapoolsemad aasaga kirved on leitud Venemaalt Volga ja Oka jõe vaheliselt alalt. Eestist on neid leitud üle 20. Aasaga rauast putkkirveste eeskujuks olid suurima tõenäosusega hilispronksiaegsed pronksist Akozino-Mälari tüüpi kirved.

Aasata kirveid on leitud Soome edela- ja lõunarannikult, Baltimaadest, endiselt Ida-Preisimaalt ning Loode-Vene aladelt (jn 1). Idas ulatub nende levikuala Kama jõgikonnas kuni Permi aladeni, kus algelised ja lihtsa teostusega rauast putkkirved tulid kasutusele 5.–3. sajandil eKr ning olid kasutusel vähemalt 5. sajandini pKr. Kesk-Venemaal ulatus nende levikuala lõunas Djakovo kultuuri alalt kuni Oka jõeni. Leedus olid putkkirveste hilisemad variandid kasutusel kuni 11. sajandini. I aastatuhandel pKr oli putkkirves Kirde-Euroopas kasutatud esemetüüp, mille levikupiirkonnaks olid läänemere- ja volgasoome ning läänebalti hõimude alad.

Putkkirveste eripäraks on see, et neid võidi erinevalt silmaga kirvestest kasutada nii tavalise kui ka ristkirvena. Nii rauast putkkirveste erinev kuju, lai levikuareaal kui ka pikk kasutusperiood näitavad, et tegemist oli tõenäoliselt mitmeotstarbelise tööriistaga, mida võidi vajadusel ka relvana kasutada.

Eestist on enne Kohtla leiu päevavalgele tulemist leitud umbes 50 rauast putkkirvest, millest eraldi uurimust pole koostatud. Ka Läti rauast putkkirvestest ilmus viimane ülevaade Harri Moora sulest juba 1938. aastal. Selles on käsitletud 250 tolleks ajaks leitud putkkirvest. Kõige põhjalikum ja uusim käsitlus Leedu putkkirveste kohta ilmus Arvydas Malonaitise sulest 2003. aastal. Leedust leitud 824 rauast aasata putkkirvest liigitas ta viide tüüpi. Leedu putkkirveste uurimine näitab, et neil on vähe kindlalt dateerivaid välistunnuseid. Laias laastus võib öelda, et lihtsamad kirved on varasemad ja tera suunas kaarduva teramikuga kirved on kõige hilisemad (jn 2).

Ühe Kohtla putkkirve (TÜ 2309: 203) valmistamistehnoloogia uurimiseks võeti ette metallograafiline analüüs Tartu ülikooli arheoloogia laboris. Kirves saeti pikisuunas pooleks (jn 3), lihviti, poleeriti ja söövitati nitaaliga. Kirve ristlõikes paljastus üllatavalt keeruline ülesehitus: selle sepistamiseks oli kasutatud nelja erinevat komponenti (jn 4). Kirve teral võis eristada terasest kihti, mis oli karastatud ja noolutatud (jn 5: a). Kirve põhiosa oli väikese süsinikusisaldusega rauast ja selle puhul võis üle kogu kirve täheldada piklikke šlakipesi, mis ilmselt pärinevad algse rauakangi voltimisest selle puhastamisel (jn 5: b). Putke sees oli rohkelt šlakki sisaldav toorraud (jn 5: c) ja tera sisse oli lisatud väikese süsinikusisaldusega teras (jn 5: d). Sepakeeviste kvaliteet eri komponentide vahel kõikus palju. Hästi õnnestunud keevisjooni võis leida terasest teraosas (jn 5: e) ja kirve põhiosa ning tera sees oleva komponendi vahel. Samas oli palju šlakki jäänud kirve teraosa ja põhiosa vahele (jn 5: f).

Kirve ehituse paremaks mõistmiseks tegi Karmo Kiilmann kaks putkkirve koopiat, mis lõigati samuti pikisuunas pooleks. Sepistamisele eelnes plastiliinist mudeli valmistamine, mis aitas planeerida materjalide suurust ja kuju (jn 6: a). Esimese koopia valmistamisel jäi putke sisse pandud täide täitmata tühimikku lõpuni kinni (jn 6: b). Selle vältimiseks kasutati teise koopia tegemisel vähem kompaktset täidet (jn 6: c) ja täide lisati sinna juba enne putke lõpuni kokkurullimist (jn 7). Eksperimendi tulemusena oli lihtsam mõista, miks oli putkes šlakirohket toorrauda kasutatud. Esiteks pidi see täide lisama kaalu, kuid ei pidanud seejuures sitke olema. Teiseks sobibki putke täitmiseks paremini püdelam materjal, mis võtab kergemini putke kuju. Ka teraossa lisatud täide oli oluline, kuna see aitas muidu üsna õhukesest materjalist torru keeratud kirve profiili kolmnurksena hoida. Viimane on aga puutöö juures tähtis, et kirves ei hakkaks materjali sisse kinni jooksma.

Kui putkkirved on väliselt üsna sarnased, siis metallograafilise analüüsi tulemusel on tuvastatud vähemalt neli erisugust tehnoskeemi (jn 8). Uuritud Kohtla kirvele sarnane šlakirohket toorrauda sisaldav kirves on välja tulnud Lätist Mazkatuži kalmistult. Teine tehnoskeem on seni esindatud vaid ühe leiuga Perilast ja selle puhul on ühest tükist põhiosale peale keedetud teine suurem tükk rauda (jn 8: 2). Kolmas tehnoskeem on esindatud Alulinna ja Nikitinski leidudega (jn 1). Selle puhul on kirves valmis sepistatud lisakomponente lisamata (jn 8: 3). Neljas sepistamisviis on samuti laia levikuga, näiteid on nii Leedust Marvelė kalmistult kui ka Venemaalt Nikitinski kalmistult. Kirve sepistamisel on putk keedetud massiivse tera ümber, seejuures on nii Venemaa kui ka Leedu kirves korralikust terasest teraosaga (jn 8: 4). Praeguse uurimisseisu juures võib esitada hüpoteesi, et 1. ja 2. sajandil pKr kasutati lihtsamaid tehnoskeeme, alates 3. sajandist lisandusid keerukamad kirveste valmistamise viisid.

Kohtla putkkirve valmistanud sepp tundis hästi talle kättesaadavaid materjale ja kirve sepistamine oli oskuslik. Kirve valmistamisel kasutatud materjale võib pidada oma otstarvet hästi täitvaiks ja näib, et prooviti optimeerida materjalide töötlusastmega: iga komponendi puhul oli seda materjali töödeldud nii vähe kui võimalik. Šlakirohke toorraua leidumine esemes viitab kirve valmistanud sepa osalusele rauatöötlusahelas kas raua sulatajana või siis vähemalt toorraua rikastajana.