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A compositional study of a gold-plated Viking Age pendant from the Åland Islands

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During the University of Helsinki field school excavations in 2020 in Bartsgårda, Åland, a well-preserved, intricately decorated copper alloy pendant (ÅM 820:79) was discovered in the upper layers of the Late Iron Age house foundation (Ilves 2021). Measuring 33 mm in diameter, it has a 10 mm wide strap eyelet and a total height of 42 mm. The thickness of the pendant is 2 mm (5 mm by the eyelet), and it weighs 11.8 g.

The pendant, dating to the Viking Age, has a non-figurative ornament (fig. 1). Centrally on the disc, there is a triangular motif with concave, hatched sidebands and a prominently protruding sunken annulet in the middle. The arms of the triangle are fusing and widening into triangular ends decorated with five tiny knobs/metallic pearls each and anchored under the border belt running on the edge of the pendant. The central triangle is surrounded by three curling double bands' motifs and volutes, intertwined with each other and with a circular inner ring of a double band. Both the volutes and the circular inner ring emanate from and are connected by three rectangular shapes with concave sides that carry a decoration of six tiny knobs/metallic pearls in three pairs. All the knobs on the pendant seem to have had a central dot. The oblique line-decorated strap eyelet is designed into the main ornament by the use of double bands.

During the discovery, the pendant was hypothesised to have been gilded, an assumption later verified during the conservation of the artefact (Lehtinen & Pouta 2021). The pendant has a rich, well-preserved plating of gold. On the reverse side, the central area of the disc has a distinctly silvery appearance. These observations prompted a non-destructive X-ray fluorescence analysis for the identification and quantitative determination of the copper-based metal the artefact was made of and the metals used for the coating(s). The surface XRF analysis was conducted after the conservation.

Analysis

The compositional analysis was carried out using a Rigaku NEX-DE VS bench-top energy dispersive X-ray fluorescence spectrometer (ED-XRF). The instrument was operated in point analysis mode with the beam diameter adjusted to 1 mm to detect major, minor and trace elemental concentrations of both the copper-based alloy used in manufacture and the alloy compositions of the coating on the artefact's surfaces.

The results presented in Table 1 are normalised mean values of 4–6 measured points per area of interest. The analysis was carried out in a helium atmosphere using a tube voltage of 60 kV and 35 kV for high-Z and mid-Z elements, respectively, with a total acquisition time of 120 s. The analytical results were quantified using Rig-

Fig. 1. Cast pendant from Bartsgårda, Åland. Photo: Sari Pouta, Konservointipalvelu Löytö OY.

		Fe	Cu	Zn	As	Ag	Sn	Sb	Au	Hg	Pb
Pendant ÅM 820:79		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
Pendant alloy, uncoated back side	µ (n=6)	1,50	80,95	6,78	3,46	0,13	2,69	0,36	0,63		3,49
	σ	0,75	2,63	1,47	0,72	0,01	1,48	0,13	0,10		0,44
Gold-coating front side	µ (n=4)	1,02	42,49	3,28	0,80	1,46		0,20	43,98	5,04	1,73
	σ	0,05	7,56	0,68	0,38	0,17		0,06	6,40	0,78	0,03
Silvery-coloured layer back side	µ (n=6)	1,65	80,88	5,83	3,65	0,15	1,79	0,33	0,78		4,94
	σ	0,43	1,68	1,54	0,51	0,03	0,88	0,09	0,20		1,39

		Fe	Cu	Zn	As	Ag	Sn	Sb	Au	Hg	Pb
Standard 1115 Commercial Bronze A		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
Certified value		*0,13*	*87,90*	*11,70*	*n.d.*	*n.d.*	*0,10*	*n.d.*	*n.d.*	*n.d.*	*0,01*
Analysed result	µ (n=3)	0,12	87,80	11,40	n.d.	n.d.	0,07	n.d.	n.d.	n.d.	n.d.

Table 1. ED-XRF determined alloy compositions for the pendant and the standard reference material.

aku's software and fundamental parameters. The data accuracy is demonstrated by analysing a reference bronze standard of a certified composition (NBS 1115 Commercial Bronze). The results show good agreement with the certified values.

The material was macroscopically identified as a copper-based alloy. The ED-XRF analysis revealed that the pendant was made of brass, an alloy of copper and zinc. At the time, brass was produced by a cementation process developed by the Romans, in which copper metal was mixed with zinc carbonates or oxides, heated under reducing conditions, producing metallic zinc vapour, diffusing into the copper, and creating brass (Bayley 1990; Bayley et al. 2014). Brass, favoured for its golden-like appearance, was part of the organised Viking Age trade, and standardised brass ingot bars, with regulated size and alloy composition, have been documented at the Viking period commercial centres, such as Hedeby, and in the 10th century hoard of brass bars from Myrvälde on Gotland (Sindbæk 2001; 2008; La Niece et al. 2012; Merkel 2018).

In the ED-XRF analysis, the pendant alloy composition was determined by analysing multiple uncoated areas on the artefact's back side, showing averaged concentrations of copper (Cu) at c. 81 wt%, c. 6.8 wt% zinc (Zn), c. 2.7 wt% tin (Sn), c. 3.5 wt% lead (Pb), c. 1.5 wt% iron (Fe) and c. 3.5 wt% arsenic (As). Minor concentrations of antimony (Sb) at c. 0.4 wt%, silver (Ag) at c. 0.1 wt% and gold (Au) at c. 0.6 wt% were also detected.

In principle, elements present in brass in minor and trace quantities (below 1 wt%) are usually considered unintentional additions in the alloy (i.a. Bailey 1990). Thus, in the current case, the copper was alloyed at least with zinc and tin. The relatively high iron and lead values (at 1.5 wt% and 3.5 wt%) may derive from impurities in the copper or zinc minerals. However, lead concentrations above 2 wt% can indicate intentional addition, as lead has a viscosity-reducing capacity, which is useful when producing complex mould-forms – being cheaper than copper, lead may also have been added for economic reasons (Liversage 2000; La Niece et al. 2012). Yet, in data retrieved from the surface of the pendant, elevated Pb and Fe values can derive from patination and corrosion processes (Lutz & Pernicka 1996; Orfanou & Rehren 2015; Holmqvist et al. 2019).

Being a golden-coloured alloy, brass is an ideal material choice for a gilded pendant. The amount of Zn in brass enhances its golden tone, and approx. 10% or more of zinc in brass is estimated to create the most gold-like colour (Mecking 2020). The zinc level of the Bartsgårda

Fig. 2. Stereomicroscope images of the pendant's surfaces, a–b) gilding and decorative motifs on the front side, c) silvery-coloured corrosion on the back side. Photos: Elisabeth Holmqvist, University of Helsinki.

pendant is less (c. 6.8 wt%) and, thus, perhaps not optimal, but tin and lead also reduce the reddish hue of copper in brass, creating a more gold-like appearance (Mecking 2020). In this context, the amount of arsenic in percentages is also interesting. Arsenic up to 1–2% can be expected to be universally present, yet similar As levels can derive from deliberate alloying, as arsenic can improve the casting properties of the alloy, lower the melting point of the copper and affect the colour of the alloy to create a more gold-like colour (Hosler 1995; Lechtman 1996; Bayley et al. 2014; Charalambous et al. 2021). In the Bartsgårda pendant, the arsenic value was c. 3.5 wt% and may link to the use of arsenic-rich copper or zinc sources, deliberately added arsenic or both. The increased tin and lead values of the pendant alloy also indicate that it was not produced of fresh brass (see Bayley et al. 2014, p. 125), but at least tin was also added in the mixture and may derive from material mixing with recycled bronze.

The gilding material composition was analysed by selecting preserved gilded spots on the surface that covered the beam diameter of 1 mm (fig. 2a–b). The gilding was applied on the pendant as an alloy of copper (c. 42.5 wt%), gold (c. 44 wt%), silver (c. 1.5 wt%), iron (c. 1 wt%), lead (c. 1.7 wt%), zinc (c. 3.2 wt%) and mercury (c. 5 wt%). The mercury content derives from the amalgamation process, used to melt the gilding on the brass surface. This technique of using mercury in gilding was used until fairly recently, although it is very poisonous.

We also examined the potential silver coating on the back side of the pendant (fig. 2c). However, the silvery-coloured spots did not show increased levels of Ag. Furthermore, Sn was not detected in increased levels, excluding the option of a tinned back side of the artefact. It appears more likely that the discoloured surface areas are caused by corrosion: arsenic impurities reacting with the parent alloy (Cu_3As, see MacLeod 1991, p. 228), sometimes causing a silvery appearance on a copper alloy artefact.

Context

The pendant from Bartsgårda is one of a kind from Åland, but it is not a unique find. The parallels, however, remain few, and when it comes to decoration, the artefact from Åland excels in detail in comparison to the pendants of the same type.

The geographically closest parallels to the Ålandic find are from the well-known and well-studied Viking Age trading post of Birka. Two gilded bronze pendants from graves 901 and 502 (Arbman 1943, Taf. 98:23–24) are comparable to the find from Åland, especially the white metal gilded pendant from grave 901. The latter, niello-decorated and bearing gilding on both sides, has, in fact, been converted into a brooch being secondarily equipped with an iron needle device (Gustafsson 2008, pp. 44–45) and was thereby living its second life when deposited. Although following the general setup of a central triangle with splayed arms surrounded by an inner ring that bifurcates into three volutes, the details of the ornamentation are quite different on each of the three pendants.

In the study of cast pendants with Nordic ornamentation focussing on the grave finds from Birka, Johan Callmer (1989, p. 23) assigns the above-mentioned two pendants from Birka to the group A2, the so-called Stora Ryk type, based on a parallel from Sweden. In 1936, a hoard dated to the 10th century was discovered from Stora Ryk in Dalsland that, among other things, contained several bronze and silver pendants (Andersson 2019). One of the gilded pendants in this hoard is of the same size and decoration style as the pendant from grave 901 on Birka as well as the pendant from Bartsgårda. In fact, because of a circle in the middle of the central concave-sided triangle, hatched bands and dots being part of the decoration on the pendant from Stora Ryk, it bears much stronger similarities to the pendant from Bartsgårda than to the ones from Birka.

At the time of the study by Callmer, the finds from Stora Ryk and Birka were the only specimens of that type known from the Fennoscandian region. However, three gilded pendants of this design have also been documented from an important Viking Age trading settlement of Hedeby. There are at least two more gilded pendants of that type known from Denmark – from Bederslev on the island of Fyn (Callmer 1989, p. 38) and the Viking Age settlement of Over Randlev (Kleingärtner 2007, pp. 290, 423; see also Jeppesen 2000, p. 16). This strongly indicates that the main region of use for this type of pendants was in southern Scandinavia (Kleingärtner 2007, p. 58). In addition, there is one pendant from eastern England – from Tathwell Louth, Lincolnshire – that is exhibiting the same decoration; the pendant is considered of Scandinavian manufacture (Leahy & Paterson 2001, p. 195, fig. 10:6; Paterson 2002, p. 269).

All discussed pendants are cast imitations, and no moulds have been found. The main production site remains unknown, but the distribution of the type indicates that it was possibly based in southern Scandinavia. Also, finding a match between an artefact composition and the source metal via geochemical data comparison is challenging because of the mixing of metals in the alloy manufacture and possible re-melting and recycling of metals. However, close correlation between trace elemental signatures of finished artefacts can indicate chronological and technological groups (La Niece et al. 2012; Bray et al. 2015; Radivojevic et al. 2018). Although a lot of the typological comparanda for the Bartsgårda pendant comes from Hedeby, the lead and arsenic values of the pendant do not correlate with those reported for the Hedeby brass bar ingots. In fact, Merkel (2018, p. 297) notes that high-arsenic brass, containing ca. 1–2 wt% of As 'has not been identified at Hedeby at all'. Thus, there is no material match between the Hedeby brass and the analysed pendant. Yet, arsenic in percentage levels has been reported in Saxon brass ingots found in London and associated with arsenic-rich ores in north Germany (Bayley et al. 2014) and in Islamic brass artefacts (Craddock et al. 1990).

The pendant from Bartsgårda is the eastern- and northernmost of the other known finds of the same type. It was lost in a dwelling house that was in use from the second half of the Merovingian period to the end of the Viking Age, at the site that belongs to a group of larger Late Iron Age settlement sites in the Åland archipelago contrasting to the dominating pattern of single farms characteristic to the islands (Ilves & Perttola 2020). Small-scale archaeological excavations conducted at the site so far do not allow establishing the context in which this settlement can be interpreted, but among the things pointing towards affluence and long-distance networks, the find of the gold-plated pendant of exquisite craftsmanship could be considered an indication of considerable prosperity and international connections.

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