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BRACTEATE PENDANT FROM THE LINNAKSE HOARD: ARCHAEOMETRIC DISCUSSION OF THE SILVER ARTEFACT

The article presents the research results of a small fragment of a silver ornament from the hoard (*tpq* 1059), discovered in Linnakse village in northern Estonia in 2010. An archaeometric study method was applied to estimate the materials and techniques used for the production of this rare artefact and to establish the original shape, function and origin of the decoration. A scanning electron microscope supplied with an energy dispersive (EDS) X-ray micro analyzer was used for the analyses of materials. It turned out that the ornament was made from an alloy with a high content of silver at a maximum of 98.4%. The beaded wire soldered along the edge was made from a similar alloy as the ornament; the front side has traces of amalgamating gilt. The die impression decorating the ornament resembles the obverse of the coins minted during the reign of the Anglo-Saxon king Aethelred II and the imitations struck after them in Scandinavia. The only find that has several similarities with the Linnakse ornament originates from a silver hoard discovered in Kännungs (*tpq* 1025–1030) on Gotland in 1934 and was called by Mårten Stenberger (1947) a bracteate pendant. It is possible that the place where such types of silver ornaments were made was Gotland, which had reached an outstandingly high level in jewelry crafts.

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Introduction

In the late summer of 2010, a history enthusiast Erkki Heinsalu discovered a Late Viking Age (*tpq* 1059) hoard from a field in the northern part of the Linnakse village in central Harjumaa. 1311 coins, two small silver bars, some silver beads and pieces of hack silver had been placed into a hand-made clay vessel with a narrow opening and lay as a rather compact assemblage amongst the vessel fragments at the depth of 25–30 cm in a soil without any traces of a cultural layer (Kiudsoo & Russow 2011, 225 f., fig. 3). Archaeological investigations of the find location revealed that a large burial ground had been on the same field with both cremation and un-cremated burials from the 3rd–4th century until the 12th–13th century. The silver hoard had been hidden in the vicinity of the earliest burial site –

the *tarand* grave (Tamla et al. 2011). This allows us to conclude that the Linnakse hoard is so far the only one from the Late Iron Age hoards in Estonia where the find context, proved by facts, refers clearly to connections with an old burial place (Leimus et al. 2014).

The article concentrates on the study and research results of a piece of silver from the Linnakse hoard. It is important to note that the small item that was initially considered to be part of a widely used Late Viking Age silver coin proved, at closer inspection, to be a fragment of a rare decoration. Since such items had previously never been found in Estonia, I considered it necessary to publish an article about this item and so pass information about it on to scientific circles. An archaeometric study method was applied to reconstruct the whole item from its fragment and to establish the original shape, function and origin of the decoration. In the process I delved into the production technologies of analogous items. Archaeometry is the application of scientific methods and techniques to archaeological investigation and often looked upon as a link between the so-called traditional science of archaeology and other research areas (Murray 2001, 105). The objective of archaeometric studies is to use techniques from other scientific fields to obtain as much information as possible about the materials and techniques used for the production of archaeological items, about the craftsmen and their skills, tools, working environments, specialization, etc. and to learn about the production, trade and cultural environment of the time on a broader scale (Olin 1982; Yellen 1982; Aspinall 1986; Wisseman & Williams 1993; Killick & Young 1997; Edwards & Vandenabeele 2012). To establish the possible origin of the item I looked for parallels in archaeological collections in the neighbouring countries as well as more distant regions. The analysis of the material composition of the fragment was made at the Science Centre of Materials Research of the Tallinn University of Technology (Analysis report 2015).

External observation of the item and conclusions about its production

The 19 × 12 mm and 1 mm thick fragment of silver sheet with three straight and one curved side originates from a decoration, where a profiled wire with a 1.8 mm diameter has been soldered to the curved side (Fig. 1). It is most likely that the fragile item had been cut with a knife or shears for trading purposes. Unlike with chopping or tearing, the edge of a soft and thin silver sheet remains straight only if cut with a knife or shears. The barely perceptible yellowish sheen on the surface of the fragment could indicate worn gilt. If the item had been gilded, probably amalgamating was used – i.e. an ancient art of goldsmithing that became widely used in the first centuries of our era, when it replaced the method that used forging a thin sheet of gold to an item or applying glue like e.g. egg white for fastening sheet gold. The essence of amalgamating is fairly straightforward: gold is dissolved in mercury at 375 °C which produces the mass of amalgam that is then spread over the item to be gilded. Mercury vaporizes, when

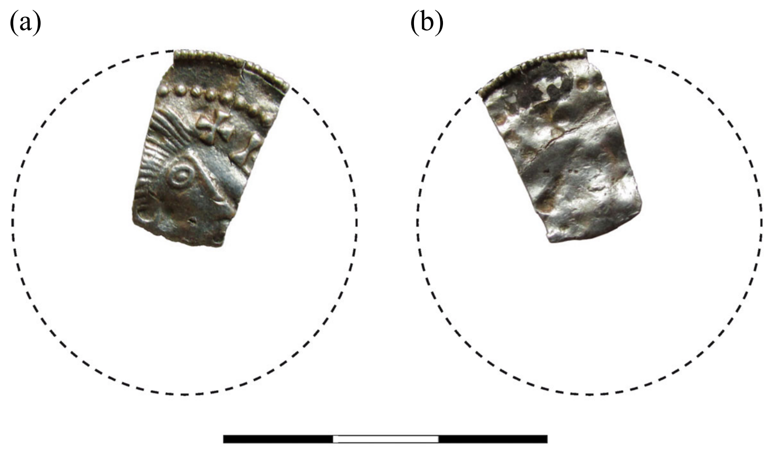

Fig. 1. Fragment of the silver ornament from the hoard of Linnakse. (a) front side, (b) rear side. Photo by Aive Viljus.

heated, and the thin coat of gold will fasten to the surface of the base metal. Presbyter Theophilus, who lived in Germany in the 12th century and was known for his outstanding goldsmithing skills, recommended in his book *De diversis artibus* ("Schedula diversarum artium") the ratio 1: 8 of gold and mercury to make the amalgam (Hawthorne & Smith 1979, 110). Amalgamating is an extremely poisonous job, which Theophilus also pointed out. Nowadays jewelers have given up hazardous amalgamating and have replaced it with galvanization (Immonen 2009, 113).

Matrixes were used to decorate items. Matrixes were press moulds, where the image, carved as a mirror image, left the desired relief projection on the thin sheet of the ornament. Finds of ancient matrixes are extremely rare; no such finds have so far been discovered in Estonia. It is therefore only possible to speculate that the matrix used to decorate the ornament in question was similar to a seal that had been used to mint gold and silver coins, such as have been discovered, for example, in York and London, England. These matrixes, with a diameter of 4–5 cm, a length of ca 10 cm and a weight of 400–500 g, were round tempered iron sticks, with the coin pattern engraved as a mirror image to one end (e.g. Pirie 1986, fig. 6, table I, V; From Viking to Crusader, 339, No. 427). When the pattern of the matrix wore out, it was possible to easily refresh it by either a new engraving or by carving a new pattern on a previously re-polished surface. The matrix pattern of the given ornament shows a fragment of a man's profile turned to the right (high forehead, straight nose, oval eye with a round pupil, a mouth marked with small curved lines, an ear and a high striped helmet resting on the forehead), eight round embossments in a row, a cross with widening ends and two triangles with facing tops. The attention of the researchers was caught by a triangular notch, probably poked by a sharp instrument, possibly an awl or a knife, in the area of the lower jaw of the man. Such small notches were pecks that were made to ascertain the authenticity of silver during trading. Almost all coins, pieces of hack silver and the two silver bars in the Linnakse hoard were "marked" with similar traces.

The reverse of the sheet did not have the golden sheen and was almost smooth, apart from an irregular thin crack and depressions caused by the pressure of the matrix that matched the reliefs of embossments on the front side. The extremely fine crack may have resulted from rolling the sheet thinner and as a structural defect during annealing (see Tamla et al. 2004, 358 f.), or as a result of tensions during the deformation that accompanied the process of cutting out the fragment. On the other hand, the crack may have appeared when the sheet was being decorated, or at a later stage, e.g. due to deformation stresses caused by the weight of the soil or a twisting of the fragile item during excavation.

The wire soldered along the curved edge is a beaded wire (Figs 2–4). It has been suggested that the beaded wire got its name from the similarity it had to a string with round beads. The oldest records about making beaded wire originate from Egypt in the 14th–13th century BC. In Europe the majority of objects decorated with beaded wire have been discovered in Greece (8th–6th century BC). They were especially wide-spread in the jewelry of the high quality Hellenistic Period. In northern Europe decorations with beaded wire occurred in the Late Roman Iron Age. The art flourished, however, during the Viking Age when beaded wire was mainly used as a decorative element on silver and gold items made in the filigree and granulation techniques (Tamla & Varkki 2009, 37 and literature referred to there). Prior to the discovery of the Linnakse hoard, the only Viking Age items decorated with beaded wire in Estonia were the golden pendants from the Essu hoard. These were of foreign origin and made most probably in the second half of the 9th century (Leimus 2006, 22, fig. 1; Tvauri 2012, 153 f.).

Fig. 2. Detail of a beaded wire soldered along the curved edge. Photo by Mart Viljus.

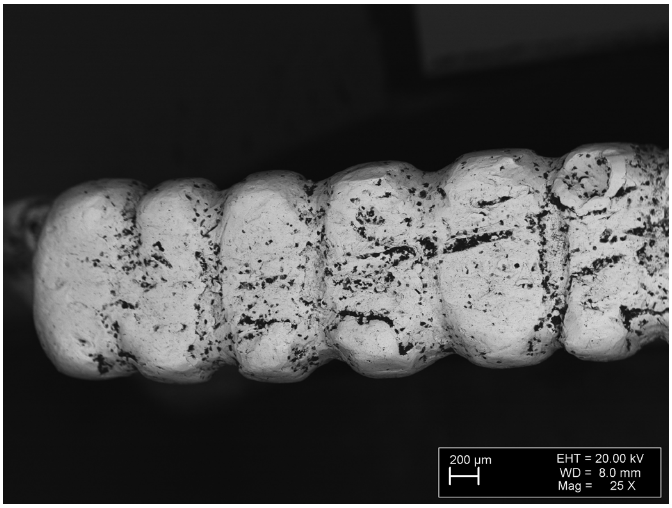

Fig. 3. Flattened outer edge of a beaded wire. Photo by Mart Viljus.

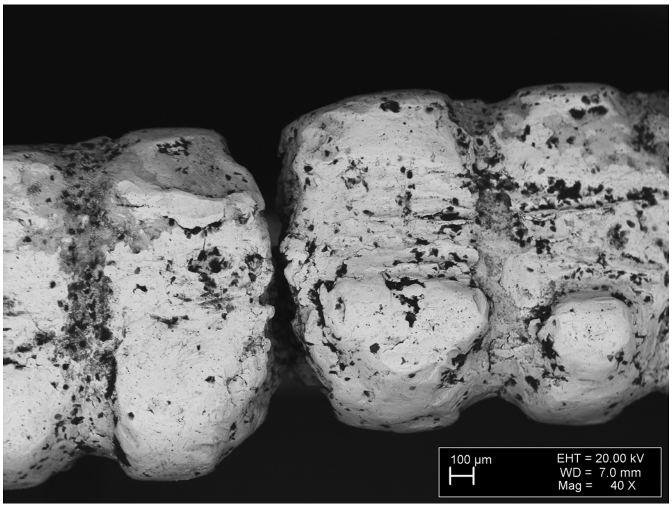

Fig. 4. Open ends of the beaded wire. Photo by Mart Viljus.

A convex wedge with a wooden handle from the Illerup (Denmark) Roman Iron Age bog hoard is the only known archaeological tool that is believed to have been used for making beaded wire (Ilkjær 2000, 117 ff.). A more accurate description of the production techniques of beaded wire can be obtained from the above mentioned tutorial by Theophilius, which, among other things, described two tools that were required to make beaded wire: an *organarium* and a *lima inferius fossa,* that may be translated as a small organ and a bead file (Hawthorne & Smith 1979, 88 ff.). On the basis of these descriptions several researchers have reconstructed the tools and made attempts to produce beaded wire with them (e.g. Duczko 1985, 18 ff., figs 3, 7, 13; Brepohl 1987, 69 ff., fig. 11). They have concluded that although Theophilius's descriptions of the small organ and the bead file were rather detailed, the reconstruction of the instruments and production of beaded wire is open to several different options (Hawthorne & Smith 1979, 89, footnote 1). Experiments with making beaded wire that took place in Tallinn in 2008 and 2009 (Tamla & Varkki 2009) were based on the knowledge that we had obtained by that time from various illustrations about goldsmithing in different times and different parts of the world. It was noted that different versions of beaded wire demonstrated small deviations in the size and rhythm of the beads and the furrows between the beads. These are qualities that external observation of archaeological items associates with the "handwriting" of different masters. Because beaded wires have so many variations and deviations it is not possible to explain their production with just the two tools described by Theophilus. Therefore, the question was approached rather from the viewpoint of the technology of metal treatment and scientists attempted to find more universal (simpler) tools for making beaded wire and establish the working methods. After several attempts, two iron knives (a working knife and an auxiliary knife) proved to be the best tools – achievable by any blacksmith. It is fairly easy to make beaded wire with two knives for anyone who knows the material properties of gold and silver, but specific working methods are required (Tamla & Varkki 2009, figs 3–10). The experiments proved that there are several ways to reach the desired outcome: the appearance of the beaded wire depends greatly on the tools the master uses and on how much time and energy he is willing to invest. To the naked eye the beaded wire soldered to the fragment of the Linnakse ornament seems fairly homogeneous, but a closer look through a microscope or a magnifying glass shows differences in the sphericity and size of the beads, as well as the space between the beads (Figs 2–4). These characteristics rule out the possibility that the master who made this beaded wire had access to the organarium of two plates that functioned on the principle of a press tool, described by Theophilus (Tamla & Varkki 2009, fig. 2). However, the use of a bead file (Duczko 1985, figs 3–4) or two knives (Tamla & Varkki 2009, figs 3–4) is a possibility.

The craft of soldering items together with metal solder was mastered by Mesopotamian jewelers already in the third millennium BC, and this technique is in use in goldsmiths' workshops to the present day. Soldering is considered to be one of the most complicated skills, since apart from good technical knowledge it requires a good deal of experience. Soldering metals together is based on the know-how that the solder needs to be at a lower temperature than the metals to be merged, hence in the process solder that is poured on the metal plates to be merged runs in between the plates, thus forming a strong interface that connects the plates after cooling. Usually the solder is made of two or three components, one of which being the metal to be soldered. Therefore the solder used for soldering silver always contains silver, and often copper as the second metal. Common combinations are also silver with zinc and silver with tin (Scott 1991, 22; Immonen 2009, 113). As a rule items that have been soldered with metal generally display some visible traces (e.g. slight unevenness of the soldering line or residue of solder), which are attempted to be polished off in the finishing touches.

In addition to metal soldering, jewelers were familiar with another way of fastening details together already from the ancient times – the so-called chemical soldering, where the "solder" that unites metals is created in a process between copper minerals or artificial copper compounds (which will turn into copper oxides while heated, but in the process into metal copper) and the silver of the soldered details. Joachem Wolters (1975; 1983), researcher of the history of goldsmithing, has found eight such compounds described in different written sources, the earliest of which dates from the third millennium BC Mesopotamia, and the latest from 12th century Europe. The best known compounds were minerals that contained copper, such as malachite, azurite, patina – i.e. a copper alloy resembling enamel polish that covers old bronze objects (the chemical content being mostly copper carbonate, containing natural oxides and oxides of bronze additives line tin (Sn), lead (Pb), zinc (Zn), arsenic (As), acid copper salt (appears e.g. on effect of vinegar in bronze vessels) or copper acetate, copper vitriol or copper sulphate and a mixture of black (copper (II) oxide or tenorite) and red (copper (I) oxide or cuprite) copper oxides that forms in the burning of copper (see Hawthorne & Smith 1979, 121 f.). For chemical soldering a so-called santerna paste has to be prepared. To make the paste some of the above mentioned copper alloys are mixed with glue – e.g. gum acacia (acacia resin) or fish glue, and water and then the granules, the beaded wire or filigree wire decorations are "glued" to the required spot that has been cleaned with borax ($Na_2B_4O_7$ $10H_2O$) or a solution of sodium saltpeter ($NaNO_3$), baking soda ($NaHCO_3$) and sodium chloride (NaCl) and sprinkled with coal dust to facilitate the process. After that the item is slowly heated. This kind of soldering can be described as a series of chemical reactions, where at temperatures from ca 100 °C copper compounds turn into copper oxides and at the temperature of 600 °C the organic matter in the glue will turn into carbon and the added coal dust will create a reducing environment. The following reducing process will reduce coal and copper oxides into metallic copper, which in contact with silver will start forming first a solid solution or alloy of silver and copper (copper diffuses into silver and vice versa at the atomic level). The lowest melting temperature of silver-copper alloy is 779 °C, but only with 28.5% copper content, which will not form immediately, but definitely at a certain time and temperature. Hence heating has to be continued until a sufficient amount of copper has melted (diffused) into silver, in order to form an adequate layer of molten alloy for soldering together the details. It is not possible to differentiate with chemical or physico-chemical methods between solder added as metal and that produced in chemical soldering. It may be possible to differentiate between these by determining the content of a larger amount of coal particles (see also Zoll-Adamikowa et al. 1999, 92).

The 0.3 mm wide space between the ends of the beaded wire (Fig. 4) seems to suggest that the hoop of beaded wire that decorated the edge of the ornament had not been completed as a hoop prior to soldering. It seems likely that soldering was started from one end of the wire and moved gradually along until the ends of the wire met. Naturally the wire had to be annealed in the process to maintain its elasticity. Finally the outer edge of the wire was for some reason flattened (Figs 3–4). Since no traces of defects that occur easily with metal soldering could be detected on the fragment, it is likely that chemical soldering had been used.

Materials research

As it was not possible to take a sample from such a small and rare item, the research concentrated on the study of the front and reverse sides and one of the cut edges of the fragment. A scanning electron microscope Zeiss EVO MA-15 supplied with an energy dispersive (EDS) X-ray micro analyzer Inca Energy 350 at speeding voltage 20 kV was used for analyses, which is an effective instrument for surface observations, determination of the content of chemical elements and for mapping one or several chemical elements. Four questions were put forward for the analyses: 1) what was the content of the alloy used for making the ornament? 2) does the barely perceptible yellowish sheen on the fragment refer to the use of amalgamated gilding or to the oxidation of silver? 3) what was the content of the beaded wire alloy? 4) what was the content of the solder used to fasten the beaded wire to the ornament?

A comparison of the analyses of samples from various places on the front and reverse sides of the ornament and from one of the cut edges showed that the non-homogeneity of the material structure was small, which in turn permitted a comparison of the results based on mean values. It turned out that the ornament was made from an alloy with an exceptionally high content of silver at a maximum of 98.4%, with a very small amount of other elements. The other more significant elements were copper (1.2%) and magnesium (0.4%). The assumption made by external observation that the yellowish sheen might be amalgamated gold was proved by the materials research: on the front side both gold (0.5%) and mercury (0.4%) were found. No gold was found on the reverse side of the ornament.

The content of the alloy used for making the beaded wire was analysed in five places on the cut edge and the analyses proved that the beaded wire was made from a similar, possibly even the same, alloy as the ornament.

The study of the solder content gave contradictory results. Since the wire had been soldered to the ornament extremely skillfully and no traces of solder could be detected even under microscope, a spot was selected for the research at the edge of the ornament where the beaded wire had most contact with the ornament (Fig. 5). Unfortunately the result (98.4% silver, 1.1% copper and 0.5% magnesium) did not detect solder. Therefore it is possible that the so-called chemical soldering process had been used to fasten the beaded wire.

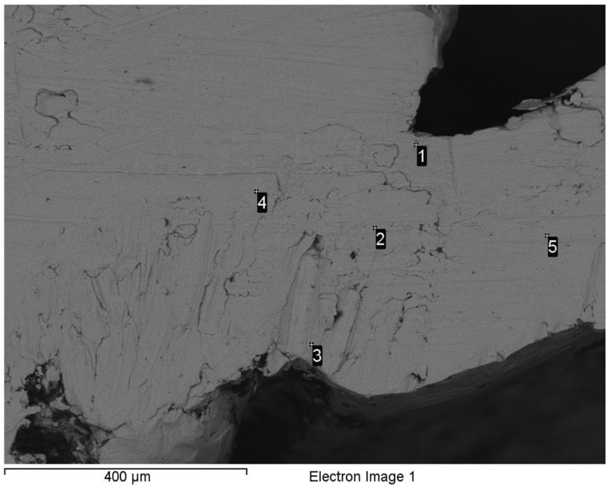

Fig. 5. Cut end of the beaded wire. Numbers indicate the points investigated with EDS X-ray micro-analyzer. Photo by Mart Viljus.

Reconstruction attempt, the nearest counterpart and probable origin

The curved edge of the ornament with the beaded wire was most helpful in the reconstruction of the original form and size of the object. Considering the length of the curve and its curvature the object must have had a diameter of 3.4–3.5 cm, and was probably a thin circular pendant or a decorative plate fastened to clothes (Fig. 1). It was not possible to reconstruct the back of the head, neck and chest of the man depicted in profile on the ornament, yet the surface of the figure as well as images next to the figure bore significant similarities to the coins minted during the reign of Anglo-Saxon king Aethelred II the Unready (978–1016) and also to the images on the front side of the imitations (Fig. 6).

(a) (b)

Fig. 6. Obverse of a penny of Aethelred II (a) and its Scandinavian imitation (b). Photo by Aive Viljus.

Hence it is very likely that the rest of the image details were similar to or even coincided with those. Materials research confirmed the opinion reached by external observation that the yellowish sheen on the surface of the ornament was worn gilt. Analyses demonstrated that only the front side had been gilded.

Fig. 7. Bracteate pendant from the silver hoard of Kännungs, Gotland. After Stenberger 1947, fig. 207: 1.

Estonian archaeological collections do not have items similar to the Linnakse ornament. No such items are known from literature, and colleagues from Finland, Denmark, Norway, Latvia, Poland, Germany and Russia do not know of such items. The only find that has several similarities with the Linnakse ornament originates from Gotland. More precisely, a hoard that was discovered during field work in 1934 in the Kännungs village, Hellvi parish in north-east Gotland included coins, silver bars, fragmented and whole ornaments (*tpq* 1025–1030), and also a fragile ornament that Mårten Stenberger called a bracteate pendant (Stenberger 1947, No. 288, fig. 207: 1). That pendant (*op. cit.*, 115–116) had been severely damaged (in the earth?), but the surviving thin circular plate with a diameter of ca 2.5 cm and a ca 1 cm wide frame surrounding the plate, soldered from various beaded wires (Fig. 7), leaves no doubt that the object resembles the Linnakse ornament in many aspects. The Kännungs ornament also depicts a relief man's bust in profile to the right, a row of nodules and triangles with facing points, applied with a matrix. The only difference in the image concerns the man's head: on the Linnakse ornament the head is covered with a high striped helmet, the Kännungs ornament depicts dense stripes featuring a thick hairdo combed backwards. The outer wire of the wreath-shaped frame soldered together from 8–9 beaded wires, which had separated from the ornament but was nevertheless fairly well preserved, was at least one third thicker than the other wires. It is possible that also the wreath that surrounded the Linnakse ornament had also been soldered together from various wires; at least the flattened outer edge of the beaded wire seems to indirectly suggest it. Irrespective of small differences, both objects are similar in the way a complicated and time-consuming technology was applied to make them, which required completely different skills and tools than ordinary handicraft.

Summary

Silver items are not found in large quantities in Estonia or elsewhere because their production requires a metal that in pure form is found only in rare places and which is separated from other compound metal ores with significant complexity (Oldeberg 1966, 29 ff.; Raukas 2000, 11; Brepohl 2001, XiV ff.). This is the main reason why silver is considered to be a precious metal and silver objects are looked upon as luxury goods, which have never been obtainable to all members of society. However, silver items belong to the treasury of material culture and they are a thank-worthy source of history, that offer valuable information about people and societies that made and used such items and so related to the surrounding world. It should be stressed that the value of ancient objects does not depend on the rare and precious raw material: similarly to any hand-made object from any material, the most important information is data about the object in general and its find context. Thanks to the law-abiding conduct of the person who discovered the Linnakse silver hoard its find context had preserved well and this allows us to conclude that this hoard is so far the only one from the Late Iron Age hoards in Estonia where the find context, proved by facts, refers clearly to connections with burial place.

The archaeometric study of the fragment of the bracteate pendant from the Linnakse hoard indicated that it had been made from an alloy with a very high content of silver and with working methods that refer to significant professional knowledge of the craftsman and his considerable experience in jewelry work. Especially noteworthy are the soldering skills of the master. Since the material studies of the object could not trace the actual solder, it can only be suggested that the beaded wire had been fastened to the artefact by so-called chemical soldering. It is highly possible that the matrix that had been used to ornament the thin plate in the centre of the pendant had been made by the same craftsman, since the fine décor rich in detail refers also to natural artistic talent, special tools and work experience. However, the use of the matrix can also indicate that such kind of pendants may have been made as small batches. Although no exact counterpart is known for the Linnakse pendant, the existence of silver ornaments and their fragments that are similar in style and crafting method in some hoards in Gotland allows formulating a hypothesis that such pendant had been made in the first part of the 11th century in one of the workshops in the area which had reached an outstandingly high level in jewelry crafts.

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BRAKTEAATRIPATS LINNAKSE AARDES: HÕBEDAST ESEME ARHEOMEETRILINE KÄSITLUS

Resümee

2010. aastal avastati Harjumaalt Linnakselt metallidetektori abil hilisviikingiaegne (*tpq* 1059) aare. Savipotti pistetud 1311 münti, kaks hõbedakangikest, mõned hõbehelmed ja hakkhõbedatükid asetsesid anumakildude vahel kultuurkihi tunnusteta künnikihis. Aarde leiukohal toimunud järeluuringutel selgus, et väärisvara oli peidetud või mingil muul põhjusel pandud 3.–4. sajandil rajatud tarandkalme juurde.

Linnakse aarde esmasel ülevaatamisel peeti üht hakkhõbedatükki hilisviikingiajal massiliselt käibel olnud anglosaksi vermingu poolmikuks, kuid hiljem selgus, et tegemist on ehteasja fragmendiga, mille sarnaseid pole Eestist varem avastatud. See ajendaski esemekatke üksikasjalikumat uurimist ette võtma. Kasutati arheomeetrilist uurimisviisi ja keskenduti eseme algse kuju ja välimuse rekonstrueerimisele ning selle valmistanud meistri oskuste, töövõtete ja tema käsutuses olnud instrumentide väljaselgitamisele. Fragmendi materjalikoostise analüüsimine toimus Tallinna Tehnikaülikooli Materjaliuuringute Teaduskeskuses.

Uuringuid alustati eseme mõõtmise ja detailse välise vaatlusega, mille põhjal selgus, et kolmest küljest sirge ning ühest kaarjas 19 × 12 mm suurune ja 1 mm paksune plekitükk on välja lõigatud 3,4–3,5 cm läbimõõduga sõõrjast ripatsist või ehteplaadist, mille kaarjas servas on profileeritud traadist raam (joon 1–4). Ehte detailiderikas ja reljeefne pinnakaunistus on valminud matriitsi abil, millega õhukesele hõbeplekile pressitud mustrist on peegelpildis jäänud profiilis mehepea osaline kujutis, ridastikku kühmukesed, ristimärk ning kaks kolmnurka. Nendel kujunditel on suur kokkulangevus anglosaksi kuninga Aethelred II Nõutu valitsemisajal (978–1016) vermitud rahade ja järelmüntide esikülje pildiga (joon 6). Esemekatke esikülje vaevumärgatava kollaka läike kohta oletati, et see on kulunud kullatis või on tegemist korrosioonilaikudega. Piki kaarjat serva kinnitatud profileeritud traat on nn pärltraat, mille "pärlite" sfäärilisuse ja suuruse erinevus ning pärlitevaheliste vagude erinev laius (joon 2–4) välistavad võimaluse, et see valmistati Theophiluse õpetusraamatus "De diversis artibus" kirjeldatud kahest plaadist koosneva ja stantsi põhimõttel töötanud *organarium*'iga (Hawthorne & Smith 1979, joon 10). Samas ei saa välistada sealsamas kirjeldatud *lima inferius fossa* ehk pärliviili (Hawthorne & Smith 1979, 90) või pärltraadi valmistamise eksperimentaal-arheoloogilise katse läbiviimisel kasutatud kaht nuga (Tamla & Varkki 2009, joon 3–4), mille abil valmiks samuti "vigadega" pärltraat. Pärltraat on ehte külge kinnitatud niivõrd meisterlikult, et pole näha ainsatki jootmisjälge. See andis aluse oletuseks, et kasutatud pole metallijoodist, vaid nn keemilist jootmist, kus metalle ühendav joodis tekib protsessi käigus vasemineraalidest või kunstlikult valmistatud vaseühenditest ja liidetavate detailide hõbedast. Niisuguse joodise valmistamis-oskus, mille kohta jagas õpetusi ka Theophilus, eeldab põhjalikke erialaseid tead-misi ja selle kasutamine pikemat juveliiritöö kogemust. Pärltraadiotste vahele jääv tühik (joon 4) osutab sellele, et pärltraati pole enne ehte külge kinnitamist võruks valmis tehtud. Lõpuks on pärltraadi välisserva mingil põhjusel lamendatud (joon 3–4).

Materjaliuuringuteks ei olnud sedavõrd väikese ja haruldase eseme küljest proovitüki võtmine mõeldav, mistõttu piirduti fragmendi esi- ja tagakülje ning ühe lõikeserva analüüsimisega. Selleks kasutati skaneerivat energiadispersiivse röntgenmikroanalüsaatoriga elektronmikroskoopi, mis on tõhus instrument pinna vaatlemiseks, keemiliste elementide sisalduse määramiseks ja ühe või mitme kee-milise elemendi kaardistamiseks. Vastuseid otsiti neljale küsimusele: milline on ehteplekisulami koostis? kas fragmendi vaevumärgatav kollakas läige osutab eseme kuldamisele või oksüdeerumisele? milline on pärltraadisulami koostis? millise koostisega joodist kasutati pärltraadi kinnitamiseks? Fragmendi esi- ja tagaküljelt ning ühest lõikeservast üle pinna mitmest punktist tehtud analüüsi tulemuste võrd-lemisel selgus, et materjalistruktuuri ebaühtlus on väike ja et ehe valmistati kõrge, maksimaalselt 98,4% hõbedasisaldusega sulamist, kus teisi elemente on vähe. Tähtsuselt järgmised elemendid on vask (1,2%) ja magneesium (0,4%). Välisel vaatlusel tehtud oletus, et eseme kollakas läige võib osutada kullatisele, sai kinni-tuse: eseme välisküljel leidus nii kulda (0,5%) kui ka elavhõbedat (0,4%), mis osutab amalgaamkuldamisele. Kuna eseme tagaküljelt kulda ei avastatud, siis saab väita, et kullatud oli vaid esikülg. Pärltraadi valmistamiseks kasutatud sulami-koostist uuriti lõikeserva viiest punktist ja analüüsitulemused näitavad, et see tehti ehteplekiga sarnasest, võimalik, et koguni samast sulamist. Joodise koostise uurimisel saadi vastakaid andmeid. Kuna pärltraat on ehte külge joodetud sedavõrd perfektselt, et joodise jääke pole isegi mikroskoobis näha, valiti uurimiskohaks ehte servast punkt, kus traat puutub ehteplekiga kõige tihedamalt kokku (joon 5). Paraku ei osuta saadud tulemused (hõbedat 98,4%, vaske 1,1% ja magneesiumi 0,5%) sellele, et oleks "tabatud" joodist. Samas ei lükka analüüsitulemused ümber, vaid pigem toetavad oletust, et traadi kinnitamiseks kasutati nn keemilist jootmist.

Eesti arheoloogiline leiumaterjal ei sisalda Linnakse ehtele sarnaseid hõbe-esemeid. Neid pole teada ka Soomest, Taanist, Norrast, Lätist, Poolast, Saksa-maalt ega Venemaalt. Ainus ehteasi, millel on Linnakse leiuga suur sarnasus, sisaldub Ojamaalt Kännungsi küla maadelt avastatud aardes (*tpq* 1025–1030) ja Mårten Stenberger (1947, nr 288, joon 207: 1) nimetab seda brakteaatripatsiks.

Kõnealusest esemest on säilinud umbes 2,5 cm läbimõõduga reljeefse kujundusega sõõrjas plaat ja seda ümbritsenud pärltraadilõngadest kokku joodetud umbes 1 cm laiune raam (joon 7). Võimalik, et ka Linnakse ehet raamiv pärg oli mitme traadilõnga laiune, sest kaudselt osutab sellele pärltraadi välisserva lamendamine. Olenemata väikestest välistest erinevustest ühendab mõlemat ehet nende keeruline valmistamisviis, mis eeldab lihtsast ehtevalmistamise kunstist oluliselt põhjalikumaid erialaseid teadmisi hõbedast, samuti erioskusi ja -instrumente hinnalise materjaliga töötamiseks. Kuigi Linnakse brakteaatripatsile pole täpset vastet teada, lubab stiililt ja valmistamisviisilt suuresti sarnaste ehete ning nende fragmentide esinemine Ojamaa mitmes aardes püstitada hüpoteesi, et neid meisterdati mõnes sealses väärismetallesemete valmistamisele spetsialiseerunud töökojas. Samas ei olnud need ilmselt unikaalehted, sest nende valmistamisel kasutatud matriitsid osutavad pigem võimalusele, et mingil ajal (kõige tõenäolisemalt 11. sajandi esimesel poolel) olid seda tüüpi ehteasjad sedavõrd soositud, et neid valmistati lausa väikeste seeriatena.