A 6th-8th c. wire-drawing iron plate with silver residue from a Vendel Period workshop in Old Uppsala, Sweden

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Research Article

Keywords: Archaeometallurgy, wire drawing, SEM-EDS analysis, Scandinavian Archaeology

 Posted Date: July 6th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3143773/v1

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Abstract

Metal wire is in modern society manufactured by drawing metal rods through dies with conical holes of decreasing diameters, until the desired thickness is obtained. The history and origin of this technique remains unclear, although it was likely developed from earlier wire-making techniques such as strip-drawing and roll-drawing. Proper wire-drawing was an established technology in Europe during the High Middle Ages, and numerous draw-plates have been found at Scandinavian trading centres or hoards from the Viking Age. Here, we report the technical examination of an iron draw-plate found in Uppsala in central Sweden. The draw-plate was excavated in a Vendel Period fine metals workshop, located immediately next to the royal hall in Old Uppsala, an important religious centre during pagan times. X-ray and scanning electron microscopy (SEM) analysis of the draw-plate revealed silver particles in the plate's holes, indicating drawing of silver wire. The plate is dated to the 6th – 8th c., which makes it one of the oldest confirmed tools for wire-drawing so far encountered. The presence of this tool in the workshop indicates that some high-quality jewellery in this region was locally produced. Thus, the finding of this draw-plate increases our understanding of Vendel Period jewellery production, and of the social organization of this craft.

1. Introduction

Decorative metal wires of gold and silver found many uses in the ancient world: they were woven into textiles, employed in jewellery such as filigree work, wound around knife handles and arrowheads, and hammered into harder metals to create damascene patterns (Arrhenius, 1968; Ogden, 1983; Scheel, 1989). Today, metal wire is made by drawing rods of solid metal through draw-plates or dies containing series of differently sized conical holes, where each drawing step reduces the diameter of the wire (Oddy, 1977). Before the wire-drawing technique was invented, metal wire was produced by methods such as hammering, casting, block-twisting, strip-twisting, strip-drawing, and roll-drawing (Oddy, 1977; Wärmländer and Söderberg, 2019; Özsen and Willer, 2016). Determining which methods for wire production were used where and when is not only of historical interest, but can also help to provenance an object and to identify fakes (Carroll, 1970; 1972; Ogden, 1983). For example, as wire-drawing was not known in South America before the Spanish arrival (Muros et al., 2007), ancient South American “antiquities” containing drawn wire must be forgeries.

The origin of the wire-drawing method has been debated for over a century, but no clear answers have been provided (Carroll, 1972; Newbury and Notis, 2004; Oddy, 1977; Thomsen and Thomsen, 1974). The earliest literary sources describing wire-drawing are De diversis artibus (On Divers Arts), written by the 12th c. Benedictine monk Theophilus (Teophilus, n.d.), and De la pirotechnia, written by the 16th c. Italian metallurgist Biringuccio (1540). Both authors describe wire-drawing as an established technique, which it apparently was in Europe during the High Middle Ages. The so far earliest archaeological finds of confirmed wire-drawing tools are from Scandinavian trading centres dating to the Viking Age (AD 793–1066), such as Birka, Haithabu, and Staraya Ladoga (Ambruster, 2012; Arrhenius, 1968; Davidan, 1982; Wärmländer and Wählander, 2021).
Here, we present the technical analysis of a pre-Viking Age iron draw-plate (Fig. 1). The tool was encountered in 2015 during an excavation of a Vendel Period (ca AD 540–793) fine metals workshop located next to the royal hall in Old Uppsala, Sweden’s religious centre during pagan times (Ljungkvist et al., 2017b).

2. The site context

Old Uppsala was a power centre with documented princely/royal presence or interests at least between the 6th and the 16th centuries AD, i.e. from pre-Viking Age to Sweden’s Early Modern Era (a.k.a. the Renaissance period) (Beronius Jörpeland et al., 2017; Ljungkvist and Frölund, 2015; Sundqvist and Vikstrand, 2013). Thus, the place has witnessed multiple shifts in economic activities and social organization. Between the 6th and 8th c. AD Old Uppsala was transformed into a monumentalized site with the expansion of a large central estate and construction of huge burial mounds for a royal dynasty (Ljungkvist and Frölund, 2015). This transformation pre-dates the re-urbanization of post-Roman Europe in the 8th century, and coincides with an increased social stratification and the emergence of more stable kingdoms in European societies. The results of the Old Uppsala excavations have allowed researchers to discuss the structural patterns of the central estate, and to draw conclusions about the relations between the rulers and the inhabitants of the surrounding village (Beronius Jörpeland et al., 2017).

The archaeological investigations have also revealed the organization of crafting activities in at least two workshops, located on an artificial terrace in the immediate vicinity of the great royal hall. While only fragments of the workshops have so far been excavated, there is evidence for iron smithing, bronze casting, bead production, and gold and silver smithing to which finds of amber, glass and garnets can be associated (Ljungkvist et al., 2017a; Ljungkvist et al., 2017b). Thus, everything points towards a major production area with a wide variety of crafts. It seems that the great hall and the surrounding workshops were abandoned by the end of the 8th c (Ljungkvist et al., 2017b) (page 99). The studied iron plate (Fig. 1) was found in a very dark debris layer from the workshop among numerous waste objects from the varied production. Specifically, it was found in the upper part of a thick layer that currently dates between the 5th and 8th centuries AD, and can therefore be dated to around the 6th-8th c.

3. Materials

The studied object is a rectangular (68 x 17 x 3 mm) perforated plate made from a single piece of hammered iron (Fig. 1). It contains 38 round conical holes. The wider ends of these holes display diameters in the range 1.0–2.5 mm, while the narrower ends have diameters in the range 0.7–1.5 mm (Fig. 1). The plate has inventory number 90-KG15 and is currently curated at Upplandsmuseet.

When encountered at the excavation site the plate was completely covered with corrosion products and some petrified wood. Cleaning with a scalpel and dental tools followed by microblasting with 50 µm aluminium oxide particles (DentalCentral GmbH, Germany) removed most corrosion down to the metal surface, and revealed that the object contained a number of circular holes. Most of these holes are filled
with corrosion products (Fig. 1), but some of the larger ones came open during the cleaning process. After mechanical cleaning the iron plate was repeatedly soaked in 0.1% NaOH, pH 11, until tests with silver nitrate showed that no chloride ions could be detected in the liquid. This procedure was followed by: 1. soaking in luke-warm deionized water and then in ethanol; 2. drying; 3. blasting with 50 µm glass beads (DentalCentral GmbH., Germany); 4. again soaking in ethanol; 5. drying; 6. coating with dinitrol paste (Dinitrol UN1139, Dinol GmbH, Germany); and finally 7. coating with microcrystalline wax (Mobilwax 2360, ExxonMobil Co., USA).


The iron plate was photographed with a D5000 digital SLR camera (Nikon Corp, Japan), and radiographs were recorded with an ANDREX BW 155 X-ray unit (Yxlon International A/S, Denmark) operating at 74 keV. Scanning electron microscopy (SEM) analysis was carried out with a table-top TM-3000 unit (Hitachi Ltd., Japan), operating at 15 keV for EDS analysis and in back-scatter mode for imaging. The TM-3000 SEM unit is equipped with a large sample chamber, which allowed the entire object to be positioned inside the machine and then analysed (i.e., no sub-samples had to be taken). As the plate consists of a conductive material (iron), no coating or other preparation of the plate had to be done prior to the SEM investigation, which was carried out at high vacuum (around 10⁻⁵ Torr). The SEM-EDS data was analysed with the Quantax 70 software (Bruker Inc., USA).

5. Results

The X-ray image shows that the object contains 38 tapered round holes (Fig. 1). The wider ends of these holes display diameters in the range 1.0–2.5 mm, while the narrower ends have diameters in the range 0.7–1.5 mm. Because the plate is heavily corroded, some of the holes may originally have been smaller than their current size. In the X-ray image, small white specks can be seen in some of the holes (Figs. 1 and 2). These specks correspond to particles of a material that is denser than the surrounding iron. Close-up SEM images of the holes revealed that many of them contain irregularly shaped metal particles, located on top of or embedded in the corroded iron surface (Fig. 3). SEM-EDS analysis of a number of such particles showed that they all consist of pure silver, with no additions of copper or other alloying elements (Fig. 3).

6. Discussion

The large amount (n = 38) of differently sized conical holes in the studied iron plate suggests that it is a wire-drawing tool, used to produce metal wires with diameters in the range of 0.7–1.5 mm (Fig. 1). The tiny silver particles in some of the holes, observed with our X-ray and SEM analyses (Figs. 1–3), support this interpretation, and indicate that the drawn metal wires were made of silver.

Earlier discussions of similar objects have noted that iron plates with conical holes may also be tools for nail heading (Eilbracht, 1999). It might therefore be argued that the plate could have been used to
produce tiny brad nails of silver, for use in e.g. jewellery-crafting. However, our SEM-EDS analyses showed that the silver particles in the holes were very pure, as no traces of copper or other alloying elements could be detected (Fig. 3). It is well known that pure silver is too soft a material to be used in utilitarian items such as nails. On the other hand, soft pure silver is a perfectly suitable material for decorative metal wires. Thus, we argue that the purity of the silver particles (Fig. 3) demonstrates that the plate was used for drawing thin silver wires, and not for making silver nails. That said, many crafting tools can be used for multiple purposes. The purity of the silver particles on the draw-plate furthermore suggests that the metal-workers in Old Uppsala knew how to purify silver from mixed alloys by the cupellation process. Another possible explanation, however, is that silver might have been imported in bars of very high purity.

Finding this draw-plate in one of the Old Uppsala workshops is interesting for many reasons. First of all, it is one of the oldest confirmed tools for wire-drawing. A number of later draw-plates have been found at Viking Age trading centres around Scandinavia, such as Haithabu (Armbruster, 2012), Birka (Arrhenius, 1968; Duczko, 1985; Wärmländer and Wåhlander, 2021), and Staraya Ladoga (Armbruster, 2012; Davidan, 1982). The Viking Age tool chest from Mästermyr in Gotland, Sweden, includes a tool that could be a coarse draw-plate for making thick wires (Arwidsson and Berg, 1983), but it might also be a nail header (or a multi-tool for both purposes). Compared to those objects, the Old Uppsala draw-plate is a rather primitive version of the tool, as it consists of a single sheet of iron with a seemingly random distribution of the drawing holes. In contrast, the iron draw-plate from Birka is made from numerous layers of iron plating welded together for additional strength, with seven fitted dies of softer iron that possibly could be replaced (Arrhenius, 1968). The draw-plate from Staraya Ladoga is made of bronze and has 72 holes systematically organized in three rows from smallest (0.2 mm) to largest (2.0 mm) (Armbruster, 2012; Davidan, 1982). The draw-plate from Haithabu is heavily corroded and thus difficult to characterize (Armbruster, 2012), but may be similar in design to the plate from Uppsala. Thus, the tool from Old Uppsala might represent an early design for an iron draw-plate.

On the other hand, we have previously shown that crude wire-drawing tools of bone and antler were sometimes used in Sweden during the Viking Age and Middle Ages (Wärmländer and Söderberg, 2019; Wärmländer and Wåhlander, 2021). This shows that the craftspeople did not always put in an extra effort to make a drawing tool look “nice”. Arranging draw-plate holes in symmetrical lines is esthetically pleasing, but does not improve function. The studied draw-plate was likely discarded when it was old and worn, and it is possible that holes were continuously added during the plate’s lifetime, which could explain the holes’ irregular pattern. In fact, except for the irregular holes, the Old Uppsala plate looks rather similar to some modern steel plates for wire-drawing.

When the wire-drawing technique was developed, the first draw-plates were likely made from bone or antler. Thus, even if the studied object is an early version of an iron draw-plate, it is most certainly based on previous experience of wire-drawing with bone and antler plates. A draw-plate should ideally be made of a material that is harder than the wire to be drawn, although Thomsen and Thomsen (1976) have shown that drawing dies made of copper, silver, or gold, respectively, can be used to draw wire of the same material as the die itself. By that reasoning, the roll-drawn chain mail rings of iron found in Zemplín,
dated to between the 1st c. B.C. and the 2nd c. C.E. (Özsen and Willer, 2016), must have been produced with a draw-plate made of iron (or steel).

Together with the other tools and raw materials for jewellery-making in the Old Uppsala workshops (Ljungkvist et al., 2017b), the finding of this draw-plate suggests that some of the high-quality jewellery in Vendel and Viking Period Sweden could have been locally produced, although import of prestige jewellery clearly occurred (Wärmländer et al., 2015). One striking example of possible local production is the gold and garnet pendant previously found at the Old Uppsala site (Ljungkvist et al., 2017a). As stated above, draw-plates have been found also at many of the Scandinavian trading centres from the Viking Age (Armbruster, 2012; Arrhenius, 1968; Davidan, 1982; Duczko, 1985; Wärmländer and Wåhlander, 2021). Thus, it appears that the drawing technique was used early in Scandinavia to produce solid wires of precious metals.

Finally, the location of the fine metals workshop immediately next to Old Uppsala’s great hall is in stark contrast to where smithies and workshops for base metals usually were located, i.e. in the outskirts of the village or settlement. A workshop for fine metals is less noisy than a smithy, but equally dangerous in terms of fire hazard. However, given the high value of the gold, silver, and gemstones in the workshop, it makes perfect sense to place it close to the great hall and its warriors.

7. Conclusions

Our investigations of the studied iron object show that it was a draw-plate used to produce silver wire. With a dating around the 6th – 8th c., it is one of the oldest draw-plates so far encountered. The presence of this tool in a fine metals workshop located immediately next to Old Uppsala’s royal hall increases our understanding of Vendel Period jewellery production, and of the social organization of this craft.

Abbreviations

SEM-EDS
Scanning electron microscopy with energy-dispersive spectroscopy

Declarations

Acknowledgments: We thank Kjell Jansson at Stockholm University for help with the SEM analysis.

Funding: None.

Competing Interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability: All data and results upon which this study is based are presented in the article.
References


Figures
Figure 1

Photograph (bottom) and radiograph (top) of the studied iron draw-plate, which has the dimensions 68 x 17 x 3 mm. Images by MJ.
Figure 2

Close-up image of the radiograph in Fig. 1, showing that some of the draw-plate holes contain particles of a high-density material. Image by MJ.
Figure 3

Left: SEM image of a corroded hole in the iron draw-plate. The orange rectangle shows the location of a dense-material particle. Centre: Close-up image of the particle. Right: SEM-EDS spectrum showing that the particle consists of pure silver. Images by SW.