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A ‘Roman Brass’ Age: a transformation in copper-alloy composition in Estonia and northern Latvia during the Roman Iron Age, identified by pXRF

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ABSTRACT

Brass quickly overtook bronze as the dominant copper alloy across vast areas of the Roman world and beyond during the 1st century BC. It has also been established that the quality of this brass changed over time. To establish whether a rapid transition from bronze to brass also took place in the north-eastern Baltic, over 1200 copper-alloy objects were analysed non-destructively by pXRF. They were primarily sourced from the *tarand* cemeteries of Estonia and northern Latvia, which date to the Pre-Roman and Roman Iron Ages. The aim was to establish which alloys were in use during these periods, then to determine whether any chronological trends were visible and, if so, for which typological groups. The results show that there was a major shift from bronze to brass towards the end of the Pre-Roman and the early Roman Iron Ages. This is followed by a decline in the use of brass in favour of gunmetal over the following centuries. The results also suggest the existence of an introductory period when traditional bronze and newly arriving brass items circulated together. However, this period better matches a time slightly earlier than that traditionally proposed for the start of Estonia’s Roman Iron Age. This pXRF survey presents a better understanding of the arrival of brass in the north-eastern Baltic and adds to our knowledge about the effectiveness of long distance trade and communication networks that transferred new objects, ideas, and technologies to these distant communities.

KEYWORDS

archaeometallurgy, copper alloy, Roman Iron Age, Baltic Sea, lead isotope.

Introduction

It is widely understood that the ancient formula for copper alloy was a heated mixture of copper and tin, known today as bronze. But what is less well known is that a different formula quickly became dominant across vast areas of the Roman world and beyond during the 1st century BC (Craddock & Eckstein 2003; Craddock et al. 2004; Montero-Ruis & Perea 2007). This new formula was a mixture of copper and zinc, which the Romans called orichalcum and which we call brass today (Rehren & Martinon Torres 2008, 169). Brass was already known to the Greeks and Etruscans from the 7th century BC, but it was difficult to produce and, therefore, considered both expensive and exotic (Craddock 1978, 1). However, by the 1st century BC the Romans had adopted a new technique that enabled brass to be manufactured on an industrial scale. This new 'cementation' technique was quite different to traditional bronze making. It required the heating of zinc oxide with charcoal and copper in reducing (low oxygen) conditions, achieved using lidded crucibles (ibid., 9). This new Orichalcum brass was rapidly adopted for military fittings and coinage, which suggests that its manufacture and distribution were controlled to some degree by the Roman state, at least in the beginning (Dungworth 1997, 903). An important factor in the rapid increase in brass objects in Europe is thought to have been the coinage reform of the emperor Augustus around 23 BC, when brass was introduced as the new base metal (Burnett 1987, 54). It has also been established that the quality of this brass (in terms of zinc content) changed over time (Caley 1964; Dungworth 1996). Based on evidence from brass coinage, zinc content was at its highest (20 to 28%) during the early Roman Empire (Craddock & Eckstein 2003, 224). The zinc content, however, started to decline below 20% during the second half of the 1st century AD, to virtually none by the early 3rd century AD (Dungworth 1996, 229, fig. 1). Caley (1964) suggested that this decline was due to increased recycling practices, possibly caused by a disruption in the supply of zinc ore, or a loss of technological know-how. Dungworth (1997, 903), however, argued against this, suggesting that the decline in zinc content was a deliberate choice and that by the late empire the mixed copper alloy, called gunmetal (a mixture of bronze and brass, but not necessarily from recycled scrap objects), had become a popular choice. Either way, there was a decline in the zinc content of Roman period brass over time, the knowledge of which is of some use in dating archaeological material (see Bliujienė 2013, 363, fig. 241; Pollard et al. 2015, 704, fig. 2). This dating technique has recently been applied to a limited group of copper-alloy artefacts from *tarand* cemeteries of Estonia and northern Latvia (Roxburgh 2021, 202). The quality of the brass in a series of early bracelets was found to better match the brass of the early Roman Empire. The date for similar objects found in countries more closely associated with the Roman world also supported the notion that they were in circulation in Estonia at an earlier date than previously thought (ibid.). But did a rapid transition from bronze to brass take place in the far reaches of the north-eastern Baltic as well? Or was it too distant to be part of this new 'Roman Brass' Age? A better understanding of the arrival of brass and the potential decline in zinc content is quite important, especially in terms of how closely it matches the pattern seen in areas closer to the Roman world. It is also of some interest to trace the direction from which it came, in terms of trade routes and communication networks that transferred new technologies to distant peoples.

To address this question, a large number of objects were analysed non-destructively by portable X-ray fluorescence spectrometry (pXRF) to establish the basic copper alloy classification for each item. Despite some limitations (Shackley 2010; Speakman & Shackley 2013), this device is widely used for elemental analysis of archaeological materials, including corroded copper-alloy objects (Gigante et al. 2005; Martinón-Torres et al. 2012; Roxburgh et al. 2018; Bliujienė et al. 2020; Wallace et al. 2020). The items were mainly sourced from *tarand* cemeteries of Estonia and northern Latvia (see Fig. 1, also Lang 2007, 170–216; Ciglis 2013; Olli 2019b) which date to the Pre-Roman and Roman Iron Ages (500 BC to 450 AD).

The aim of this research is to establish which copper alloys were in use during the Pre-Roman and Roman Iron Ages, and then to determine whether there were any chronological trends in alloy choice and, if so, for which typological groups. The following questions were formulated:

Is there evidence of a transition from bronze to brass in the north-eastern Baltic?

If so, did the transition occur at a similar time as in other more southerly areas of Europe?

Again, if so, is there evidence of the zinc decline seen in other parts of Europe during the Roman period?

Historiography

The Roman Empire was one of the most wide-reaching, globalising phenomena in European history (see Hopkins 2002; Pitts & Versluys 2014; Witcher 2017, and others), and its northern borders were in place along the Rhine and Danube rivers by the 1st century BC, the time when brass was rapidly becoming available. Research into the composition of Roman brooches in present-day Slovenia by Istenič and Šmit (2007, 140) showed that brass was in regular use in Europe by 60 BC. Slovenia is one of the Balkan states whose territory partly belonged to the province of Pannonia in Roman times. The link between Pannonia and the south-eastern Baltic is of some importance when considering the presence of Roman-period objects in Estonia and northern Latvia. Any objects made within the Roman provinces and subsequently traded north would most likely have left via Pannonia and travelled north along the amber route to the areas around the Vistula River delta, now part of modern Lithuania, Poland and the Kaliningrad Oblast of Russia (Roxburgh 2021, 185). Recent research in Lithuania has revealed that copper-alloy composition started to shift from bronze to brass between the 1st century BC and the middle of the 1st century AD. However, the evidence suggests that a large-scale shift to brass occured around 40–70 AD. This shift coincided with the beginning of Lithuania's

FIG. 1. Find locations (Roman period *tarand* areas marked by shading). Saaremaa: 1 – Kurevere, 2 – Lümanda, 3 – Mustjala, 4 – Liiva-Putla, 5 – Tõnija. Harjumaa: 6 – Lehmja-Loo, Lagedi, Rae, 7 – Kurna, Kautjala, 8 – Jõelähtme, Saha, 9 – Anija, 10 – Harju-Jaani, Raasiku, Linnakse. Virumaa: 11 – Kadrina, Sauka, Võhma, Hõbeda, 12 – Haljala, Essu, Põdruse, 13 – Rakvere, Laanemõisa, Laanevälja, Arkna, Tõrma, Reinapi, 14 – Kunda, 15 – Kohala, 16 – Iila, 17 – Kalvi, 18 – Ulvi, Ranna, Rida, 19 – Pada, 20 – Avispää, 21 – Jäbara, Moldova, Liimala, Purtse-Matka, 22 – Lüganuse, Erra-Liiva, Matka, Aa, Erra, Mustmätta, 23 – Saka, Kohtla-Järve, Järve, 24 – Kahula, Kukruse, 25 – Künnapõhja, Sõtke, Türsamäe, Udria. Järvamaa: 26 – Kaaruka, Nurmsi, Nurmsi-Sargvere, Väätsa, Laupa-Lõola. Jõgevamaa: 27 – Piilsi, 28 – Toovere, 29 – Nava. Viljandimaa: 30 – Kõpu, 31 – Holstre, 32 – Määro, 33 – Luige. Tartumaa: 34 – Kobratu, 35 – Paali, Tatra, 36 – Jaagupi, Külitse, Meeri, Unipiha, Kulaku, 37 – Lutike, Neeruti, 38 – Verevi, 39 – Aakre, 40 – Kakumetsa, 41 – Mäletjärve. Võrumaa: 42 – Pikkjärve, Truuta, 43 – Kassi, 44 – Hannuste, 45 – Virunuka, 46 – Sadrametsa. Northern Latvia: 47 – Kaugars, Strante, 48 – Vīksnas Kapusils, Mūsiņa Lizdoles, Gailītis, 49 – Auciems, Striķi.

early Roman period, a time of rapid change in both settlement organisation and burial customs, as well as a time when a whole range of new costume ornaments were being adopted by local communities (Bliujiene et al. 2021, 41).

There has been some difficulty in dating the beginning of Estonia's Roman Iron Age because the contents from excavated *tarand* cemeteries have proved to be quite co-mingled (Lang 2007, 180) – for example, bones and grave goods in these cemeteries were frequently deposited from various periods, thus a certain degree of comparison with the dates of find assemblages from neighbouring countries has been necessary. Evidence from settlement sites is also very sparse due to the lack of excavation. It should also be remembered that the eastern Baltic was, of course, never part of the Roman Empire, so that the terms Pre-Roman Iron Age and Roman Iron Age are somewhat arbitrary in classifying this archaeological period. In Latvia, for example, the terms 'earliest Iron Age' and 'early Iron Age', introduced in the Soviet times, are still popular. A better, more 'correct' criterion for these periods has never been established, thus a best fit (based on the dates of the brooches) at present is that the Roman Iron Age began in the second half of the 1st century AD. It is thought that during this time the communities living in north-eastern Estonia came into direct contact with those around the Vistula River delta (Lang 2007, 259). The importance of this connection has attracted scholarly attention since the late 19th century (Grewingk 1877; Hausmann 1896; Hackman 1905; Schmiedehelm 1923). As in Lithuania, the Roman period in Estonia saw rapid transformations, such as the introduction of the new iron-working technology, many new costume ornaments and new burial customs (see Peets 2003, 267; Lang 2007, 115, 191). This start date for the Roman period in Estonia broadly coincides with the dates in the neighbouring countries of Finland, Latvia and Lithuania, which also place the start in the 1st century AD (but include the first half of the century as well).

The countries of the north-eastern Baltic, including Estonia and Latvia (the northern part), have never had natural raw material resources for producing copper-alloy objects (Lang 2007, 115). All copper alloys had to be imported (either as ingots or finished goods) before being remelted into local products. Local copper-alloy melting started as early as the late Bronze Age (ibid.). However, there is only little data on bronze melting and casting activities from the Pre-Roman and Roman Iron Ages. From the few surviving moulds found by archaeologists, it can be concluded that the technology for working with bronze must have existed (ibid., 120). However, the technology required for producing 'Roman' brass was much more complicated than that for bronze (Pollard & Heron 1996, 196–204; Craddock 1998). Unlike the process of making bronze (which requires heating of copper and tin, or scrap bronze in an open-topped crucible), the cementation process of making brass required a reducing (oxygen-free) sealed crucible where zinc could be heated to the point where it vapourised. This gaseous zinc could then enter a solid copper ingot that was present in the same container, thus forming the golden-coloured copper alloy we call brass. Brass could, of course, be melted down using the older bronze techniques, but this would have resulted in brass with ever decreasing levels of zinc in it each time the scrap brass was recycled. This could never have achieved the high zinc brass produced using the cementation technique. Also, this local brass remelting would likely have been at risk of being mixed with scrap bronze. Thus, at some point there must have been, as Bayley (1998) puts it, a time when 'older prehistoric traditions were merging with newly introduced Roman ones'. In this case, the older bronze-working traditions of the north-eastern Baltic merged with imported new brass-working technologies.

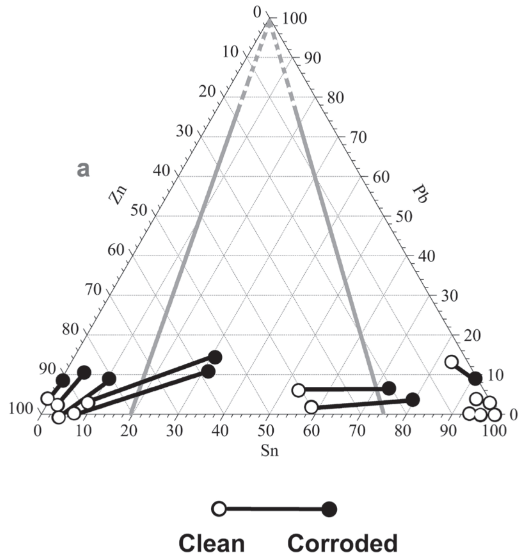
Until recently, research into the objects made of copper alloy dating to the Pre-Roman and Roman Iron Ages has concentrated on typological matters (e.g. Moora 1938; Schmiedehelm 1955; Laul 2001; Lang 2007; Olli 2019a). In recent years, thanks to advances in archaeological science and pXRF in particular, there has been a growing interest in the materials from which the objects were made. This is especially true for the Roman-period copper-alloy objects found in the eastern Baltic (e.g. Roxburgh & Olli 2019; Bliujienė et al. 2020; 2021; Roxburgh 2021). The latest research by Roxburgh (2021) selected four well-defined object types recovered from a *tarand* cemetery and subjected them to pXRF analysis. The results, when compared to evidence from other areas of northern Barbaricum as well as from Roman provinces, suggest that some items made of high-quality brass were likely to have been traded north from as far as Roman provinces, arriving in north-eastern Estonia via the amber-producing areas of the Vistula (Roxburgh & Olli 2019, 227). Furthermore, some items were possibly in circulation in these north-eastern coastal communities in the first half of the 1st century AD, which is half a century before the generally recognised start of Estonia's Roman Iron Age (Roxburgh 2021, 202).

Methodology

Objects from three time periods were selected. Firstly, artefacts from the Pre-Roman Iron Age (500 BC to 50 AD), in order to better establish the composition of copper-alloy items before the start of the Roman Iron Age. Secondly, objects from the early Roman Iron Age (50 AD to 200 AD), to establish the types of copper alloys that had newly arrived in the region. Lastly, artefacts from the late Roman Iron Age (200 to 450 AD), to establish any changes in alloys in the surviving (but stylistically and technically evolving) object types, whose ancestors date from the earlier periods. Subsequently, the compositions of later, newly arrived objects were also established. The objects were identified and dated based on the three most important publications on the period (Schmiedehelm 1955; Laul 2001; Lang 2007). As the focus of this paper is to better understand the alloys in circulation during these periods, an exhaustive typological review is beyond its scope. The data presented here is primarily organised into broad object categories (i.e. brooches, bracelets, finger rings, etc). The objects were then identified by their typological names or other identifying features (e.g. the shape of an object's cross-section), closely following Lang (2007) in the first instance, then supported to a lesser degree by Laul (2001) and Schmiedehelm (1955). The dates assigned to the objects closely follow Lang (2007). The periods when the cemeteries were thought to have been in use were also compared with the broader circulation dates of the object groups to assign a best fit for each object. A complete list of the objects, containing more detailed typological information, is available online at https://www.researchgate.net/publication/360515680_Data_for_'Roman_Brass'_Age .

The pXRF methodology closely follows the methodology published by Roxburgh et al. (2018) and in subsequent papers (e.g. Roxburgh & Olli 2019; Lillak & Roxburgh 2021). The limited penetration depth of these machines, when measuring the surface of corroded copper alloys, means that they cannot achieve an accurate reading for the original composition. This is because the corrosion process causes uneven leaching of copper and zinc (decuprification and dezincification) when compared to the remaining elements (Robbiola et al. 1998, 2108; Chiavari et al. 2007). To gain an accurate reading, a sizeable area of an object's surface has to be destructively cleaned to expose fresh internal metal. Given the current state of research, it is highly unlikely that permission would ever be granted to damage large numbers of objects in this way. The non-destructive survey method employed here adopts a much gentler approach. It has been established that although the measurement results of corroded surfaces deviate considerably from those of cleaned fresh metal, there is sufficient information available to allow an estimate of an object's original composition. Previous research has been able to visualise the changes between corroded and non-corroded measurements on Roman copper alloys (see Fig. 2: a). To compensate for the systematic deviation due to corrosion (seen in Fig. 2: a), it is neccessary to re-estimate the boundary lines between brass, gunmetal and bronze (see Fig. 2: b, as well as Appendix (diagram a) for previous positions). This has the effect of sorting large numbers of corroded measurements into groups that more closely match their original compositions. This approach has already been successfully employed (see Roxburgh 2021). The appendix also provides visual guides for objects made in the brass tradition (diagram c), bronze tradition (diagram d) and without a particular alloy preference (diagram b). It is also important to understand that a group of measurements giving a seemingly random result, such as diagram b, may also indicate a now lost surface treatment (such as a coating of tin to give a silvery appearance). This is discussed at length elsewhere (Bayley & Butcher 2004, 43; Bliujienė 2013, 360; Olli & Roxburgh 2018, 54–59).

A Bruker Tracer III-SD pXRF device was used to collect the elemental data. It was operated on its portable test bench and set up according to the manufacturer's standard operating guide. The devise was fitted with a yellow filter (set to position 1). This is the recommended setting for measuring high mass elements found in a copper alloy. Trial testing showed that the signal was stable at 60 seconds using the 40kev-10um setting. One measurement was then taken per object. The outputs were saved as PDZ files, from which a spectrograph could be produced. These were individually checked for inconsistencies using the manufacturer's own S1PXRF software. The CU1 and CU3 calibrations supplied by the manufacturer were then used to convert the data into quantitative numerical weights, before being transferred into a Microsoft Excel spreadsheet. Subsequently, data normalisation was done to remove the effects of soil contamination and light element residues. After that the results were visualised using ternary diagrams, which is useful to allow clusters of measurements to be compared against one another. This is in line with the scheme published by Bayley and



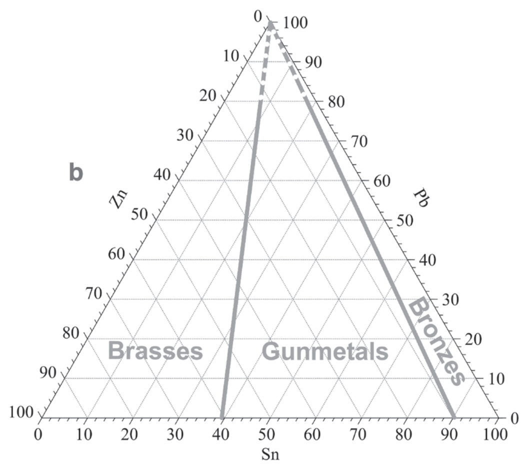


FIG. 2. Ternary diagrams illustrate the classification scheme. The upper diagram (a) shows how much the measurements can deviate between corroded and cleaned alloy surfaces (after Roxburgh et al. 2018, 63, fig. 2). The lower diagram (b) presents modified division lines to better classify corroded objects (after Roxburgh 2021, 193, fig. 5c).

Butcher (2004, 24). To aid scientific repeatablilty, the calibration of the device was compared to that of the Niton XL3t GOLDD XRF analyser using a shared set of samples. These results are published in Lillak & Roxburgh (2021, 78, appendix 2).

The analysis was divided into two parts as follows.

Part 1 – a total of 1246 items were measured by pXRF, taken from 49 locations across Estonia and northern Latvia (see Fig. 1). 271 items were assigned to the Pre-Roman Iron Age (object selection for the early *tarand* cemeteries was primarily based on the removal of all items that could be assigned to a later date). There were also 123 items dated to the early Roman period and 852 items dated to the late Roman Iron Age. The results of this first part are presented in pie charts to better show the ubiquity of each alloy in a given region at a given period.

Part 2 – a narrower group of 1053 objects was selected from part 1. This was formed of objects that could be readily assigned to the following categories: bracelets, brooches, pins, rings, spirals, spiral finger rings, closed finger rings, neck rings, ornaments. The aim was to better investigate the consistency of the alloys present within each category across the three time periods given. The results of this second part are presented in ternary diagrams.

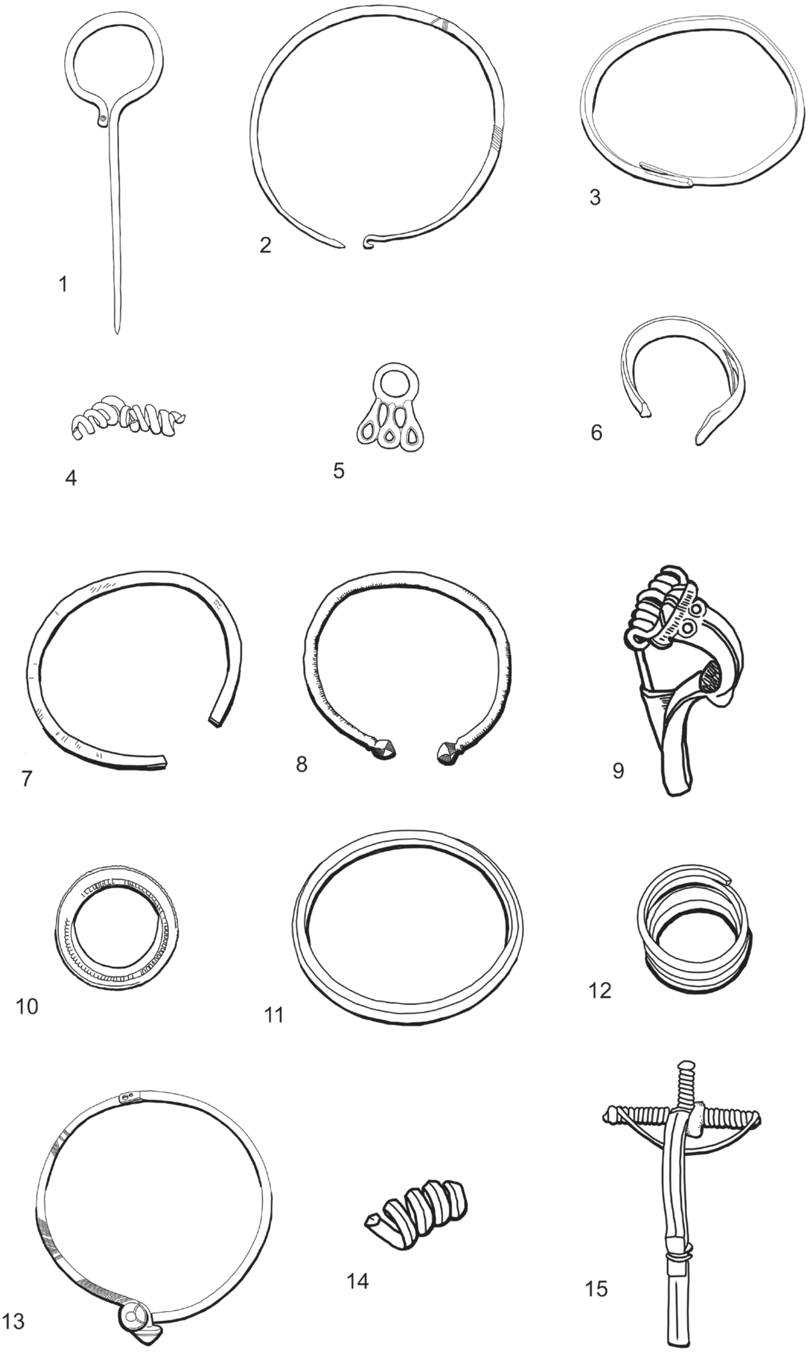


FIG. 3. Examples of analysed objects (from Lang 2007): 1 – pin (shepherd's crook), 2 – neck ring (Bräcksta type), 3 – bracelet (flat-convex cross-section), 4 – spiral (flat-convex cross-section), 5 – ornament (Volga-Oka), 6 – ring (flat-convex cross-section), 7 – serial armband (thin), 8 – bracelet (knob-ended), 9 – eye brooch (main series), 10 – finger ring (flat-ridged cross-section), 11 – serial armband (late), 12 – finger ring (spiral), 13 – neck ring (mushroom-ended), 14 – spiral (flat-ridged), 15 – crossbow brooch (tendril foot).

Material

This section is presented in two parts as per the divisions given in the methodology section. Examples of some of the most common object types are given in Fig. 3.

PART 1

The Pre-Roman Iron Age includes 125 bracelets, 41 rings, 15 fragments or molten globules, three mounts, nine neck rings, 27 ornaments, 18 pins, 28 spirals, five curved tubes. There are 194 objects from Saaremaa and 76 from north-eastern Estonia.

The early Roman Iron Age includes 45 bracelets, 61 brooches, ten finger rings, five neck rings, one pin, one curved tube and one unknown fragment. There are 113 objects from north-eastern Estonia and one from south-eastern Estonia, as well as nine from northern Latvia.

The late Roman Iron Age includes 310 brooches, 153 finger rings, 118 spiral tubes, 113 metal beads, 80 bracelets, 29 neck rings, 19 pendants, 12 fragments or molten globules, nine belt fittings or mounts, six pins, one chain hanger, one ornament, one strapend, one wire. There are 36 items from Saaremaa, 353 from south-eastern Estonia, 320 items from north-eastern Estonia, 38 from north-western Estonia, 20 from central Estonia and eight from south-western Estonia. There are a further 76 items from northern Latvia.

PART 2

The Pre-Roman Iron Age includes a total of 183 objects, including 99 bracelets, 27 ornaments, 23 spirals, 17 pins, 11 rings and six neck rings.

Bracelets – there are 80 bracelets from Saaremaa and 19 from north-eastern Estonia. They can be further organised by typology or cross-sectional shape as follows: flat-convex (64), D-shaped (20), O-shaped (8), flat-ridged (2), rectangular (1) and serial armbands (3). According to the locations given in Fig. 1, the Saaremaa sites are 1–5 and the sites in north-eastern Estonia are 11, 20, 21.

Ornaments – there are 27 ornaments, all from Saaremaa. They can be further organised as follows: Volga-Oka mounts (14), Ananyino belt mount (1), spoon-shaped mounts (6), other fragments (6). The sites are 1–5.

Spirals – there are 12 spiral objects from Saaremaa and 11 from north-eastern Estonia. They can be further organised by cross-sectional shape as follows: flat-convex (13), flat (6), flat-ridged (2), rectangular (2). The Saaremaa sites are 1–4. The site in north-eastern Estonia is 21.

Pins – there are 13 pins from Saaremaa and four from north-eastern Estonia. They can be further organised as follows: shepherd’s crook (8), ring-head (3), rolled head (1), fragments with an O-shaped cross-section (5). The Saaremaa sites are 3–5. The site in north-eastern Estonia is 21.

Rings – there are six rings from Saaremaa and five from north-eastern Estonia. All the rings are open-ended and can be further organised by cross-sectional shape as follows: flat-convex (6), flat-ridged (2), O-shaped (3). The Saaremaa sites are 2–5. The site in north-eastern Estonia is 21.

Neck rings – there are two neck rings from Saaremaa, three from north-eastern Estonia and one from south-western Estonia. They can be further organised as follows: Bräcksta type (3), upturned trumpet-ended (1), fragments with an O-shaped cross-section (2). The Saaremaa site is 4. The sites in north-eastern Estonia are 11, 21. The site in south-western Estonia is 30.

The early Roman Iron Age includes a total of 194 objects, including 71 bracelets, 63 finger rings and 60 brooches.

Bracelets – there are 69 bracelets from north-eastern Estonia, and two from northern Latvia. They can be further organised by typology or cross-sectional shape as follows: knob-ended (30), serial armband (26), flat-convex (11), hollow (2), D-shaped (1), spiral (1). The sites in north-eastern Estonia are 13, 16, 19–24. The sites in northern Latvia are 47, 49.

Finger rings – there are 38 closed finger rings from north-eastern Estonia, two from central Estonia, 21 from south-eastern Estonia, and two from northern Latvia. They can be further organised by cross-sectional shape as follows: hollow-ridged (30), hollow-convex (10), D-shaped (8), flat-convex (6), flat-ridged (4), O-shaped (4), other (3). The sites in north-eastern Estonia are 13, 19, 21, 22. The sites in central Estonia are 26, 29. The sites in south-eastern Estonia are 35, 36, 39, 42. The sites in northern Latvia are 47, 48.

Brooches – there are 53 brooches from north-eastern Estonia, one from south-eastern Estonia, and six from northern Latvia. They can be further organised by typology as follows: eye – main series (18), Prussian series (36), Estonian series 1 (1), Estonian series 2 (3); disc, group 8 (1); wire type, Almgren 15 (1). The sites in north-eastern Estonia are 11–13, 16, 19, 21–24. The site in south-eastern Estonia is 36. The sites in northern Latvia are 47–49.

The late Roman Iron Age includes a total of 675 objects, including 307 brooches, 134 spiral finger rings, 128 spirals, 80 bracelets, 26 neck rings.

Bracelets – there are 50 bracelets from north-eastern Estonia, 13 from south-eastern Estonia, one from south-western Estonia, and 16 from northern Latvia. The bracelets can be further organised by typology and cross-sectional shape as follows: serial armbands – late (46), D-shaped (9), rectangular (8), flat-convex (7), hollow-convex (6), other (4). The sites in north-eastern Estonia are 21, 22. The sites in south-eastern Estonia are 35, 36, 39. The site in south-eastern Estonia is 31. The sites in northern Latvia are 47, 49.

Spiral finger rings – there are 11 spiral finger rings from Saaremaa, 77 from north-eastern Estonia, 36 from south-eastern Estonia, and ten from northern Latvia. They can be further organised by typology and cross-sectional shape as follows: flat-convex (72), hollow-convex (14), O-shaped (14), flat-ridged (10), D-shaped (7), other (17). The sites in north-eastern Estonia are 13, 16, 19, 21, 22. The sites in south-eastern Estonia are 35, 36, 39, 42, 45, 46. The sites in northern Latvia are 47, 49.

Neck rings – there are 22 neck rings from north-eastern Estonia, two from south-eastern Estonia, one from south-western Estonia, and one from northern Latvia. They can be further organised by typology and cross-section as follows: trumpet-ended (10), mushroom-ended (9), other (7). The sites in north-eastern Estonia are 13, 21, 22. The sites in south-eastern Estonia are 35, 42. The site in south-western Estonia is 31. The site in northern Latvia is 48.

Spirals – there are 11 spirals from Saaremaa, 24 from north-eastern Estonia, 75 from south-eastern Estonia, and 18 from northern Latvia. They can be further organised by cross-sectional shape as follows: flat-convex (86), flat-ridged (28), rectangular (4), O-shaped (3), other (7). The Saaremaa sites are 1–5. The sites in north-eastern Estonia are 11, 21, 22. The sites in south-eastern Estonia are 35, 36, 39, 42, 45, 46. The sites in northern Latvia are 47–49.

Brooches – there are 122 brooches from north-eastern Estonia, 37 from north-western Estonia, 20 from central Estonia, 105 from south-eastern Estonia, six from south-western Estonia, and 17 from northern Latvia. They can be further organised by typology as follows: cross-ribbed – southern Estonian (26), Latvian (54), other (18); crossbow – tendril foot (80), triangular foot (6), other (15); eye – late Estonian (37); disc (36); head shield – knob foot (10), other (3); symmetrical (6); penannular (6); other(10). The sites in north-eastern Estonia are 11–14, 16–24. The sites in north-western Estonia are 6–10. The sites in central Estonia are 26–28. The sites in south-eastern Estonia are 34–46. The south-western sites are 32, 33. The sites in northern Latvia are 47, 48.

Results

The results are presented in two parts. The first part gives the alloy classifications of 1246 objects dating to the Pre-Roman and Roman Iron Ages. The results are displayed in pie charts to visualise the different alloy percentages per time period and per region. The second part presents the compositions of 1053 objects selected from the better dated typological groups. They are organised and displayed in ternary diagrams. These diagrams visualise how similar (or dissimilar) the alloys of the objects are within each typological group.

PART 1

Figure 4 shows the compositions of 1246 objects sorted into bronze, brass and gunmetal. The objects are subsequently sorted by period. The top pie chart presents 271 objects from the Pre-Roman Iron Age (500 BC–50 AD). The lower two charts present 975 objects from the Roman Iron Age. The Roman material is divided between objects with an early date and with a late date. Accordingly, there are 123 objects associated with the early Roman period (50–200 AD) and 852 objects related to the later Roman period (200–450 AD). The results show that the dominant alloy in the Pre-Roman Iron Age is bronze (99%). The dominant alloy of the early Roman Iron Age is brass (68%) and the dominant alloy of the late Roman Iron Age is gunmetal (57%).

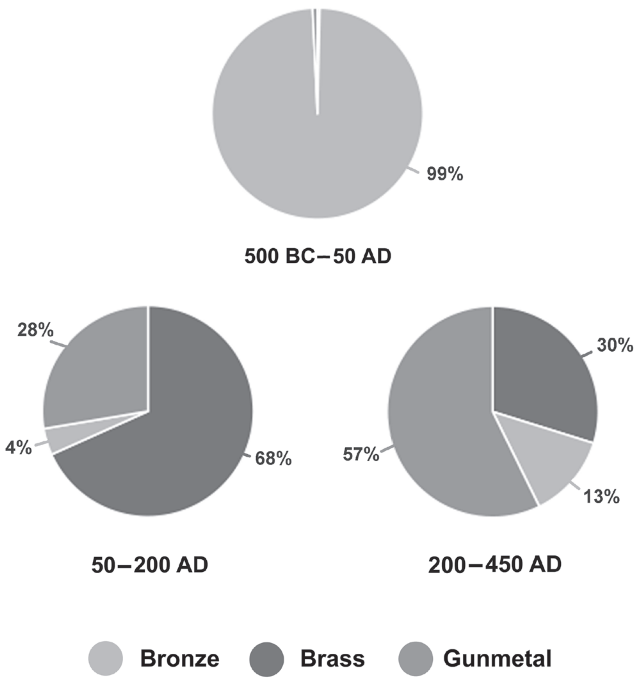


FIG. 4. Percentage of objects classified as bronze, brass and gunmetal, separated into Pre-Roman, early and late Roman time periods.

Figure 5 provides a more detailed overview of the compositional changes over time by region. The first region (top left) is north-eastern Estonia. The objects from that region are 100% bronze, dating from the Pre-Roman Iron Age. This changes noticeably to a 71% dominance of brass during the early Roman period, with the proportion of bronze reduced to only 4%. Brass is still dominant (47%) during the late Roman period but is closely followed by gunmetal (45%). The proportion of bronze increases slightly but accounts for only 13% of the objects (Fig. 4).

The objects from central Estonia originate from a slightly later date (150–450 AD) and are dominated by gunmetal (73%). After that, brass and bronze are about equally represented (15% and 12%, respectively). The objects from south-eastern Estonia date to the same period and have a similar result: gunmetal dominates (64%), followed by brass (22%) and bronze (14%). The objects from northern Latvia (100–450 AD) are almost identical in composition to those from south-eastern Estonia.

The objects from north-western Estonia date from a slightly later period (200–450 AD) and the results are different to those presented above. Gunmetal accounts for 50% of the objects, followed by brass (32%) and then bronze (18%). Saaremaa's

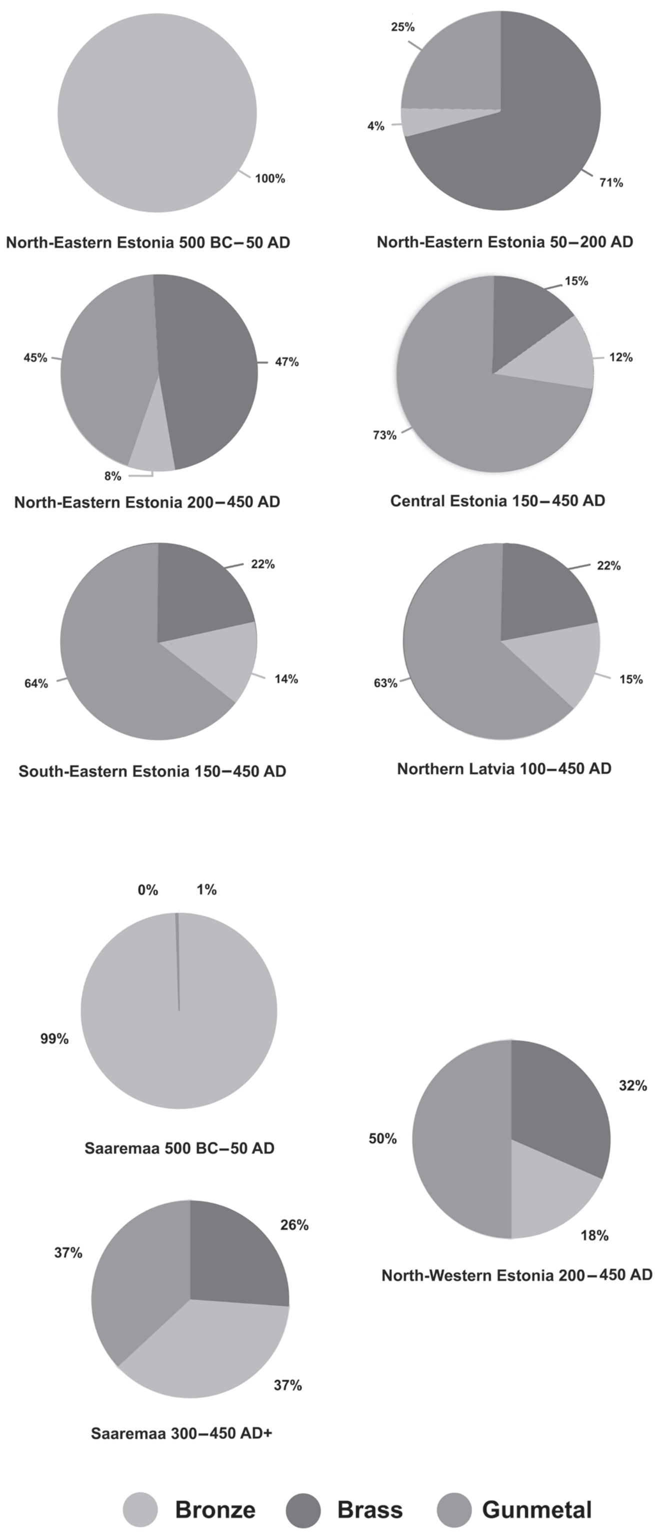


FIG. 5. Percentage of objects organised by region and by time period.

objects from the Pre-Roman Iron Age are made of bronze (99%), which closely matches the results from northern Estonia. The results for Saaremaa's late Roman Iron Age (300–450+ AD) are again quite different, showing an equal proportion of bronze and gunmetal (37% each), and a lower proportion of brass (26%).

PART 2

All the objects dating to the Pre-Roman Iron Age were included, but objects with dates only attributable to the broader Roman Iron Age were excluded from this part. This is because they could not be directly compared to object groups with a more focused early or late date.

The 183 Pre-Roman objects in Fig. 6 (bracelets, ornaments, rings, neck rings, pins and spirals) are all made of bronze. Nevertheless, this changes quite considerably in the results of the 194 objects from the early Roman Iron Age (Fig. 7). The results of the 71 bracelets show a clear trend between certain groups made of brass or bronze. All of the 26 serial armbands are in bronze. No other bracelets are made of bronze. Only one of the 30 knob-ended bracelets is in gunmetal, the rest are in brass. The remaining bracelet groups are a mixture of gunmetal or bronze, with no clear alloy preference. The brooches also show a trend between groups. All the 18 eye brooches from the main series are in brass. The 24 'Prussian' eye series brooches are equally made of brass or gunmetal. The one imported disc brooch is also in gunmetal, and the one imported wire brooch from the Danube River region is the only brooch in bronze. There appears to be no strict typological preference for the alloys chosen for the 65 closed finger rings. However, the bulk of them appear to be made of gunmetal (44). Also, the 16 rings produced in brass have a lower zinc content compared to the bracelets and brooches mentioned above (none exceed the 80% line for Zn).

The results of the 675 objects from the late Roman Iron Age can be described as follows. Bracelets (88) are the first object group in Fig. 8. There are 46 late serial armbands in the group, with the majority (35 items or 76%) made of brass. There are nine bracelets with a D-shaped cross-section and 77% of them are also in brass. There are seven bracelets with a flat-convex cross-section, 71% of which are made of brass. Further, there are eight bracelets of rectangular cross-section and 75% of them are in brass. There is also a smaller group of six bracelets of hollow-convex cross-section, of which five (83%) are in brass. The results for the 307 late Roman brooches show little preference in alloy choice. Within this group there are 100 crossbow brooches, of which 61 are gunmetal, 29 are brass and ten are bronze. There are also 98 cross-ribbed brooches, of which 66 are gunmetal, 19 are brass and 13 bronze. There are 37 late Estonian eye brooches, 24 in gunmetal, 11 in brass and two in bronze.

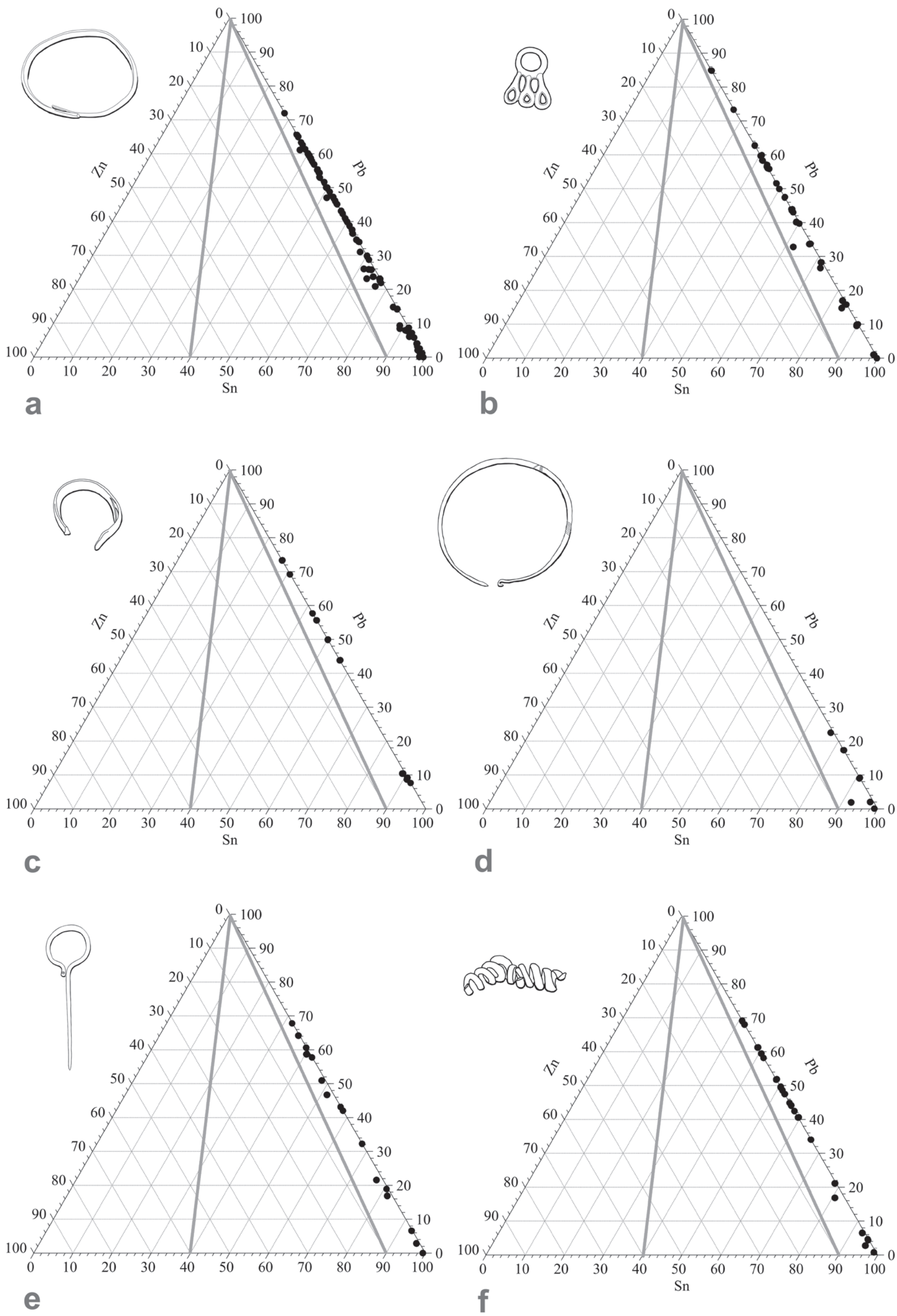


FIG. 6. Pre-Roman Iron Age. a – bracelets, b – ornaments, c – rings, d – neck rings, e – pins, f – spirals.

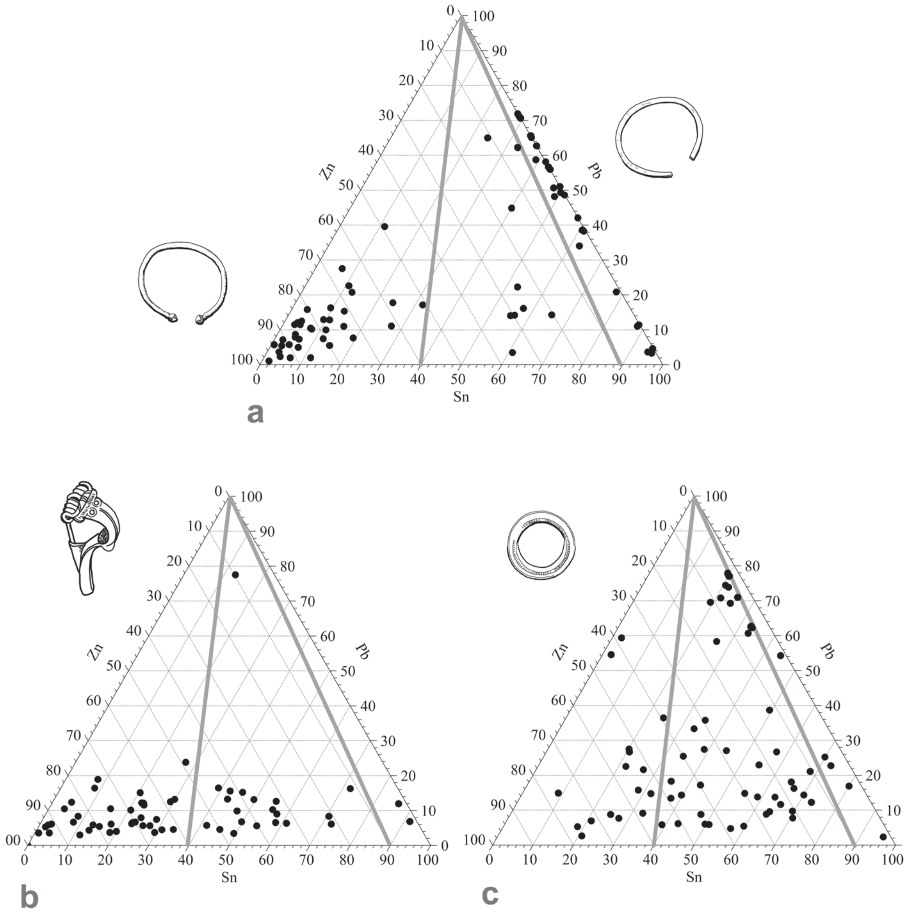


FIG. 7. Early Roman Iron Age. a – bracelets, b – brooches, c – closed finger rings.

There are 36 disc brooches, of which 24 are gunmetal, six are brass, and six are bronze. Also, there are 13 head-shield brooches, of which eight are gunmetal, four are brass and one is bronze. As to the brooches, there is little evidence of alloy preference amongst the 135 spiral finger rings. There are 61 spiral finger rings in gunmetal, 41 in brass, and 29 in bronze. There are 128 other spiral objects and they too show little alloy preference. There are 64 in gunmetal, 39 in brass and 25 in bronze. Finally, the results of the 26 neck rings also show no alloy preference. There are 13 in gunmetal, ten in brass and three in bronze.

Discussion

The aim of the research was to establish which copper alloys were in use during the Pre-Roman and Roman Iron Ages, and then to determine whether there are any chronological trends in the alloy choice for the various typological groups.

The pXRF method was able to successfully sort a large number of objects into three alloy classifications. The following can be given in answer to the questions presented earlier. There is clear evidence for a transition between the copper alloy used in the Pre-Roman Iron Age and that used at the beginning of the Roman Iron Age. The Pre-Roman Iron Age is almost completely dominated by zinc-free bronze (99%; see Fig. 4). The remaining 1%, however, comprises only one item, a spoon-shaped ornament of the Kõmsi type from Saaremaa (AI 4780: 34), which contained zinc (perhaps from recycled brass scrap). Dated to the late Pre-Roman Iron Age, it could even tentatively be from a time when brass objects were beginning to circulate. On the basis of this additional information, it can be selected for further examination. However, by the beginning of Estonia's Roman Iron Age, bronze had almost completely disappeared in favour of brass. The best quality brass (i.e. with the highest zinc content) strongly correlates with the knob-ended bracelets and the eye brooches of the main series. The early serial armbands are almost entirely bronze by comparison, and if they were in circulation during the early Roman period, one could assume that they were also in brass, if coming from the same material source as the knob-ended bracelets and eye brooches. By their composition these bronze armbands are associated more closely with the Pre-Roman Iron Age. Either their circulation date is wrong and they should be reassigned to the late Pre-Roman period, or they are evidence of the survival of a tradition of bronze-made objects that runs in parallel to newly arriving objects made of brass. This dual circulation theory matches the evidence from Lithuania and Slovenia. Istenič and Šmit showed for Slovenia that brass was in regular use for some items in the Roman province of Pannonia from 60 BC onwards. As for Lithuania, Bliujienė suggests that the copper alloy started to shift from bronze to brass between the 1st century BC and the middle of the 1st century AD. But then a large-scale shift to brass occurred around the middle of the 1st century AD. The dual presence of early bronze serial armbands together with high-zinc brass knob-ended bracelets match the period before this large-scale shift. However, that would suggest that these objects were in circulation before the beginning of Estonia's Roman Iron Age. It may be thought that the beginning date of 50 AD is more reflective of the large-scale shift to brass observed in Lithuanian data. In this model, therefore, the transition from bronze to brass in Estonia and northern Latvia matches the timeline of the transition in Lithuania.

The last question was whether there is any possible evidence of the zinc decline observed in other parts of Europe during the Roman period. The answer is yes. The overall results for the late Roman Iron Age (Fig. 4) as well as the results by region (Fig. 5) show a large drop in the use of brass in favour of gunmetal during this time. It also appears that the number of bronze objects started to grow again towards the end of the Roman period (e.g. Saaremaa 300–450+ AD; Fig. 5). Nevertheless, the amount of brass present in north-eastern Estonia seems much higher than in other regions (Fig. 5). Perhaps brass entered Estonia from here even during the late period. The zinc decline can be seen especially in the results for the closed finger rings in Fig. 7.

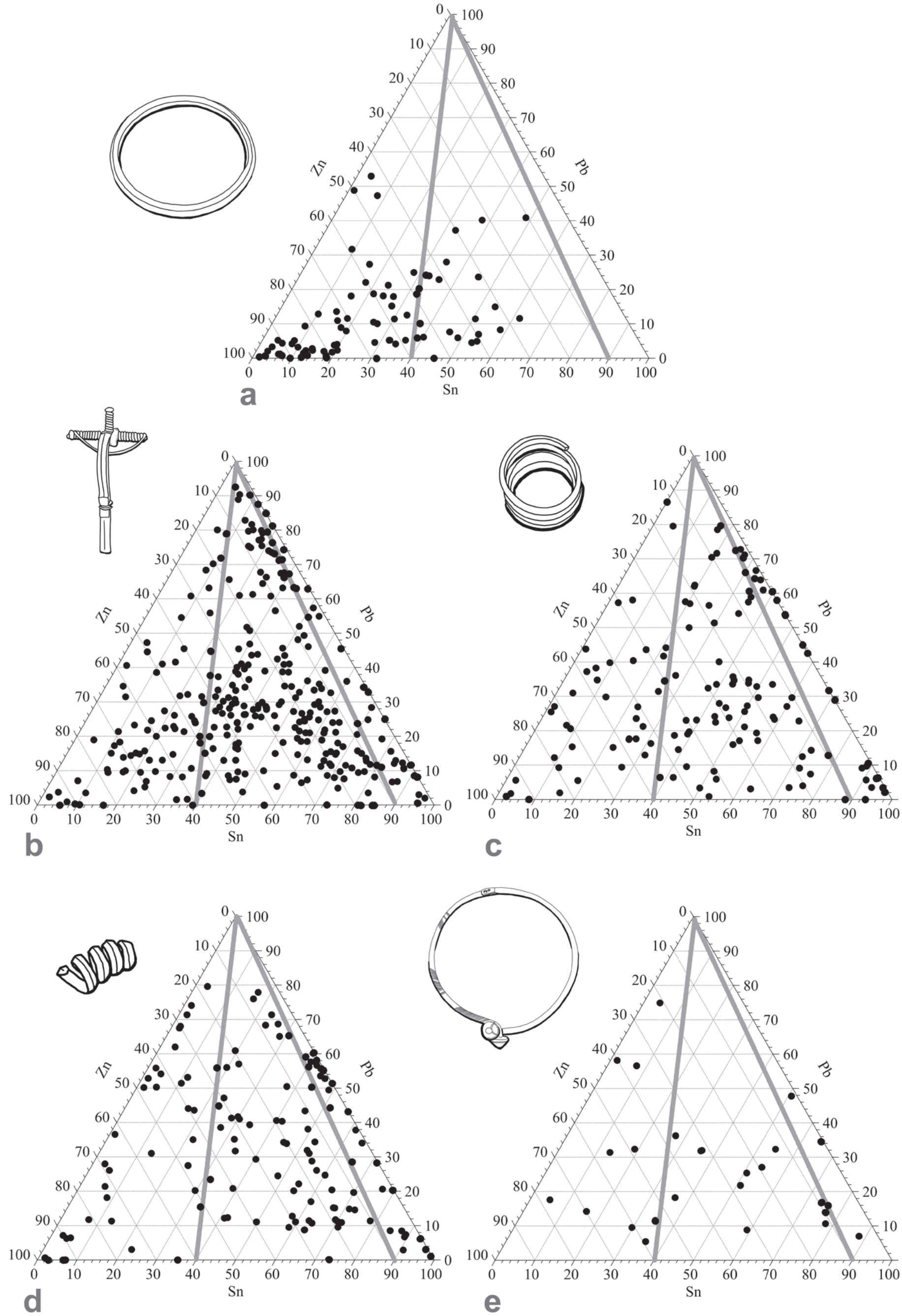


FIG. 8. Late Roman Iron Age. a – bracelets, b – brooches, c – spiral finger rings, d – spirals, e – neck rings.

These rings date to around the beginning of the 2nd century AD and all of them, including the ones classified as brass, have a noticeably higher tin content that the earlier eye brooches, and knob-ended bracelets. This is also true of the Prussian series brooches which had a higher level of tin in them than the main series. The continually high amount of brass observed in north-eastern Estonia, even in the late Roman period, suggests that it arrived by sea along this coastline, either in the form of imported goods or as raw metal supply. This entry point would seem to be the favoured 'landing' location throughout the Roman period, demonstrating continuity in long-distance contacts with neighbours around the Baltic Sea and further. Once arrived, this imported metal may have been distributed to the hinterland in smaller quantities (and perhaps in different forms).

A further observation is that there has been little attempt to organise the production of objects along the lines of controlled compositions during the late Roman Iron Age. The use of brass, bronze or gunmetal appears to have become quite arbitrary by this time. However, this randomness could in some cases be evidence for tin-based surface treatments becoming popular at this time (i.e. to give the external surface of an object a silvery appearance). More detailed investigations are required on this issue in the future. An exception to this are the late serial armbands, in the case of which the results demonstrate a strong preference for brass. This is unusual, as they do not appear to match the zinc decline seen in the other objects. It could be that the start date for these objects should be earlier, i.e. the early Roman period, or that their alloy source is different. If they are from the late Roman period, could they have been valued differently in some way?

As discussed above, these results were limited to a non-destructive survey of corroded surfaces of these objects. The method has been shown to be capable of classifying items into basic groups, which allowed them to be studied based on the above research questions. Improvements in non-destructive techniques are needed now to evaluate these changes more closely in the future.

Conclusions

Brass quickly overtook bronze as the dominant copper alloy across vast areas of the Roman world and beyond during the 1st century BC. It has also been established that the quality of this brass changed over time. Based on evidence from Roman coinage, brass had the highest zinc content during the early Roman Empire, after which it declined noticeably over the following centuries. This decline in zinc content over time has been shown to be of use as a dating technique.

To establish whether a rapid transition from bronze to brass also took place in the north-eastern Baltic, a large number of objects were analysed non-destructively by pXRF. They were mainly sourced from *tarand* cemeteries of Estonia and northern Latvia, which date to the Pre-Roman and Roman Iron Ages. The aim was to establish which copper alloys were in use during these periods, and then to determine whether any chronological trends were visible and, if so, for which typological groups. It is clear from the results that there was a major shift from bronze to brass towards the end of the Pre-Roman and the early Roman Iron Ages. Subsequently, there was a decline in brass in favour of gunmetal over the following centuries. This transition is similar to the published evidence from other parts of the Roman world. The earliest known brass objects from the *tarand* grave areas appear to have been in circulation at the same time as bronze armrings. This suggests the existence of an introductory period similar to the ones identified closer to the Roman world, in Lithuania and Slovenia. The introductory period in the southerly region dates from the late 1st century BC to the early 1st century AD (but with a large-scale uptake of brass during the middle of the 1st century). However, the Roman Iron Age in Estonia is only thought to have begun in the late 1st century AD. The best hypothesis is that Estonia was also experiencing these changes, either later or perhaps at the same time as in those southerly areas. A better criterion needs to be established for defining the start of Estonia's Roman Iron Age. One of the criteria should at least be the first arrival of 'Roman' brass objects in the region, and another the time when brass became the norm.

This pXRF survey has given us a better understanding of the arrival of brass in the north-eastern Baltic and also identified a decline in its use over time, matching the patterns observed in areas closer to the Roman world. It adds to our knowledge about the effectiveness of long-distance trade and communication networks that transferred new objects, ideas, and technologies to these distant northern communities.

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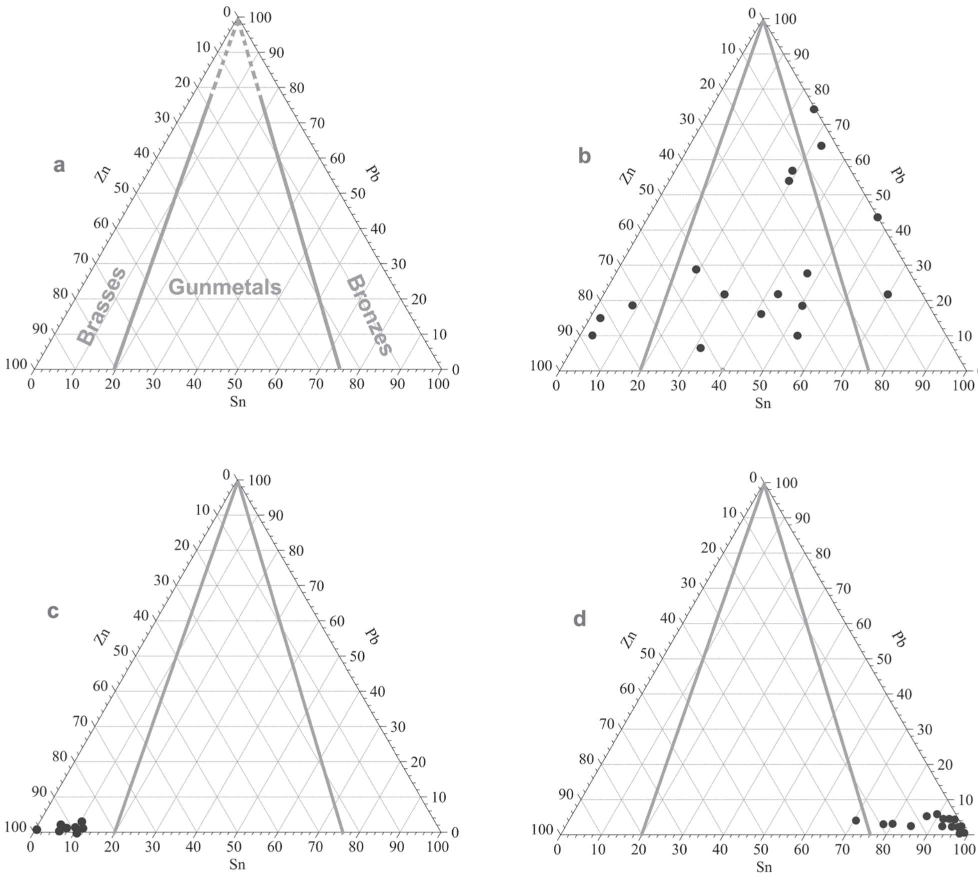
Appendix



a – alloy boundaries for uncorroded measurements (after Bayley & Butcher 2004, 24, fig. 7), b – disc brooches from north-western Europe (ibid., 176, fig. 151), c – eye series brooches (after Bayley & Butcher 1995, 115, fig. 4: 1), d – wire type A46 brooches (after Roxburgh et al. 2017, 252, fig. 5.3.16). Compiled by author.

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„Rooma messingiaeg“: portatiivse röntgenfluorestsents-spekromeetriga (pXRF) tuvastatud vasesulamite koostise muutused rooma rauaajal Eestis ja Põhja-Lätis

Marcus Adrian Roxburgh

RESÜMEE

Iidne vase ja tina sulam, mida me tänapäeval tunneme pronksina, on üldtuntud. Hoopis vähem on teada tõsiasi, et 1. sajandil eKr muutus Rooma maailma suurtel aladel ja kaugemalgi kiiresti domineerivaks hoopis teistsuguse koostisega vasesulam. See uus materjal, mida roomlased nimetasid *orichalcum*'iks ning mille tänapäevane nimetus on messing, koosneb vasest ja tsingist. Uus materjal võeti kiiresti kasutusele militaarvaldkonnas ning mündinduses, mis osutab sellele, et messingi tootmist ja levitamist kontrollis vähemalt esialgu mingil määral Rooma riik. Oluliseks teguriks messingesemete kiirel levikul Euroopas arvatakse olevat keiser Augustuse mündireform umbes 23. aastal eKr, mil messing võeti kasutusele mitteväärismetallist müntide materjalina. Samuti on kindlaks tehtud, et mündimessingi kvaliteet (tsingisisalduse poolest) aja jooksul muutus. Messingraha müntimisandmetele tuginedes oli nende tsingisisaldus kõrgeim varajase Rooma keisririigi ajal. Tsingisisaldus hakkab aga 1. sajandi teisel poolel pKr vähenema, muutudes 3. sajandi alguseks peaaegu olematuks. Languse põhjus võis olla vanametalli taaskasutuse suurenemine, mis tingitud tsingimaagi tarnimise katkemisest või tehnoloogilise oskusteabe kadumisest. On aga ka vastuargumente, mis viitavad sellele, et tsingisisalduse vähendamine oli tahtlik valik ja et hilise impeeriumi ajal muutus pronksi ja messingi segasulam levinumaks. Tänapäeval tuntakse seda punapronksina (*gunmetal*), kuid materjal ei pruukinud tingimata pärineda taaskasutusel ümbersulatatud esemeist.

Nii või teisiti vähenes messingi tsingisisaldus aegamööda kogu Rooma perioodi vältel, mida saab kasutada arheoloogilise materjali dateerimiseks. Seda võimalust on viimasel ajal rakendatud piiratud hulga Eesti ja Põhja-Läti tarandkalmete levikualalt pärinevate vasesulamist esemete uurimisel. Selgus, et varasemate käevõrude messingi kvaliteet vastab kõige enam varajase Rooma impeeriumi aegsele messingile. Rooma maailmaga tihedamalt seotud maadest leitud sarnaste esemete dateeringud toetasid samuti oletust, et need olid Eestis käibel seni arvatust varem. Kuid kas kiire üleminek pronksilt messingile toimus ka Kirde-Läänemere piirkonnast kaugemal või jäi see liiga eemale, et olla osa uues „Rooma messingi“ ajastus? Selle küsimuse lahendamiseks analüüsiti objektisäästlikul meetodil suurt hulka vasesulameist esemeid kaasaskantava röntgenfluorestsents-spektromeetriga (pXRF), et luua üksikesemete uurimiseks vajalik vasesulamite üldklassifikatsioon. Vaatamata mõningatele piirangutele saab seadet kasutada arheoloogiliste materjalide, sealhulgas korrodeerunud vasesulamist leidude elementanalüüsiks. Esemed saadi peamiselt Eesti ja Põhja-Läti tarandkalmistutelt, mis pärinevad eelrooma ja rooma rauaajast (500 eKr – 450 pKr). Töö eesmärgiks oli välja selgitada, millised vasesulamid olid kasutusel eelrooma ja rooma rauaajal ning seejärel teha kindlaks, kas sulamivalikus on kronoloogilisi suundumusi ja kui jah, siis milliste tüpoloogiliste esemerühmade puhul.

Sõnastati järgmised küsimused:

Kas on tõendeid pronksilt messingile üleminekust Läänemere kirdeosa piirkondades?

Kui jah, siis kas üleminek toimus samal ajal Euroopa lõunapoolsemate piirkondadega?

Kui toimus, siis kas on tõendeid tsingisisalduse vähenemise kohta vasesulamites, nagu see ilmnes mujal Euroopas kogu Rooma perioodi vältel?

Uuringutulemustest selgus, et eelrooma ja varajase rooma rauaaja lõpul toimus materjalikasutuses tõepoolest suur nihe pronksilt messingile. Seejärel langes messingi osakaal järgmiste sajandite jooksul punapronksi kasuks. Selline üleminek sarnaneb juba varem publitseeritud andmetega teistest kunagise Rooma maailma piirkondadest. Varasemad teadaolevad messingist esemed tarandkalmete levialalt näivad olevat olnud käibel samaaegselt pronksist käevõrudega. See viitab nn sissejuhatava perioodi olemasolule, mis sarnaneb kunagisele Rooma maailmale lähemal paiknenud Leedus ja Sloveenias tuvastatud sarnase perioodiga, mis lõunapoolsetes piirkondades vältas 1. sajandi lõpust eKr kuni 1. sajandi alguseni pKr (messingi laialdane kasutuselevõtt toimus 1. sajandi keskpaigas pKr). Ometi arvatakse rooma rauaaeg Eestis algavat alles 1. sajandi keskel pKr. Parim hüpotees antud juhul on, et ka Eesti ja Põhja-Läti kogesid samasuguseid muutusi kas veidi hiljem või isegi samal ajal lõunapoolsete aladega. Sellest lähtub vajadus sätestada parem kriteerium Eesti rooma rauaaja alguse määratlemiseks. Üks lähtepunkt selleks saaks olla „rooma“ messingist esemete esmane saabumine piirkonda ja aeg, mille jooksul messing üldiseks levis.

Artikli aluseks olnud pXRF-uuring andis meile parema ülevaate messingi saabumisest Läänemere kirdepiirkonna aladele ja võimaldas tuvastada ka selle kasutamise aeglast hääbumist, mis vastab Rooma maailmale lähemal asunud lõunapoolsemate piirkondade vastavatele mustritele. Samal ajal täiendasid uuringutulemused teadmisi omaaegsest tõhusast kaugkaubandusest ja kaubandusvõrkude süsteemist, millega edastati uusi materjale, esemeid, ideid ning tehnoloogilisi uuendusi kaugematesse põhjapoolsetesse kogukondadesse.