A preliminary report on the study of materials and techniques applied within the Åker assemblage of the Merovingian period

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ABSTRACT: Between 1869 and 2017, the Åker assemblage was uncovered as a stray and excavated find on the Åker farm located in southeastern Norway. The finds are currently located in the University Museum of Cultural History in Oslo and include belt buckles, strap mounts and fragments of weaponry (including shield mounts and a pommel). The assemblage has been dated to the second half of the 6th century or ca 600 AD. Ingunn M. Røstad has published a comprehensive presentation comprising both recent and early research on the Åker assemblage, highlighting the full spectrum of items, their decorative elements, and intended use. The current article presents a technical analysis of a selection of fourteen objects, which includes weaponry, belt buckles, and strap mounts. The aim of this paper is to explore the distinctiveness of the assemblage through analyses of the materials and techniques employed.

KEYWORDS: buckles, strap mounts, weaponry, gilded and tinned bronzes, gilded and nielloed silver casting, silver plated carvings, garnet cloisonné, Tauschierung, Merovingian period, late 6th to early 7th century, X-ray, pXRF, SEM-EDS, CT scans

Introduction

The fourteen items selected for analyses from the Åker find included in this paper are listed in Table 1. Each item is displayed and identified by its inventory number. The earliest finds were made in the period 1868 to 1912, including items with numbers C4901–21406. Metal detecting in 1992 and 1993 uncovered new finds with numbers C38000/2–9, 12. Notably, these finds included a fragment of a bird-shaped mount C38000/2A, which turned out to be the second half of the bird-shaped mount C14786 delivered to the museum in 1889. These fragments are displayed together in Table 1. Røstad discusses the various items in detail: their functional and typological properties and, by appearance, their material composition. She also argues that the Åker assemblage represents a grave and that the objects come from a single burial: an inhumation grave of the second half of the 6th century or around AD 600 (Røstad 2020, 15).

Among these artifacts, the sword-belt buckle C4901is the most elaborate and striking object (Fig. 1). It includes a loop, a shield-on-tongue, a triangular front plate, a hinge, and a back plate. Investigations have revealed that these components were made with dissimilar materials and techniques. Accurate analyses of the copper alloys were not obtained, but this study finds that the copper alloy used evidently was a bronze, and in the following, will be referred to as a bronze. It has also become evident that the major material within the find is a bronze, while precious materials are favoured for decorative purposes. In Table 1, the supporting and decorative materials of the 14 items investigated are listed separately. Notably, the following investigation on materials and techniques is not based on a systematic approach but is the result of observations and analyses accumulated over time and aims to initiate future in-depth analyses.

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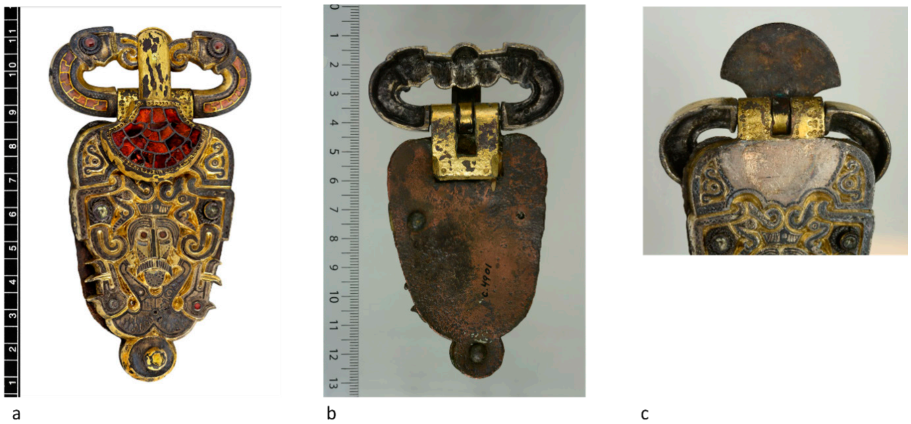

Figure 1: The large Åker buckle C4901, a. the front view; b. the reverse view; c. front view of the triangular plate with the reverse of the loop and tongue shield. Photograph 1a by Lall-Ann Chepstow-Lusty, photographs 1b and 1c by Elin Storbekk, © Museum of Cultural History, Oslo.

Based on tradition and technical evidence, the Åker find was divided into two main groups according to Slomann and Christensen (1984): a) belt buckles and strap mounts and b) weaponry, including shield mounts and a pommel. Subsequently, according to measurements of the size and shape, group A has been subdivided into three groups: Strap 1 includes items C4901, C4902, C14785, C21406; Strap 2: items C5651, C5652, C5897, C16605, and Strap 3: item C10379. Group B with weaponry include items C4903, C8347a, C14786, C16604. New items, C38000/1, 2A, 2B, 3 found after 1984, have been assigned to the weaponry of group B, while the sword-belt mounts C38000/5–9 have been assigned to Strap 1 of group A. Røstad assigned the openwork mount C38000/4 as derived from a sword belt or baldric, as well as possibly a bridle mount (Røstad 2020, 7).

Based on the size and shape of punch marks, Christensen recognised a common use of punch irons for punch work on items belonging to Straps 2 and 3, indicating that these were produced contemporarily and in the same workshop. Other tools were used for punch work on the two square strap-sliders C4902 and C14785. A common use of punch irons was not found elsewhere. Of special interest is the so-called Y-shaped punch design considered by Cleve and supported by Christensen to be essentially of a Scandinavian style, applied to the hinge combining the triangular piece to the loop of the great buckle C4901 (Cleve 1942; Slomann and Christensen 1984, 280).

The techniques used for surface decoration involve amalgam gilding, application of gold and silver as strips and foil as well as tinning, silver plating, and silver beading, *Tauschierung* (inlay work) with gold and silver, niello, garnet lapidary work (*cloisonné* and cabochon), punching, carving, soldering and riveting. Filigree and granulation have not been recorded. The materials identified within the finds are gold, silver, copper, tin, niello, garnets and an iron-looking plate for the *Tauschierung* (C38000/9). These materials are discussed in the following in this order: the description of each material includes a brief presentation of its general properties and application, followed by the analyses and use recorded within the Aker finds. Finally, considerations related to the combined used of materials and techniques in the various objects are discussed with special attention to the use of silver plating.

Analytical methods

The investigation of materials and techniques are based on visual assessment, analyses using two SEM-EDS analysers, in the following referred to as SEM-EDS I and SEM-EDS II, a portable XRF analyser (pXRF), X-radiographic imaging and CT scanning. SEM-EDS I is a Jeol 840 electron scanning microscope equipped with a micro energy dispersive analyser EDS (Link AN10000). Analyses on this instrument were carried out by Unn Plahter in the early 1990s. SEM-EDS II is a FEI Quanta 450 coupled with an Oxford X-MaxN 50 mm^2 SSD detector. The EDS was operated using the Aztec 3.1 SP1 software by Oxford Instruments (Oxford, UK). Analyses on this instrument were carried out by Elin Storbekk, Unn Plahter and Calin Steindal in 2017. The Portable XRF analyser (pXRF) conducted by Elin Storbekk was a Bruker HandheldTracer 5i, Rh X-ray tube. The X-ray images were taken by Elin Storbekk. The CT scanner was a Nikon XT H225 ST micro computed tomography (micro-CT). CT scans were taken by Ruben With and Justin Kimball.

The SEM-EDS I was used in the early 1990s and provided semi-quantitative measurements, in Tables 2, 3, and 4 rated as high (xxx), medium (xx) and low (x), while the quantitative measurements with the SEM-EDS II in 2017 were obtained in wt.%. Abbreviated references to the analytical methods used for the identification of materials of each item are included in Table 1.

Table 1: Chemical composition of and analytical methods used for the investigation of the fourteen items included in this study. See figure 2 for photographs of the items.

Catalogue Nr.	Item	Support material	Decorative techniques	Analytical methods
C38000/4	Open-work mount	Copper alloy, Red alloy	Gilded, elaborate punchwork, garnet cabochons	Visual assessment
Strap 1				
C4901	Loop	Silver, open ornamental, casting	Partially gilded, nielloed, garnet cabochons, garnet *cloisonné*, gold cell walls, beaded wire	pXRF, SEM-EDS I
	Tongue and shield	Copper alloy	gilded, garnet *cloisonné*, silver cell walls	pXRF
	Front plate	Copper alloy	Nielloed, partially gilded, carved silver plating, garnet roundels, garnet cabochons, beaded wire	pXRF, SEM-EDS I, CT
	Back plate	Copper alloy	No decor	pXRF
	Hinge	Copper alloy	Gilded, punchwork	pXRF
C38000/5-8	Sword-belt mounts	Copper alloy	Partially gilded, nielloed, carved silver plating	Visual assessment, SEM-EDS II, CT
C38000/9	Sword-belt mount	Copper alloy	Silver and gold *Tauschierung* into iron	Visual assessment
14785 + C4902	Strap distributers	Copper alloy	Gilded, nielloed silver plating, garnet roundels, garnet *cloisonné*, silver walls and backing	Visual assessment
C21406	Strap slide	Copper alloy Red alloy	Gilded, garnet cabochons, garnet *cloisonné*, silver walls and backing	Visual assessment, pXRF
Strap 2				
C5651	Buckle	Copper alloy, Red alloy	Gilded, elaborate punchwork, (garnet cabochon?), beaded wire	Visual assessment
C5897	Mount	Copper alloy, Red alloy	Gilded, elaborate punchwork (garnet cabochon?)	Visual assessment
C5652	S-shaped belt-slide	Copper alloy,	Gilded, elaborate punchwork, garnet cabochons	Visual assessment
Strap 3				
C16605	Strap distributor	Copper alloy, Red alloy	Gilded, elaborate punchwork (garnet cabochons?)	Visual assessment
Weaponry				
C4903	Bird-shaped mount	Copper alloy	Gilded, tinned, garnet cabochon	Visual assessment
C38000/2A C14786	Bird-shaped mount	Copper alloy	Gilded, tinned, garnet cabochon	SEM-EDS I
C38000/2B	Bird-shaped mount	Copper alloy	Gilded, tinned	SEM-EDS I
C38000/3	Bird-shaped hilt-fitting	Copper alloy	Gilded, tinned	SEM/EDS I
C38000/1	Shield mount	Copper alloy	Gilded, tinned, garnet cabochon	SEM/EDS I
C8347	The umbo mount	Copper alloy	Gilded, tinned	Visual assessment
C16604	Pommel	Copper alloy	*Tauschierung* silver into copper alloy (silver overlay?)	Visual assessment

In connection with an earlier study of the five items C5651, 16605, 21406, 14785, and 4902, a red copper alloy was revealed in scrapings on the revers. These areas were not analysed. Except for the analyses of the scraped silver surface of the silver loop of the buckle (C4901, Fig. 5), all analyses carried out in this work were non-destructive and obtained from uncleaned surfaces.

The SEM-EDS I analyser was used in 1992/1993. Measurements were obtained from gilding on items C38000/1, 2a, 3, 4, 6 and C4901, from silver plates on items C38000/6 and C4901, and from the silver casting of the loop C4901 as well as of tinning on copper-based castings (Fig. 6) A final report was never made, but the analyses became relevant in 2016 and 2017, when new information on the site entered the museum and added to Røstad's research which was in progress. In this connection, the more accurate quantitative measurements in wt% with the SEM-EDS II analyser were obtained. Tables 2–5 display the SEM-EDS I and II analyses. X-ray photographic imaging was obtained from the sword-belt mounts C38000/5–9; an X-ray image of a section of the belt mount C38000/8 is given in figure 12c.

Figure 2: Photographs of the investigated items listed in table 1, not to scale. Photograph: Lall-Ann Chepstow-Lusty, © Museum of Cultural History, Oslo.

In November 2022, investigations of the buckle C4901 and the strap-slider C21406, included pXRF analyses and surface examination aided with magnifying equipment. Thereafter, in March 2023, CT scanning was applied to obtain cross-sectional views of sword-belt mount C38000/8 (Figs. 10, 12), and the belt buckle C4901 (Fig. 11) at the tip where the triangular front plate is riveted to the back plate.

Materials and manufacture

Gold

Gold: properties and use

Gold was expensive, and rather than for castings, gold-saving techniques were frequently applied. Such techniques may include amalgam gilding, hammered plates, foils, and leaf in gold, or in diffusion-gilded silver. Wire or strips of gold are used for *cloisonné*, *Tauschierung* and filigree work. Gilding techniques on a selection of metalwork found in Norway dated to the

Figure 3: Sword-belt mounts, a. C38000/5, b. C38000/6, c. C38000/7, d. C38000/8 e.. C38000/9. Items a, b, c, d, have partially gilded, nielloed ornamental carved silver plating. Item e has gold and silver Tauschierung into iron (Photograph: Elin Storbekk).

Figure 4: Left: Gilded bronze buckle and mounts with punchwork décor: a. Strap-distributor C16605; b. buckle C5651; c. Strap-distributor C10379; d. S-shaped belt-slide C5652; e. Mount C5897, (scale in cm). Right: weaponry, bird-shaped items, gilded and tinned bronze: top C4903; centre C38000/2A C14786; bottom C38000/2B. Photograph by Lill-Ann Chepstow-Lusty, Museum of Cultural History, Oslo (after Røstad 2020).

first millennium have been investigated and reveal the same use of gilding techniques over time as elsewhere in Europe (Anheuser 1997). Hence, plate gilding with hammered gold or diffusion-gilded silver was found on items dated before the third century, amalgam gilding predominated thereafter (Aufderhaar 2009; Plahter *et al.* 1995; Plahter and Simensen 2002; Voß *et al.* 1998, 147–193).

Amalgam gilding involves spreading a grey amalgam paste of gold alloyed with mercury to surfaces of silver or bronze either for complete coverage or, if desired, only partially. To acquire a golden appearance, mercury was removed by heating the object (fire gilding; Voß *et al.* 1998, 192–194). As overheating may cause damage to the gilding a temperature range of 250–300 °C far below the melting point of mercury (357.9 °C) was used for the removal of mercury (Anheuser 1997). This temperature, however, is close to the melting point of tin (231.9 °C). Hence, Andrew Oddy argued that amalgam gilding adjacent to tinning on a copper-alloyed item would create problems (Oddy 1980). He, however, points out that a silvery tin-rich bronze (speculum bronze) with a high melting point is established by interdiffusion *in situ* by wiping a tin coating onto a selected area of a heated and flux-treated bronze. Subsequently, excess tin was removed, and the amalgam gilding process could proceed (Oddy and Bimson 1985).

Åker: Gold – analyses and use

Amalgam gilding and hammered gold foils and strips were recorded on the Åker finds. Amalgam gliding, however, predominates and is applied to the copper-based supports. Hammered foil, with a waffled relief, can be observed where the domed cabochon head of a rivet on the buckle C4901 is missing (Figs. 1a, 7d, 11a). On the loop of this buckle, cell work of the garnet *cloisonné* is in gold but as the garnet plates cover the foil backing, we can only assume that gold foil was used. Hammered gold strips were used as cell walls in the *cloisonné* on the loop and for the golden *Tauschierung* on the iron-plated copper-supported belt mount C38000/9 (Fig. 3e).

The Åker assemblage includes gilded and tinned copper-alloyed objects as well as partially gilded and nielloed silver. As mentioned above, amalgam gilding

Table 2: SEM-EDX analyses of gilding: quantitative in wt% and semi-quantitative marked xxx (high), xx (medium), x (low). Qunatitative analysis on a FEI Quanta 450 Scanning Electron Microscope (FEI-Thermo Fisher Scientific, OR, USA) coupled with an Oxford X-MaxN 50 mm² SSD detector (SEM-EDS II). Semi-qualitative analyses on SEM Jeol 840 equipped with a EDS Link AN10000 (SEM-EDS I).

Catalogue Nr.	Instrument	Au	Ag	Hg	Cu	Substrate	Gilded area analysed
C38000/5, analysis 1, normalised	SEM-EDS II	62.1	26.1	11.8	-	Copper-alloy	Sword-belt mount: on the side face over copper-based support. Figure 13, Table 5
C38000/5, analysis 2, normalised	SEM-EDS II	55.3	30.3	11.3	3.1	Copper-alloy	Sword-belt mount: on the side face over copper-based support. Figure 13, Table 5
C38000/6	SEM-EDS I	xxx	xx	x	?	Silver plating	Sword-belt mount: on the front face over silver plating.
C4901	SEM-EDS I	xxx	xx	x		Silver plating	The triangular silver plate of the Buckle: on the nose ridge of the face. Figure 14

Table 3: SEM-EDS analyses of gilding on copper-alloyed substrate of weaponry. See table 2 for details on the instruments.

Catalogue Nr.	Instrument	Au	Ag	Hg	Cu	Sn	Fe	Gilded area analysed on:
C 38000/2A	SEM-EDS I	xxx	?	x	x	?		Bird-shaped mount
C38000/2B	SEM-EDS I	xxx	-	x	x	?		Bird-shaped mount
C38000/1	SEM-EDS I	xxx	x	x	xx	x	x	Shield mount
C38000/4	SEM-EDS I	xxx	?	x	xx	?		Open work mount
C38000/3	SEM-EDS I	xxx	?	x	-	-		Bird-shaped hilt fitting

would normally have been carried out as a last step, *i.e.*, when soldering, tinning and niello inlay were completed. Accordingly, amalgam gilding on the Åker items was found overlapping niello. Punching on ornamental castings was evidently done after the amalgam gilding, as is evident from the crisp-looking surface texture of punch marks that were applied to the gilded bronze.

The bronze on the sides of the sword belt mounts (C38000/5–9) and the domed rivet heads are gilded. This could indicate that the sides of the mounts were amalgam gilded after the ornamented plates in silver were attached to the copper-based support and after the domed heads were applied to the rivet. Markedly the gold layer in the BSE-imaged site 1 in figure 13b of the sword mount C38000/5 appears remarkably thick.

Analyses of gilding on the side face of sword-belt mount C38000/5 were conducted with the SEM-EDS II. The analytical results illustrated in figure 13 and listed in Table 5 reveal that the gold contains a high level of silver, and the mercury content confirms the use of amalgam gilding. Given that the gold layer rests on the copper-based support, the presence of silver was intentional in the amalgam's formulation. Conversely, using the SEM-EDS I analyser the rather high silver level in the thin gilding over silver plating on the human face on the buckle C4901, can be attributed to the diffusion of silver from the underlying silver plating.

The SEM-EDS I analyser revealed that the gilding on copper-based castings of the weaponry (C38000/1, 2B, 3) contained a minimal level of silver in the amalgam gilding. Portable XRF analyses confirmed the use of amalgam gilding in all gilded parts of the buckle (C4901). Analyses of the exposed waffled golden foil at the tip of the buckle's triangular plate revealed a content of gold with a small amount of copper (Figs. 7d, 11a).

2.2 Silver

Silver: properties and use

Silver was less expensive than gold and was used casted, hammered into foil and plates, and made into wire. Like gold, silver was frequently used in saving techniques, where silver foil or sheets were applied to a base metal. Susan La Niece discusses several methods for silvering, such as the use of silver foil or sheets attached mechanically (riveting and keying), with adhesives, by soldering, or by diffusion bonding, as well as depletion and mercury silvering (La Niece 1990).

She finds a lack of evidence for amalgam silvering in the Roman world and argues that this might be related to the fact that silver does not form an amalgam as easily as gold. She also argues that due to corrosion silver foils or sheets are less commonly preserved than gold foil or sheets and therefore might seem less frequently used. She also points to tinning on copper-based alloys as a substitute for silvering and to the confusion owing to the misinterpretation of 'white' metal as 'silvered' rather than tinned (La Niece 1993, 201, 209; Meeks 1986, 133).

Åker: Silver – analyses and use

Silver casting, silver plating, strips of silver and beaded silver wire are identified.

Table 4: SEM-EDX analyses of silver. Quantiative analyses in wt%. Semi-quantitative analyses: xxx (high), xx (medium), x (low). SEM-EDS analyses in wt% were performed on a FEI Quanta 450 Scanning Electron Microscope (FEI-Thermo Fisher Scientific, OR, USA) coupled with an Oxford X-MaxN 50 mm² SSD detector. SEM-EDS analyses in concentrations high, medium and low are obtained with SEM Jeol 840 equipped with EDX Link AN10000.

Catalogue Nr.	Ag	Au	Cu	Cr	Object analysed	Manufacture
C38000/5, normalised wt%	85.5	8.8	5.7		Silver plate on sword mount, figure 13, Table 5	Silver plate
C38000/6	xxx	xx	?		Silver plate on sword mount	Silver plate
C4901	xxx	x	x		Silver mount for garnet cabochon on the loop to the left in figure 1a	Silver hammered foil
C4901	xxx	x	x		Silver plate triangular front plate, bearded cheek, figure 14	Silver plate
C4901	xxx		x		Silver cast loop reverse	Silver cast dendrites
C4901	xxx	x	x	xx	Silver cast loop reverse, figure 5a	figure 5c

Only the loop of buckle C4901 is cast in solid silver. Ornamental-carved silver plates on copper-based support are partially gilded and nielloed. This technique is applied to the triangular front face of the large buckle, the sword-belt mounts C38000/5–8 (Fig. 3) and the strap distributors C4902 and C14785. CT scans show that the silver plates are closely bonded to a box-shaped copper-based substrate (see below). Both mechanical measurement and the BSE images (Fig. 13a) indicate that the thickness of the silver plates might be close to 1.5 mm and CT scans (Figs. 10–12) strongly indicate that patterning of these plates was accomplished through a carving process when soldered onto the bronze support as opposed to being cast or embossed before the bonding occurred (see below).

Except for the *cloisonné* of the silver cast loop, silver appears to have been used for waffled backings and cell walls in the remaining *cloisonné*. Evidently, strips in silver were applied as inlay for the *Tauschierung* on the iron sword-belt mount C38000/9 and as onlay for the cast copper-alloyed pommel C16604. Beaded silver wires encircle cabochons on the belt buckle C4901 and the outer edge of loop of buckle C5651 (Fig. 4). A single beaded wire encircles the cabochons on the loop of buckle C4901, while a twisted, possibly three-ply beaded wire encircles the cabochons on the triangular plate. The beads on loop C4901 are slightly less than 1 mm in diameter. On both items, beads are uniform in size with an equatorial 'seam' suggesting that they were shaped by deformation of a round sectioned wire with a double-edged tool or swage (Ogden 1982, fig. 4.38).

SEM-EDS II analyses of silver plate of mount C39000/5 are given in figure 13, Table 5 and SEM-EDX I analyses of mount C38000/6 and the triangular plate of the buckle C4901 are listed in Table 4. SEM-EDS II analysis in wt.% of silver plate obtained on the side face of the sword-belt mount C38000/5 revealed a rather high level of gold (see Fig. 13b, Table 5). Portable XRF analyses of cell work on the shield-on-tongue (C4901) confirmed the presence of silver and the uncovered waffled backing

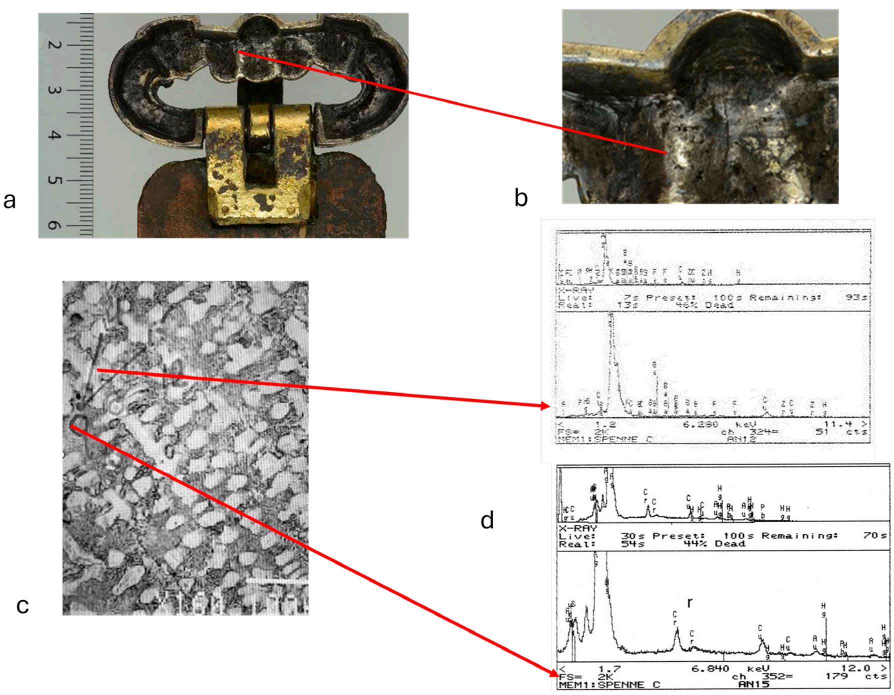

Figure 5: The reverse face of the loop of C4901, a. the reverse face, b. a close-up of an area with silver uncovered in a scraping, c. BSI image revealing dendrites exposed in the scraping, d. SEM-EDS I: upper spectrum obtained from the dendrite shows silver with some copper, lower spectrum obtained between the dendrites shows silver with some chromium as well as copper, © Museum of Cultural History, Oslo.

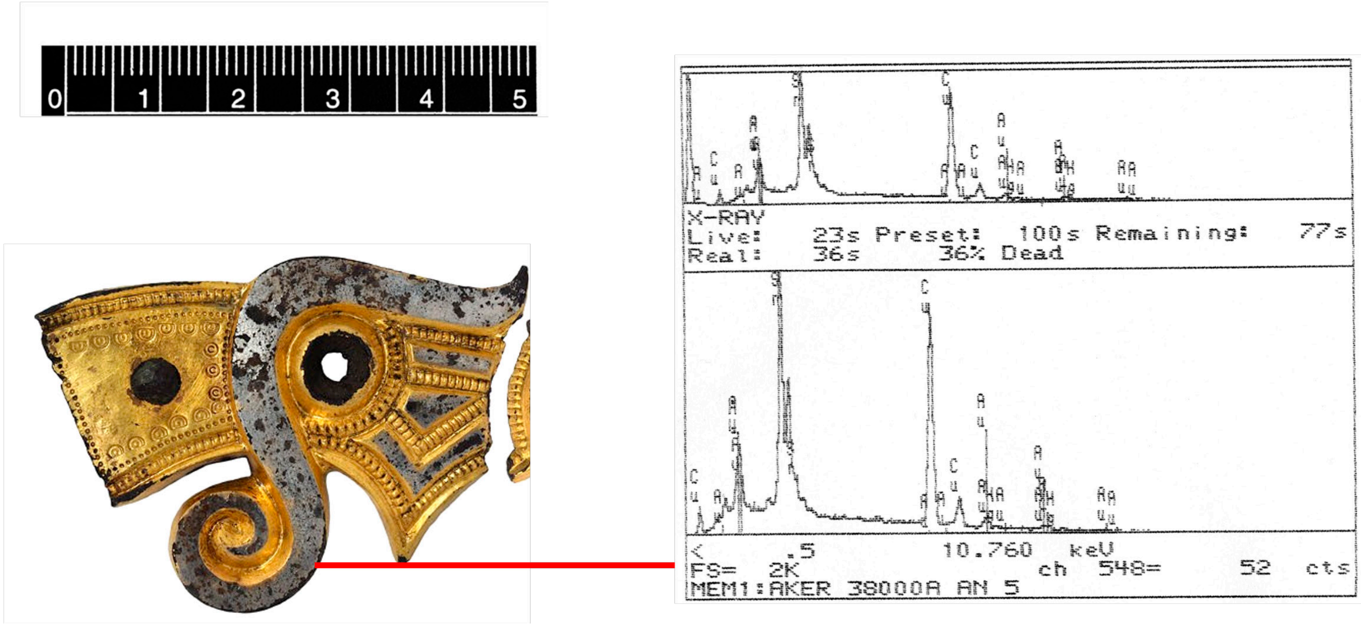

Figure 6: Bird-shaped mount C38000/2A: SEM-EDX I shows a high tinned-bronze (speculum bronze), © Museum of Cultural History, Oslo.

foil on the strap slide C21406 were identified as silver. Analyses obtained on the front face of the silver cast loop revealed silver with a copper content.

SEM-EDX I analyses of the silver cast loop were obtained from a scraping on its reverse (Fig. 5b). The loop was formed as a thin open-backed casting, which represents an economic use of metal (Coatsworth and Pinder 2002, 81–82). The BSE image figure 5c reveals a casting with a dendritic microstructure. Figure 5d (upper spectrum) shows that the dendrites are composed of silver and copper while the matrix contains silver with copper and chromium (lower spectrum). In absence of accurate analyses, no attempt has been made to find if the content of chromium could be linked to a specific silver deposit.

2.3 Copper

Copper: properties and use

Copper was relatively abundantly available. Alloyed with tin, it forms bronzes. The properties of bronze change with increasing levels of tin and may be separated into three groups: low tin bronze (2–5 %), medium tin bronze (8–15 %), and high tin bronze (15–30 %) (Delrue 2008, 159–162). Low-tin bronzes have colour and properties that are approximately equal to pure copper. The alloy is malleable and suitable for hammering into plates but with less rigidity and strength than bronzes with a higher level of tin. Like pure copper, however, the alloy forms a rather viscous melt with a high melting point and a narrow melting range, making it less suitable for casting (Delrue 2008, 159–162).

The medium-tin bronze (8–15 %) has increased strength and hardness, which makes this bronze well-suited for functional objects. Higher amounts of tin further cause the melt to be more fluid and the melting range wider and lower, making it more suitable for casting. The term high-tin bronze applies to bronzes with 15–30 % tin. Increasing the content of tin leads to brittleness and hardness of the bronze, and close to 20 % of tin, the colour becomes silvery and can be polished to a high gloss. This alloy, also called speculum bronze, has good corrosion resistance and can replace silvering in both durability and appearance (Delrue 2008, 161).

As mentioned above, bronze can be tinned in situ by applying a coating of melted tin to a warm and flux-treated copper-alloy surface. In this process, a silvery high-tin bronze is established by interdiffusion (Meeks 1986, 144). The use of tinned copper alloys occurs since the Early Bronze Age and became a widely used technique in Roman times (Giumlia-Mair 2005; Meeks 1986, 134–136). On the basis of analyses carried out in recent decades, it has become clear that what has previously been described as silvering has often turned out to be tinning (Meeks 1986, 133).

Åker: copper – analyses and use

Bronze is used as bulk material for ornamental casting, casted support for silver plating and garnet *cloisonné*, for hammering, and as a high tin bronze for replacing silvering. In addition, nails for riveting are recorded. In all cases but the pommel (C16608), the bronze is completely hidden by decorative elements such as gilding, silver plating, tinning and *cloisonné*.

Accurate analyses of the copper alloy were not obtained, but in connection with an earlier study of the five items C5651, 16605, 21406, 14785, and 4902, a red copper alloy was revealed in scrapings on their reverse. Evidently, bronze rather than brass was used for the casting. Portable XRF confirmed that copper alloy was used for the hinge and the shield-on-tongue on buckle C4901 and while measurements of tin were indistinct, the use of bronze is suggested. SEM-EDX I analysis has been obtained from the speculum bronze on the bird-shaped mount C38000/2A and reveals a bronze with a high level of tin (Fig. 6).

Niello

Niello: properties and use

Niello had a rich application as a black inlay for metal decorations in the first millennium. The black material consists of metal sulphides. Silver and copper sulphides have been used separately and mixed, and lead sulphide has been added to the silver and copper sulphide mixtures (La Niece 1983, 286–288).

La Niece's research finds that by Roman times, niello consisted mostly of one metal sulphide: silver sulphide for inlay in silver and copper sulphide for inlay in bronze (La Niece 1983, 285). A silver/copper sulphide mixture, on the other hand, could be used for nielloing both silver and copper. There are varying views on when mixed sulphide came into use, but probably towards the end of the 5th century (La Niece 1983, 288; Mozgai *et al.* 2021, 61–62). However, although the mixed silver/copper sulphides became gradually dominant in England in the early Anglo-Saxon periods, the use of silver sulphide continued (Stemann Petersen 1998, 138). In addition to the use of silver sulphide, Stemann Petersen mentions several findings of the 5th century with mixed sulphides of silver and copper. Hence, the niello on most of the silver objects found within the Staffordshire Hoard is composed of silver sulphide, even though the mixed sulphide at the time was in general use and dominant in Anglo-Saxon silver works (Blakelock and Fern 2019, 7, note 1, fig. 3.4). Due to technical reasons described in the following, these sulphides were applied in a solid state.

Pure silver sulphide has its limits: with a melting point of 861 °C, it decomposes before it melts and must therefore be applied in its solid state. Another restrain is that silver sulphide applied to copper turns to silver and the niello turns grey. Hence silver sulphide is not suitable for nielloing copper. But, as it becomes malleable at around 600 °C, it can be compressed and suitable for laying into recesses in silver-based supports. The use of copper sulphide as niello is problematic. It has a high melting temperature of 1121 °C, which is higher than the metals on which it would be laid (La Niece 1998, 50). In addition, unlike silver sulphide, solid-state copper sulphide is hard and problematic to handle, a difficulty that apparently led to it falling out of use (Stemann Petersen 1998, 138).

The mixed sulphide of silver and copper, on the other hand, is malleable at room temperature, has a low melting point (680°C), and it can preferably be handled in its solid state. Its parallel use to silver sulphide increases from the middle of the 5th century (Mozgai *et al.* 2019, 1607; Stemann Pedersen 1998, 147). Only towards the 11th century, when lead sulphide was added to the silver/copper sulphide, a niello with a low melting point (500°C) was applied as a melt and over time replaced the earlier techniques (La Niece 1983, 288).

Åker: niello – analyses and use

Niello is only applied to silver: the silver casting of the loop and the sheet silver on the triangular of the buckle C4901, the sword belt mounts C38000/5–8 and the two strap distributors C4902 and C14785 (Stemann-Petersen 1998, 143; see discussion there on a case where an insert of silver in bronze forms the substrate for niello). It fills narrow channels, dots, and triangular grooves of the zig-zag border. CT scans reveal that the grooves for niello have a V-shape, indicating that they were carved (see below).

SEM-EDX I analyses of niello on the belt buckle C 4901 and the sword belt mount C38000/6 show that the niello consists essentially of silver sulphide. A low level of copper could be considered an incidental element. The mixed silver and copper sulphide suitable for nielloing copper and silver was not found. The SEM-EDX I analyses of the niello, in the beard stubs of the human head, on the buckle, show small inclusions in the niello containing gold and mercury. These inclusions are visible in the BSE image as luminous grains and may be due to contaminants from the gilding.

La Niece has suggested that such contaminants could also be due to the use of scrap metal for the manufacture of the niello, such as using offcuts of silver with amalgam gilding (La Niece 1998, 50). She argues that the niello could have been made in the same workshop as the objects and not purchased as a finished product. This is substantiated by the fact that niello can decompose during storage, especially in a humid environment. To ensure quality, it may have seemed beneficial that the making of niello was done in connection with the making of the jewellery, rather than acquired readymade. La Niece also points to the poor affinity between the sulphides and the metals to which they were applied. To ensure the grip between the niello and the metal, the niello was laid into deep grooves with roughened-up surfaces. Thus, with a close view of the niello and surfaces in the grooves, and by judging their state of preservation, differences in ability and craftsmanship might be studied. The V-shape of the grooves is demonstrated in CT images (Figs. 10–12). Further examination of surface texture of channels to be nielloed remains to be investigated.

According to Storbekk, it must also be considered that rather than poor skill, losses of niello are also due to post-depositional conditions such as those introduced by modern agricultural chemical action. Possibly, this could to some extent explain why the strap distributer C14785, excavated in 1889, is in worse condition than the distributor C4902 excavated in 1868.

Notably, all silver surfaces examined within the Åker find feature zig-zag borders with niello infill identified as silver sulphide. Such zig-zag borders with niello inlay are frequent throughout the 6th century but comparatively rare in the 7th century and absent from the Sutton Hoo regalia (Blakelock and Fern 2019, 487, note 319; Bruce-Mitford 1978, 119–121). However, Bruce-Mitford observes zig-zag borders made with triangular punches without niello infill on the magnificent Swedish shield (Buce-Mitford 1978, figs. 89a, c, f and i). Likewise, the umbo mount C8347 displays a plain zig-zag border made with triangular punches on a tinned surface, and therefore without niello infill.

Garnets

2.5.1 Garnets: properties and use

Garnets consist of a group of silicate minerals in which red varieties may include pyrope, a magnesium-aluminium garnet, and almandine, an iron-aluminium garnet. These, however, rarely occur alone but in mixtures (solid solutions). Research reveals that Merovingian jewellers made use of the six different types of garnet (Calligaro and Perin 2019, 112; Pion *et al.* 2020, 37). Types I, II, and III a,b classified as almandine-rich stones derive from sources in India and Ceylon, while Types IV and V classified as pyrope-rich stones are assigned to sources in Bohemia and other unknown sources in Europe (Adams 2016, 12; Gilg and Hyršl 2014).

Adams finds that stones with the largest dimension of 15–20 mm most likely derive from the almandine-rich sources in the East rather than the pyrope-rich stones of Europe (Adams 2011, 17). Stones of the pyrope type would be less than 10 mm, possibly 7 mm, and she refers to more recent works where small-sized (6x6 mm^2) Bohemian pyrope stones are used (Hyršl 2001). Small flat stones from the Staffordshire hoard measure 10 mm or less and dominate in the *cloisonné* (Hyršl 2001; see also Pion *et al.* 2020, 27). According to Pion *et al.*, the *cloisonné* style developed in the 5th and 6th centuries (Pion *et al.* 2020, 23). Garnets in *cloisonné* and cabochons were equipped with backings in gold, silver, or gilded silver foil. Initially, plain foil functioned as backings but in the late 5th century, the waffled pattern became dominant (Adams 2008, 420). The patterned profile causes light scattering that gives the garnets a reinforced glow (patterns in this context are referred to as paillons) (Pion *et al.* 2020, 23). Foils with square hatched grids, deep and shallow, have been observed in The Sutton Hoo hoard and described as punched or made with a die (Meeks and Holmes 1985).

Alexsandra Hilgner and others describes three different techniques of garnet *cloisonné*, where a standard garnet *cloisonné*, the most common, is made with garnet plates shaped to fit into cells, walled with thin metal strips soldered to the base (Hilgner 2018, 303, 305; Horváth 2012, 215). Flat garnet plates were used as inlays in various *cloisonné* cell patterns, often geometrically designed with the aim of symmetry (Horváth 2012, 210). According to Adams, quatrefoil patterns deriving from stones in fingerrings evolved in the second half of the 5th century, while the so-called mushroom shape appeared in *cloisonné* cell work in the second half of the 6th century and was favoured amongst *cloisonné* findings in Anglo-Saxon England. The mushroom shape has a semi-circular top with a right-angled cut forming a 'stem' below (Adams 2016, 97–98).

Åker: Garnets – analyses and use

Cabochons are applied to most objects. Round flat garnet plates seem to be used only for the eyes of the human face on the buckle C4901 and the bird's eye of the two strap distributors C14785 and C4902. A strip of garnet *cloisonné* with stepped walls is applied to the silver cast loop. Ornamental designs in garnet *cloisonné* are applied to the copper-based supports of the shield-on-tongue of the buckle C4901, the strap slide C21406 and the two strap distributors C4902 and C14785. All garnets have waffled foil backings (Fig. 7).

PXRF analyses were obtained from the garnet *cloisonné* of the loop and shield-on-tongue of belt buckle C4901, and the strap slide C21406. The analyses show the

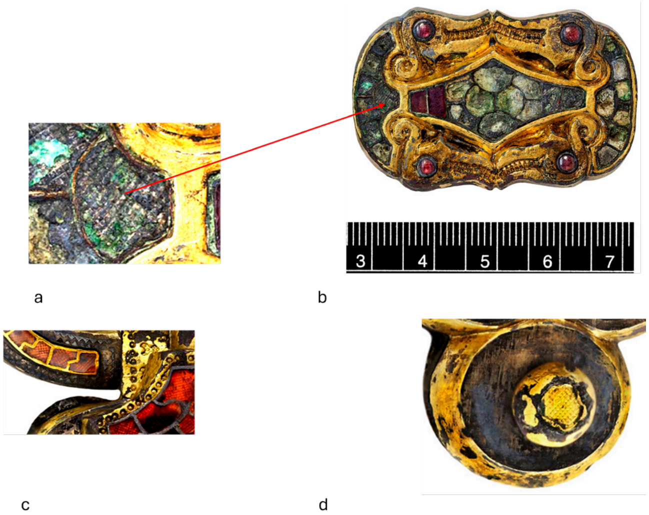

Figure 7: Waffled patterned backing foils of the garnets, a. strap slide C21406, close-up of waffled silver backing; b. strap slide C21406, notice the mushroom shapes in the centre; c. shield-on-tongue and loop of buckle C4901; d. detail at the tip of the buckle's triangular plate where the domed head of the rivet is lost and the gold, waffled foil is exposed, © Museum of Cultural History, Oslo.

content of aluminium and silicon and indicate a higher proportion of iron than magnesium. This may suggest an almandine-rich garnet ascribed to sources in India rather than a pyrope-rich garnet originating in Europe (see above). Further analyses are in demand. The garnet plates measure *c.* 7 mm or less, *i.e.* on the shield-on-tongue C4901 and strap slide C21406 garnets are close to 0.7 cm across while on the loop they are smaller, close to 0.5 cm. The flat round plates of the eyes of the human face are close to 0.4 cm in diameter and on the loop, plates are close to 0.4 cm.

How the garnets and the *cloisonné* are crafted and designed has not been explored in this work. However, analyses and visual assessment verifies that only the cell walls in the *cloisonné* of the silver cast loop are in gold, while on the copper-based castings and silver plating cell walls are in silver.Where garnets are lost on the strap distributers C4902 and C 14785 and the strap glider C21406 (Figs. 2, 7b), the waffled backing looks like silver. Portable XRF confirms that the waffled foil of strap glider C21406 is in silver.

The ornamental (geometric) design of the *cloisonné* on the shield-on-tongue is shaped in a rather disorderly manner, suggesting that cell walls may have been adjusted to already cut garnet plates rather than the opposite, perhaps due to insufficient lapidary skills (Horváth 2012, 210, note 4). Most of the garnet plates of the *cloisonné* of the strap slider are lost, but the remains of cell walls and silver foil backings reveal an occurrence of some plates shaped as mushroom. Hence, in the centre, four mushroom-shaped plates, applied in a quatrefoil pattern meet with alternating heads and stem (Fig. 7b). This is perhaps unusual as it seems that frequently all four stems or heads(?) meet in the quatrefoil patterns. In addition, a mushroom-shaped plate is used bordering each side of the central field (Fig. 7a). Based on the visual examination of the surface texture, goldsmith Hans Gerhard Loos found that the garnet plates for *cloisonné* on the loop were more carefully finished than those on the shield-on-tongue. He also found that the cell walls of the *cloisonné* on the shield appeared to be soldered to the base metal, thus classifying it as a "real" *cloisonné* (Hovarth 2012, 15).

Tauschierung and cloisonné, design patterns

Tauschierung

Tauschierung involves the inlay of softer metals into channels made in a harder metal of a contrasting colour. A false *Tauschierung* technique is gained when the softer metal is overlaid rather than inlayed, *i.e.*, not forced into channels. To strengthen the bond between the substrate and overlay, heat is applied. Gold and silver *Tauschierung* on iron was used on the iron plate of the sword mount C38000/9 (Figs. 3e, 8d). A silver *Tauschierung* is recorded on the bronzed pommel C16604. Notably, the design on the pommel has some in common with the design of the garnet *cloisonné* of the Skrävstad pommel (Fig. 8g; Adams 2016, 10–11). The silvery design in *Tauschierung* on the pommel C16604 renders a quatrefoil knot. The design has features in common with the silver and gold *Tauschierung* with quatrefoil knots on objects such as the Niederstötzingen grave 9 buckle and the belt mount of Rödingen (Figs. 8a, 8e; Adams 2010, 27). To create mushroom elements, however, the knots on the pommel are in this case divided by a mirrored image of a swastika.

The silver and gold *Tauschierung* on iron in the sword-belt mount (C38000/9) includes a stepped design between curved elements such as can be observed on the belt mount of Rödingen with silver and gold into iron (Fig. 8e) and the garnet *cloisonné* patterns on mounts and pommel in the Staffordshire Hoard (Blakelock and Fern 2019, 177; Adams 2010). Adams draws attention to complex quatrefoil knots divided by a swastika to create mushroom elements and finds that a mushroom shape occurs fully developed in both *cloisonné* and in *Tauschierung* made in the second half of the 6th century (Adams 2016, 91–94). Notably, she brings awareness to the fact that *Tauschierung* with the inlaying "of wire, into 'iron or bronze, is less demanding than creating patterns

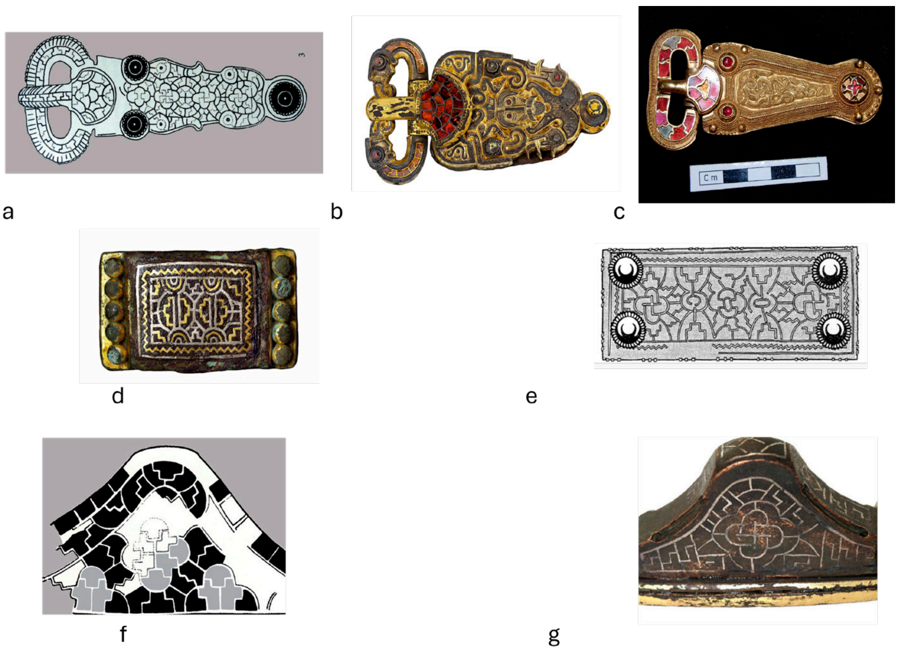

Figure 8: a. Drawing Niederstotzingen buckle, grave 9, Tauschierung – gold and silver into iron (after Adams 2016, fig. 5); b. Åker, silver-plated buckle C4901 (after Røstad 2020, fig. 1); c. Taplow, golden buckle, Britisch Museum asset number 1600965001, late 6th century, d. Åker, sword-belt mount C38000/9, Tauschierung, silver and gold into iron (after Røstad 2020, fig. 7); e. Drawing Rödingen 97, belt mount with Tauschierung, silver and gold into iron (after Adams 2010, fig. 13); f. Skrävstad, pommel, garnet cloisonné (after Adams 2016, fig. 5); g, Åker, pommel C16608, false damascene with silver onto bronze, photo: Elin Storbekk.

in *cloisonné*, which depend on the demanding lapidary skills" (Adams 2016, 86–93). Hence, the similarities in design in *cloisonné* and *Tauschierung* accords with Adams comments on the mushroom shape being fully fledged both in *Tauschierung* and in *cloisonné* made in the second half of the 6th century (Adams 2016, 91–94).

Related material

Eight iron buckles featuring oval plates and shield-on-tongue designs have been discovered in Norway (Røstad 2020, 18). These buckles are characterised by their mushroom-shaped shields, one decorated with a bronze plating (Skjølsvold 1969; Grinkåsa 2012, 79). Grinkåsa posits that while these oval buckles with shield-on-tongue are prevalent on the continent, they are relatively uncommon in Norway during the Merovingian period, dating approximately from 580 to 650 AD (Grinkåssa 2012, 79). The Åker find includes two buckles with shield-on-tongue designs: the triangular buckle C4901 and the oval buckle C5651 (Figs. 2, 4), the latter of which has lost its shield. These buckles are notably more precious than those previously mentioned, with the buckle C4901 retaining its mushroom-shaped shield-on-tongue. Adams finds that the triangular buckle aligns with 6th-century continental forms (Adams 2010, 20).

A notable comparison can be drawn between the Åker buckle and the Taplow Buckle, which features *cloisonné* on both the shield-on-tongue and the loop (The British Museum, Museum number 1883,1214.1). In this case, all components are crafted with exceptional quality and gold metal, whereas the Åker buckle predominantly utilises bronze and silver, with gold serving for decorative purposes in saving techniques. A noteworthy aspect is the superior craftmanship evident in the cast silver loop, contrasted with the more moderate craftmanship and bronze casting applied to the shield-on-tongue.

In light of the composite structure of the large belt buckle C4901, which features a carved, ornamented triangular silver-plated front piece (Fig. 1), it seems relevant to compare it with the Kölked belt buckle also decorated with carved, silver plating (Fig. 9; online catalogue: https://gyujtemenyek.mnm.hu/en/record/-/record/MNMMUSEUM1225548).

The buckle cast in bronze has silver plating laid into the shield of the tongue and the oval mount. Except for the silver part the whole buckle was heavily amalgam gilded. Silver plates were engraved and punched; with sunken details filled with niello. (Privat communication Hajnal Zsuzsanna 03.02.2022).

Figure 9: The Kölked buckle, silver plated copper-based casting, found in Grave B85 of the Avar Period, site in Kölked; 1st half of the 7th c. AD, Hungarian National Museum. Dimensions: L: 8.4 cm; W: 6.8 cm; H: 1.5 cm. Inventory number: N78.2.140.

Both buckles display a human face crafted on a silver plate affixed to a bronze base. The Åker buckle is distinguished by its polychrome design, incorporating niello on the silver plating, partial gilding, and garnets, whereas the human figure on the Kölked buckle, in low relief is merely outlined with niello on silver against a nielloed background.

Røstad has been concerned with the variations in materials used for decorative elements in the Åker buckle, highlighting the extensive use of gold in the deep reliefs, contrasting with the more common application of niello to mask the shallow reliefs found in items catalogued by Menghin (Menghin 1983, 357; Røstad 2020, 19). Interestingly, the human face on the Kölked buckle is set against a black nielloed background.

Technological features

Alloys

Analyses were obtained from uncleaned surfaces and although the measurements were inaccurate, it seems that two types of amalgam gilding were used: gold with a high level of silver on the sword-belt mounts and gold with a lower level of silver on the weaponry (Tables 2, 3, 5). Likewise, analyses of the silver plating suggest that two types of silver alloys were used: a silver with a high level of gold identified on sword-belt mounts C38000/5–6 and a silver with a low level of gold on the buckle C4901 (Tables 4, 5; Fig. 13). In both cases, the content of copper in the silver is low. Notably, the gilding on the carved silver plates appears to be rather thick.

The high level of gold in the silver plates could perhaps be due to a contamination of amalgam gilding in the adjacent areas. However, the lack of mercury suggests that gold could be ascribed to an alloyed silver rather than a contamination from mercury gilding. Questions asked could be whether these alloys were intentionally generated or unintentionally derived from natural sources or the use of recycled metal. Notably, the content of gold in silver may, to some extent, have been responsible for the well-preserved state of conservation of the silver plate.

Investigations suggest that a bronze was used for ornamental casting and for casting the box-shaped support of the ornamental-carved silver plating. Furthermore, a low tin bronze was probably used for hammering the triangular back plate C4901. A medium-tin bronze would have been used for ornamental castings and for the casting of the box-shaped support for the carved silver plating. A high-tin bronze was identified on the copper-based castings of the weaponry.

Joining

The buckles C4901 and C5651 and the sword-belt mounts C38000/5–9 are composite objects with mechanical and solder joins. The rod bridges the end sections of the loop on the buckles C4901 and C5651 and a hinge attached to the front and back plate of the buckles is hooked to the rod in the loop (Figs. 1b, 1c). On buckle C4901, the shield-on-tongue is hooked is to the rod (Figs. 1b, 1c).

The ornamented triangular component is riveted to the backplate. Remains of rivets indicate riveting of the sword-belt mounts, and the rivets have domed-shaped heads; gold on the sword-belt mounts and decorated with garnet cabochons on the buckle C4901. On the sword-belt mounts, the domed-shaped heads on either side of the ledge are connected to rivets, while the three golden heads in the centre are purely decorative. Analysis of the material inside the rivet head of C38000/5 reveals that it contains tin and copper compounds. The head is X-ray transparent. The X-ray image of the rivets shows that the stem of the rivet of C38000/5 has a solid squarish section.

The silver-plated items

Røstad found that the manufacture of the strap mounts C38000/5–8 corresponds with the manufacture of type Bülach-Nocera Umbra described by Wilfried Menghin (Menghin 1983, 357; Røstad 2020, 19). CT scans obtained from the sword-belt mount C38000/8 and the triangular component of buckle C4901 (Figs. 10–12) confirm this. Cross-sectional CT scans reveal that the silver plates are soldered to the top middle section of a hollow, box-shaped copper-based support. The silver plate is placed flush with the top section, effectively concealing the support. The soldering zone between the silver plates and the support is observed as a thin, straight line, indicating a close bond between the two materials (Figs. 10–12). The line extends only as far as the silver plate goes. However, as mentioned above, CT scans also demonstrate how the deep V-shaped channels for nielloing and gilding penetrate the plating at different depth. All this indicates that the patterns are carved, not cast or embossed and that the carving of the channels must have taken place when the silver plating was attached to the copper-based support. CT scans demonstrate how the carving penetrating the silver plate corresponds with the carved channels on the sword-belt mount C36000/8 (Fig. 10, 12).

Prior to the CT scanning, SEM-EDS II analyses were obtained from the side face of the sword-strap mount C38000/5. The analytical results of the various layers seen in the BSE image in figure 13 are listed in Table

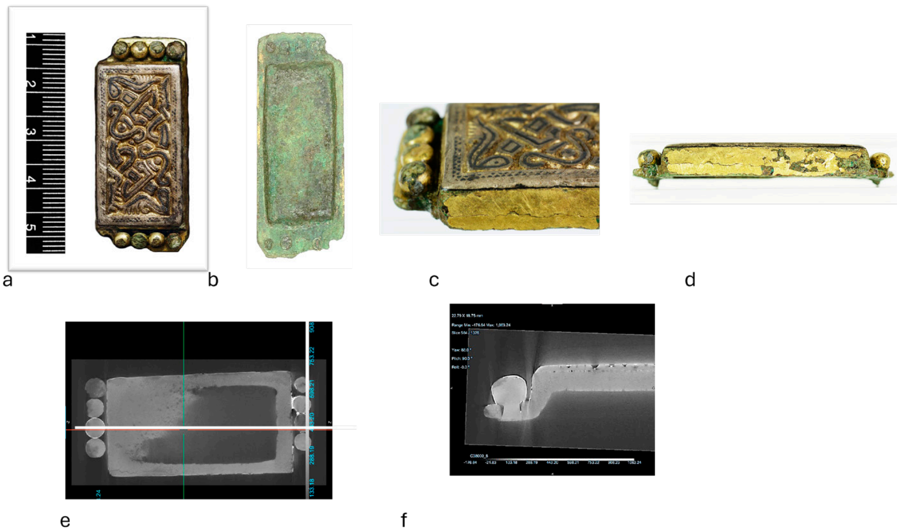

Figure 10: Sword-belt mount C38000/8: a. front face, b. reverse face, c. semi side view, d. side view, e. X-radiographic image with placement of the cross-sectional CT scan along the mount; f. the cross-sectional CT scan, © Museum of Cultural History, Oslo.

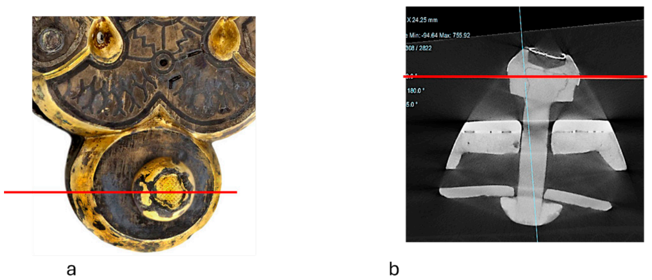

Figure 11: CT scan, obtained from the belt buckle C4901: a. detail at the tip of the buckle's triangular plate; b. the CT scan at different depth, © Museum of Cultural History, Oslo.

5. Notably, a substantial layer (1 mm) interfacing the copper-based support, and the silver plating extends beyond the silver plate and down into the ledge where the rivets are located. The function of the interface or soldering layer remains uncertain but could possibly be assigned to an early repair. A diffusion zone in the silver plate adjacent to the interface contains tin and copper, which suggests that the plate originally was tin soldered to the substrate. The silver plates were probably all tin-soldered to the substrate.

Incisions for laying out a design for the carving on the front face of buckle C4901 have been searched for but so far, explicit traces of such layout marks have not been found. A faint line (incised?) bordering the gilded cheek on the left-hand side of the human face on the buckle C4901, however, is possibly detectable in Fig. 14. Some mistakes were made on the right-hand side where beard stubs were wrongly punched into the cheek within the area to be gilded. Perhaps this indicates that the design was not marked or at least not properly marked when the stubs for nielloing were punched.

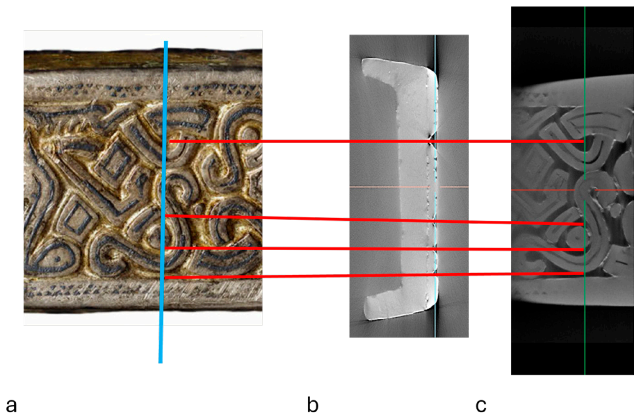

Figure 12: CT scan across the sword-belt mount C38000/8: a. photo in normal light, b. CT scan, c. X-radiographic image, © Museum of Cultural History, Oslo.

Table 5: SEM-EDX II analyses of gilded side face of sword belt mount C38000/5 (Figure 13).

Area	Ag	Sn	Cu	Au	Pb	Hg	Zn	P
Silver plate site 1 map 1	82.3		5.5	8.5				
Silver plate site 3	80.3		6.0	8.0				
Silver plate site 2 map 10	85.61	0.28	3.07	8.08	1.57			0.31
Diffusion zone site 2 map 11	37.4	28.6	15.8	8.7	5.1		2.4	1.1
Interface site 1 map 2	8.0	33.5	26.3		9.0		9.0	6.3
Interface site 2 map 13	11.5	40.9	23.7		7.6		5.8	7.4
Interface site 1 map 2	9.1	36.9	29.6		9.1			
Copper casting site 1 map 4	5.7	9.4	59.4		14.5			1.6
Copper casting site 2 map 15	10.9	23.9	34.7	5.6	17.9			4.3
Gilding site 1 map 3	28.2			67.1		12.7		
Gilding site 2 map 14	28.7		2.9	52.1		10.7		

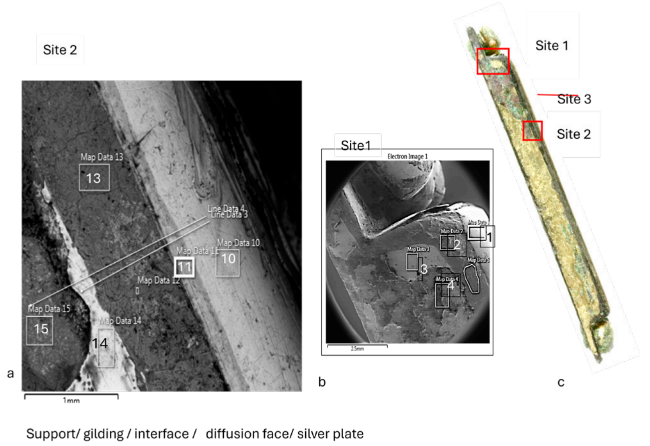

Figure 13: BSE images (SEM-EDS II) were obtained from the side face of sword-belt mount C38000/5: a. BSE image site 2, b. BSE image site 1, c photo in normal light of the side face, © Museum of Cultural History, Oslo.

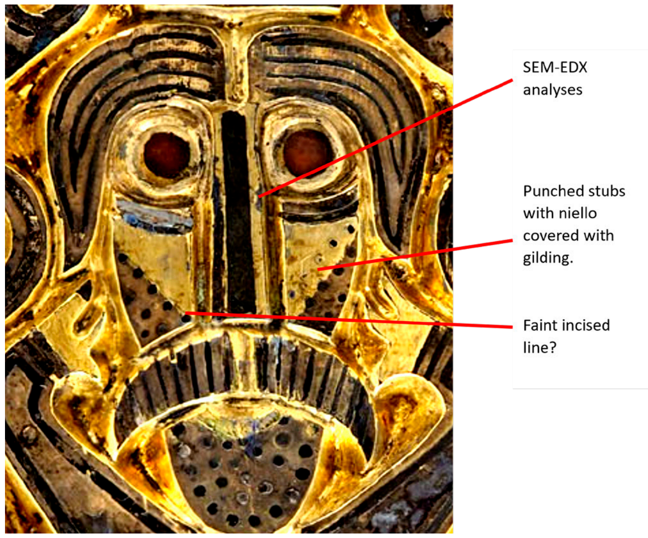

Figure 14: The front face of buckle C4901 with thin pale-yellow gilding of the cheeks and nielloed beard stubs on a silver plate plating. The thicker gilding in the relief has a deep golden glow. Round, flat garnets with waffled backings mark the eyes, © Museum of Cultural History, Oslo.

Discussion

Materials and techniques

Copper-alloy served as the primary metal used for the creation of the examined objects. The silver-cast loop of buckle C4901 is the sole piece in solid precious metal. On the remaining items, precious metals are applied for decorative purposes, such as gilding, silver plating, and tinning. These materials conceal the copper-based support, and the extensive use of amalgam gilding significantly enhances the luxurious appearance of the Åker find.

As a result, while the level of craftmanship and artistry would have been greatly valued, the limited use of precious metals indicates that the Åker find may perhaps not be classified as a *treasure* hoard (Røstad 2020, 11). Clearly to minimise costs, the artisans focused on maximising the visual impact of a small quantity of precious metals, creating jewellery that appeared to be composed of gold and silver. In line with this, the silver loop was produced with open casting silver technique. Røstad has noted the general scarcity of gold and silver during the early Merovingian period in Norway (Røstad 2020, 18). The restricted use of precious metals in the Åker find may be connected to these circumstances.

Among the materials, garnets stand out as one of the most opulent, second only to gold. Røstad commented on its rich use of the precious garnets, which were extremely rare in Norway (Røstad 2020, 19). Even more remarkable, however, is the rather moderate skill granted the *cloisonné* on the shield on the large buckle C4901, combined with the rather unprofessional punch work edging the shield. Notably, silver rather than gold was used for the cell walls of the cloisonne on copper-based supports such as the shield-on-tongue, while on the silver-cast loop, the cell walls were in gold, revealing obvious differences in preciousness as well as craftsmanship between the two types of *cloisonné* used. Interestingly, the strip of garnet *cloisonné* on the loop has a step-wall design, while the shield-on-tongue features a geometric-related design, and the strap slider incorporates the mushroom motif. The imperfections in design may reflect external influences that are not fully comprehended.

Both, ornamental casting and carving/engraving serve the purpose of creating relief designs. The casting process requires advanced knowledge of metalwork, specialised equipment and experience, while engraving can be done with relatively simple tools and equipment and is typically a skill that can be learned fairly quickly, although mastering the art can take a long time. Within the items investigated, ornamental-cast relief was identified on the cast-silver loop of the large buckle and the cast copper-based items of the weaponry and to some extent Straps 2 and 3. Ornamental-carving was identified on the carved silver plating soldered to copper-based support of the triangular front plate of buckle C4901 and the sword-belt mounts (C38000/5–8).

The copper-based castings of weaponry are concealed by gilding and tinning, while the castings of Straps 2 and 3 are concealed by gilding and decorated with elaborate punching. The carved silver platings feature a detailed design in deep relief, with niello work and partially gilding. The extent to which these techniques can be linked to specific workshops remains uncertain. Nevertheless,

Figure 15: Cast and carved bird figures: a. silver-cast loop of the large buckle C4901, b. bronze cast fragmented piece of weaponry C4903, c and d. carved silver plating on the front panel, © Museum of Cultural History, Oslo.

the common use of punch irons on the items of Straps 2 and 3 indicate a shared workshop, and it is possible that items with carved silver plating featuring shared characteristics (CT scans) derive from a common source.

Figure 15 depicts bird shapes crafted in three different materials and techniques. One is integrated into the cast silver loop of the buckle C4901 (Fig. 15a), another is shaped in the bronze-casted fragmented piece of weaponry C4903 (Fig. 4, 15b) and a third is integrated into the carved silver plating of the front plate of the buckle (Fig. 15d). The bronze casting in Fig. 15b is concealed by gilding and tinning, and the tinning that follows the curved element produces the desired silvery appearance. On the loop and the carved silver plating (Fig. 15d), partially gilding allows for fields of silver to remain exposed, and silver with a nielloed zig-zag border follows the curved element on both items. This illustrates how a selection of bird shapes has been created in various materials and techniques on buckle and weaponry.

The large buckle C4901

The buckles C4901 and C5651 consist of more than one component, whereas each of the other examined items were formed in only one piece. This analysis has revealed that the large buckle, which includes three primary components – the loop, the shield-on-tongue, and the triangular component – displays significant variations in both materials and manufacturing techniques. The distinct features of these components are detailed below.

The loop is notable for its silver cast relief, gilded and nielloed, accompanied by a linear garnet *cloisonné*. As previously mentioned, the *cloisonné* is characterised by its gold stepped cell wall, along with carefully polished garnet plates. Consequently, both materials and craftsmanship of the loop are of a notably high quality.

In contrast, the shield-on-tongue has cast copper-based support with garnet *cloisonné* and gilding applied to its surface. The cell walls are crafted in silver and applied in a slightly disorderly geometrical pattern that could indicate that the cell work was adapted to pre-cut garnet plates, indicating a deficiency in lapidary skills (Horváth 2012, 210, note 4). Additionally, plates lack adequate polishing (assessed by Hans Gerhard Loos). Moreover, the circular punch work surrounding the shield demonstrates a clear deficiency in skill. Notably, the *cloisonné* on the shield has more in common with the *cloisonné* on the strap slide C21406 than with the silver cast loop.

The triangular component features a carved, nielloed and partially gilded silver plate, crafted with notable skill. The polychrome palette comprises yellow from gold, white from silver, black from niello and red from garnets. The deep relief gilding provides a striking contrast to the flat niello-ornamented fields of silver, where delicate pale gilding is used to highlight the hands and cheeks of the human figure. This interplay of gold in two distinct shades, along with silver, niello and round garnet plates representing eyes, creates the rich and vivid polychrome display. The analyses of the primary components have demonstrated that the three main elements of the buckle exhibit notable differences in materials, technique and craftmanship potentially indicating a tradition for constructing buckles with dissimilar components or could simply be a product made from reused items of various sources.

The Y-shaped punch on the hinge of the large buckle is indicative of a Scandinavian style (Slomann and Christensen 1984, 180). This observation lead Slomann and Christensen to assert that at least one Scandinavian goldsmith "left his mark" on the buckle (Slomann and Christensen 1984, 182). The connection joining the triangular piece to the hinge has not been properly investigated, but if the attachment is original, it supports the theory that the engraved silver-plated front plate was created within a context associated with a Scandinavian environment. Conversely, if it is not original, this finding implies that the loop and the triangular plate, regardless of their origins, were combined within a Scandinavian setting.

Final remarks

This research indicates that in addition to the lapidary work, four primary trends can be identified based on materials and techniques. The first trend encompasses gilded and tinned ornament-cast bronzes used in weaponry, while the second pertains to partially gilded and nielloed ornament-cast silver applied to the loop of buckle C4901. The third trend features gilded ornament-cast bronze embellished with intricate punch work applied to mounts in to Strap 2 and 3, and the fourth involves partially gilded ornament-carved silver plating on cast bronze applied to the front plate of buckle C4901.

The casting process requires advanced equipment and a significant level of expertise, characterised by a collaborative craftsmanship within a workshop environment. Conversely, techniques such as engraving, punching and lapidary work can be done with basic tools, making them more accessible for learning, but the quality of these crafts depends upon the artisan's skill and mastery of the craft.

Given their functional roles, the loop and tongue on buckles are generally cast and typically cast in the same metal. Therefore, the combination of a silver-cast loop with a bronze-cast tongue on the large buckle C4901 may appear atypical. One might infer that, contrasting to a collaborative nature related to the casting process, a single master artisan would have been primarily responsible for the carving.

This investigation is based on a brief study of the materials and techniques. However, more systematic and accurate analyses will disclose similarities and differences of importance for the interpretation how workshop traditions, domestic and international may have been interrelated in the making of the items investigated. As source material, further in-depth analyses of the assemblage will contribute to the general knowledge of how technology spread and developed in the period involved.

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