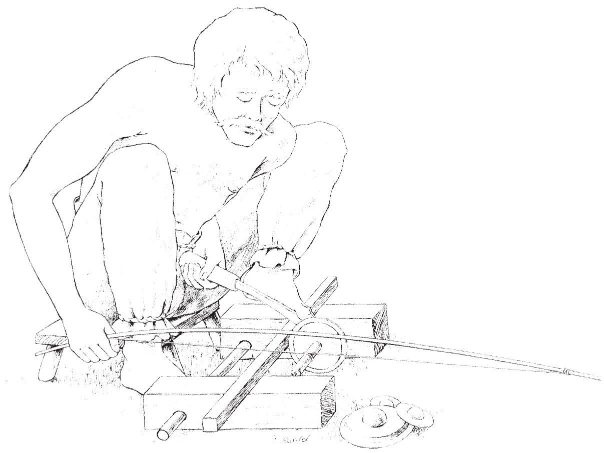
Proceedings of the 5th International
Conference " Archaeometallurgy in Europe "

Monographies Instrumentum
73



Collection dirigée par
Michel Feugère

PROCEEDINGS

of the

5th International Conference „Archaeometallurgy in Europe”

19-21 June 2019

Miskolc, Hungary

Editors:

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Layout:

Béla TÖRÖK
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éditions
Mergoil

Diffusion, vente par correspondance
Editions Mergoil - 13 Rue des Peupliers - 31280 Drémil-Lafage
e-mail : contact@editions-mergoil.com
ISBN : 978-2-35518-121-4
ISSN : 1278 - 3846

Mise en page : Béla TÖRÖK, Boglárka TÓTH
Couverture : Editions Mergoil, illustration B. Török

Impression : Aquiprint
Dépôt légal octobre 2021

TABLE OF CONTENT

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Non-ferrous metals in Roman (Late Republican and Early Imperial) military equipment from the River Ljubljanica, central Slovenia

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Abstract

The River Ljubljanica, running through central Slovenia, has yielded a wealth of archaeological finds including 79 pieces of Roman military equipment. An in-depth research of these pieces (Istenič 2019), mostly from the Middle and Late Augustan periods (15 BC to AD 14), included a study of the technological processes involved in their production, as well as the characterisation of non-ferrous metals (33 objects are in whole or partly of non-ferrous metals).
The results of analyses were compared to Roman military finds from other sites (as far as analysed) and discussed in the wider context of Early Imperial Roman military production.

Non-ferrous metals in Roman (Late Republican and Early Imperial) military equipment from the River Ljubljanica, central Slovenia

Janka Istenič
Žiga Šmit

Introduction

The 23 km long silty riverbed of the River Ljubljanica (Roman Nauportus) in its stretch across the marshy plain of the Ljubljansko barje, from Vrhnika (Roman Nauportus) to Ljubljana (Roman Emona; Fig. 1), has yielded a multitude of artefacts ranging in date from the Early Stone Age to the modern period. Among the many European rivers rich in archaeological finds, the course of the Ljubljanica across the Barje stands out for the large number of finds per riverbed length. Roman finds are very well represented. Most are pottery; the narrowly dated items indicate a peak in the periods of the Emperors Augustus (27 BC – AD 14) and Tiberius (AD 14–37; Istenič 2019, 16–21, 222–224, Figs. 1–5, 130).

The assemblage of the Roman militaria from the river dating up to the 3rd century comprises 79 items. Very few are earlier than the beginning of the Augustan period (27 BC) or later than the end of the Augustan (AD 14) or the Early Tiberian period (c. AD 14–20). Different groups of military equipment occur in different numbers: swords largely predominate over daggers and all other groups of objects, while cuirass pieces are absent altogether. Most of the militaria can reasonably safely be assumed to have entered the Ljubljanica more or less complete and without intentional damage (Istenič 2019, 16–21, 208, 210–212, 216–218, Figs. 123–127).

The available evidence suggests that the chronological and spatial distribution of Roman military equipment in the riverbed of the Ljubljanica between Vrhnika and Ljubljana was mainly determined by two factors:

– firstly, the great importance of the navigable route along the Ljubljanica for provisioning the Roman army from the mid-1st century BC to the end of the Augustan period, i.e. in the time when the Romans were engaged in conquering territories and imposing the Roman rule in the south-eastern Alps, the northern Balkans and the central Danube Basin,

– secondly, the location of the eastern border of Cisalpine Gaul/Italy after 42 BC, that is of *ager limitatus* just upstream from the bend of the Ljubljanica, where the boundary stone between the territories of Aquileia and Emona was found (Fig. 1).

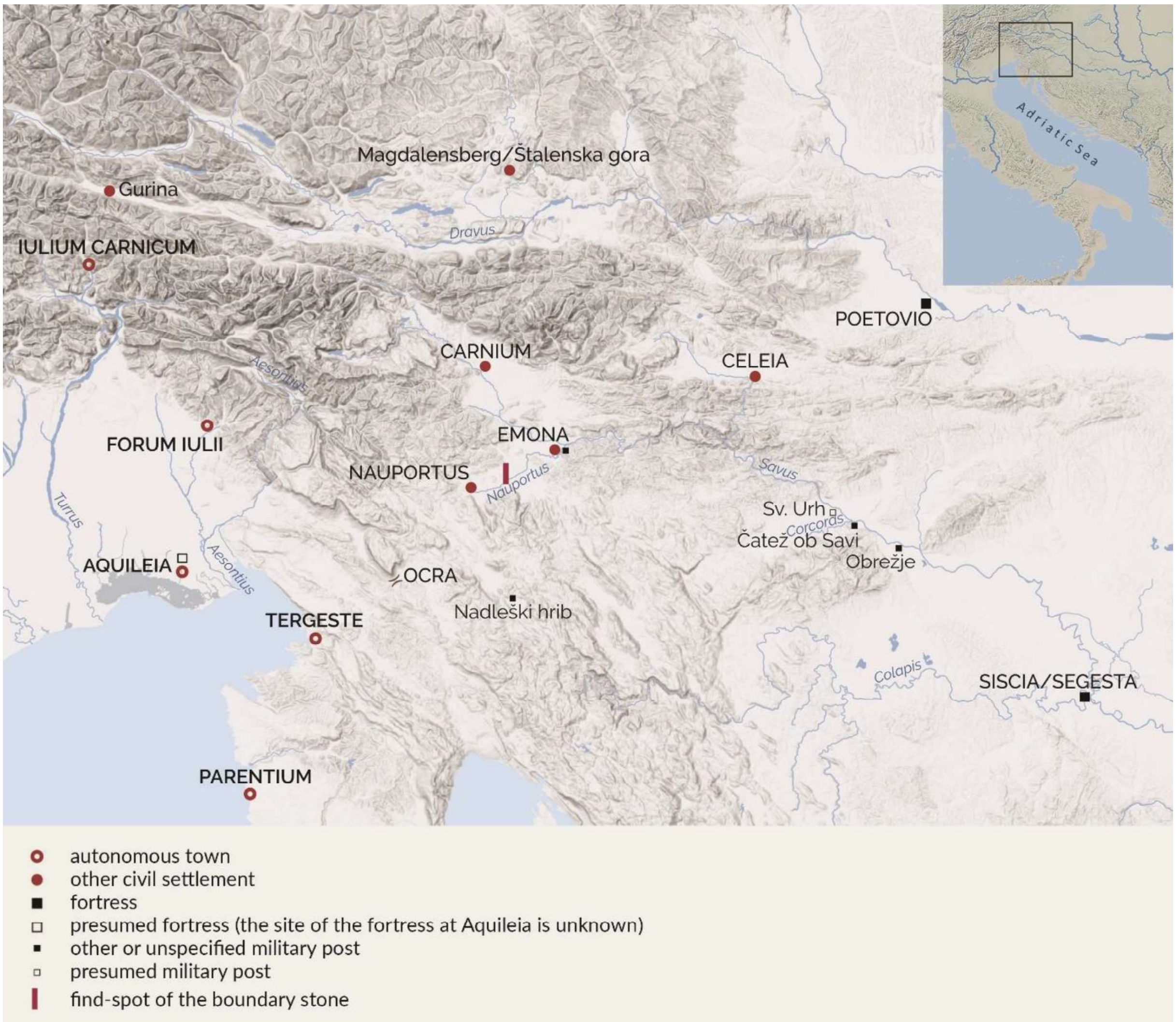

Fig. 1: The wider geo-political situation of the River Ljubljanica (Nauportus) in the first decade AD.

Both factors changed significantly roughly at the same time, at the end of the Augustan or beginning of the Tiberian period, when the road between Nauportus and Emona was built and (presumably) the colony of Emona was founded.

The high numbers of militaria and several other groups of finds from the Ljubljanica seem to be mainly related to the activities at the harbours and presumed control points along the river, as well as to the conjectured religious rituals performed before crossing the boundary of *ager limitatus* (Istenič 2019, 218–231, 235–256, Figs. 128–146).

An in-depth research of the Roman military finds up to the 3rd century (Istenič 2019) included a study of the technological processes involved in their production, as well as the characterisation of non-ferrous metals.

Objectives

The aim of the research was to gain a better insight into the production of Roman military equipment, especially the degree of its uniformity and the use of different metals, but also how this production was organised.

Experimental

Proton-induced X-ray emission spectrometry (PIXE) was selected as the analytical method. With the examples that contain light elements, i.e. those with enamels, we combined PIXE with the method of proton-induced gamma rays (PIGE).

The measurements were taken at the Tandetron accelerator of the Jožef Stefan Institute, using the in-air measuring line (Istenič and Šmit 2019, 144, 146). They were performed between 1999

and 2017, mostly on the surface of objects after the conservation procedure (Milić et al. 2009). At the points selected for metal core measurement, we removed the patina (the expression is used as a synonym for surface corrosion/oxides) in a 2–3 mm^2 large area. Inspection under a stereo microscope revealed that it was difficult to completely remove the patina, hence the analytical results from such points refer to the metal core with minimal remains of the patina. It should be noted that the areas with traces of the patina were very small in comparison with the bare metal hit by the beam.
In a few cases, we additionally narrowed the beam size to about 0.3 mm at the target. This set-up was only used for select objects as it resulted in a very low X-ray count rate (Istenič and Šmit 2019, 146).

We were able to measure the concentration of Cu, Zn and Pb with a relative accuracy of a few percent. The accuracy of small concentrations of Ag, Sn and Sb may be uncertain up to ±10% of the measured values. The detection limit of zinc was approximately 0.4%. The detection limits for lead (Pb), bismuth (Bi), arsenic (As) and selenium (Se) were about 0.05%, while the arsenic K lines could only be resolved from the lead L lines through the arsenic Kβ line – the fitting procedure, however, involved line groups evolving from the same shell, i.e. K lines for As and individual L1, L2 and L3 contributions for Pb. The detection limits for silver (Ag), tin (Sn) and antimony (Sb) were 0.1–0.2% (Istenič and Šmit 2019, 146).

Results

We examined 33 objects, in whole or partly of non-ferrous metals: nineteen swords and associated scabbards, four daggers and associated sheaths, two helmets, six pieces of military belts and two military decorations. The full data-set of the results has been published recently (Istenič and Šmit 2019, 151–189) and can be openly accessed at the first author's homepage as well as at her pages at academia.edu and ResearchGate.
By far the commonest copper alloy in the Roman military equipment from the Ljubljanica is brass. It is used for most mounts and decorative elements on sword scabbards (Fig. 2), dagger sheaths, helmets and belts.

Fig. 2: Front of the A5 sword and scabbard (sword length 723 mm), of the Mainz type, from the River Ljubljanica. Swords and scabbards of this type are the characteristic Roman infantry weapon from about 20 BC to the middle of the 1st century AD. The scabbard front sheet and fitments are brass, the sheet is tinned. The handguard plate of the sword A5 is copper, while those of other Mainz type swords are bronze.

Fig. 3: Remains of inlaid brass decoration on the front of the B2 iron dagger sheath from the River Ljubljanica. Magnification 16x.

These items were made and decorated by cold working. The brass elemental composition shows they were made from ingots, billets or possibly other objects of pure brass (Istenič 2019, 190, 192, 194; Istenič and Šmit 2019, A1, A2, A3, A5–A11, A19, A20, A23, A34, B1, B2, H2, H4, MM SG). Brass was also used to decorate iron surfaces, as inlaid decoration (Fig. 3).

Bronze is rare and only occurs as a binary copper-tin alloy in forged objects. It is used for helmets (Fig. 4), commonly for handguard plates of the Mainz type swords and in one case for the front sheet of a sword scabbard (Istenič 2019, 194, 196; Istenič and Šmit 2019, C1, C2, A6–A9, A15, A16, A19).

Tin was rarely used for soldering and exceptionally for filling (Istenič and Šmit 2019, A5, A6, A7, A13, A15, A20), but frequently for plating. All the sheet-metal (usually brass and in one example bronze) fronts of the sword scabbards are tinned (Fig. 2), as are the undersides of the handguard plates (of either bronze or copper) of swords (Fig. 5; Istenič and Šmit 2019, A5–A7, A9, A10, A16). Tin plating increases mechanical hardness, forming copper-

Fig. 4: Side of the C2 helmet (height 193 mm) from the River Ljubljanica. The helmet bowl is bronze (Cu with 10-11%). The cheek piece hinges are also bronze (Cu with *c.* 5% Sn) and the rivets that fasten them to the bowl are copper. The pure brass plume tubes (Cu with *c.* 14%, 22% and 23% Zn, respectively) were soldered to the sides and back of the bowl with a tin-lead alloy.

Fig. 5: Handguard plate (72 mm wide) underside of the A5 sword from the River Ljubljanica; tinned copper.

tin intermetallic compounds (Meeks 1993, 256-257), but was most probably present on these pieces for appearance' sake, as the polished tinned surface gave the appearance of silver (Istenič 2019, 198). A torque, probably a military decoration, is of an alloy of tin with around 2% copper; the small addition of copper made the metal much harder (Istenič and Šmit 2019, I2; Istenič and Ragolič 2021).

Fig. 6: The I1 medallion (diameter 48 mm) with the depiction of emperor Augustus from the River Ljubljanica, probably part of a military decoration; cast of tin-lead alloy and silvered at the front (silvering only detected by analyses).

Fig. 7: Back of the A7 sword and scabbard (width 60 mm) from the River Ljubljanica; soldering (tin-lead alloy) at the brass crossband on the left and copper rivet on the right.

Fig. 8: Front of the H1 belt plate (width 51 mm) from the River Ljubljanica; gilded silver.

Fig. 9: Silver inlaid decoration on the front of the B2 iron dagger sheath from the River Ljubljanica. A groove for inlaid decoration shows minute transverse incisions and remains of inlaid silver. Magnification 9x.

Binary tin-lead alloy was used for casting relatively cheap products with relief decoration (Fig. 6), for most of the soldering (Fig. 7) and in one case for surface decoration (Istenič 2019, 200; Istenič and Šmit 2019, A1, A6, A7, A8, A9, A11, A13/MM A34, B1, H4, H5, I1, I2).

Silver is rare and was used as the high-quality silver alloy (*c*. 96–97% Ag) for prestige items (Fig. 8) and for plating, the latter as: i) sheet silver covering the iron guttering of a sword sheath or ii) a thin surface layer on artefacts of brass or tin-lead alloy (Fig. 6; Istenič 2019, 196, 198; Istenič and Šmit 2019, A12, H2, I1). It was also used for decorating iron surfaces, as inlaid decoration (Fig. 9).
Most of the rivets (Figs. 4, 7) and at least one sword handguard plate (Figs. 2, 5) are copper (Istenič and Šmit 2019, A5, A6, C1, C2, H2).

Discussion

The study of the metals of the Roman military equipment from the Ljubljanica has revealed a high degree of uniformity in the materials, both in the choice of metals and in their elemental composition. This corresponds with the findings pertaining to the rather uniform construction of a large part of the Mainz type swords/scabbards (cf. Istenič 2019, 52–57, 19) and the daggers/sheaths from the Ljubljanica (Istenič 2019, 82–86), but also to the rather homogeneous picture provided by the military equipment from the Augustan period in general (Istenič 2019, 202).

The elemental composition of Roman military finds from the Ljubljanica shows how a specific metal was employed for a particular kind of product that best suited its production and function. This is clearly seen in helmets and rivets. As in prehistory, Roman helmets in the Augustan era continued to be made of bronze. The reason they were not made of brass should probably be sought in the higher hardness of the copper-tin alloy with 10% tin (just under 1000 N/mm^2) compared to the copper-zinc alloy with 20% zinc (and around 700 N/mm^2). Helmets were therefore made of bronze because of its hardness even though it required more effort when cold working (forging, polishing) than brass; tin bronze has lower tensile strength and, more importantly, lower ductility than brass (Voß et al. 1998, 184, 185, Figs. 22, 23). As for the rivets, most were of copper (Istenič and Šmit 2019, A5, A6, C1, C2, H2). The choice of metal has to do with its mechanical properties, but also price and appearance. The same is true of iron rivets, which are rare (Istenič and Šmit 2019, B1, B2, MM SG). Wrought iron (low-carbon steel) obtained from iron bloom is distinguished for its toughness, forgeability and low hardness, which allows a high degree of plastic deformation (Pleiner 2006, 16–20). The use of brass for rivets is limited to the Dangstetten type of daggers/sheaths, where the choice of brass was most probably linked to its decorative effect (Istenič and Šmit 2019, B3 and B4), and to the sword scabbards that are probably predecessors of the Mainz type and presumably not produced in (large) series (Istenič and Šmit 2019, A1–A3).

A comparison of the Roman military equipment from the Ljubljanica with the observations on the military equipment from other sites shows similarities, but also differences. The former include a consistent use of copper alloys (when performed, analyses usually revealed the use of pure brass) for items of certain types or their parts (e.g. mounts on sword scabbards and belts, plume tubes on the Haguenau type helmets), but also a predominance of pure brass among copper alloys (Craddock and Lambert 1985; Ponting and Segal 1998; Riederer 2001; Ponting 2002, 559; Riederer 2002a; Ponting 2012, 167, 168), the use of very high-quality silver alloy (at least 96% Ag) for prestige items (Riederer 1999) and plating with metals with a silvery shine, for example on the Mainz type scabbards (Klein 2003b) and other objects (Deschler-Erb 1991). It has to be noted that is not possible to visually distinguish between copper-tin alloy and brass, tinning and silvering without appropriate analyses.

As for the differences, the published evidence indicates a greater diversity of materials than that displayed by the artefacts from the Ljubljanica. In the Mainz type swords and scabbards, for example, the guttering is iron or brass (Riederer 2002a, 120, Tab. 17: 418, 419, 421), while the only other analysed handguard plate is of leaded bronze and not tinned (Riederer 2002a, 120, Tab. 17: 424). Moreover, the elemental composition of the helmet from Haltern has shown copper-tin-lead bronze (Riederer 2002a, 121, Tab. 19: 430a) to be quite different from the binary copper-tin alloy used for the helmets from Slovenia.

It seems that the uniformity in the choice of metals and in their elemental composition is particularly apparent in the Augustan period and the early 1st century AD. From the mid-1st century onwards, there seems to be an increase in the use of alloys that suggest metal recycling, although quality items continued to be produced from metals of a standard composition, i.e. those that ensured successful production (Voß et al. 1998, 201–203; Riederer 2002b; Brüggler et al. 2012, 148, 149). The relatively small number of chosen metals and the uniformity of their elemental composition suggest that the brass and silver alloys needed to make military equipment in the Augustan period, such as was found in the Ljubljanica, was mainly obtained from billets, for example several-millimetre-thick sheets of metal, as well as ingots. The same was likely true of tin-lead alloy.

The fact that the brass pieces of the Augustan military equipment from the Ljubljanica are all made of pure brass is in accordance with the techniques of their production. In contrast to the alloys only used for casting, those intended for cold working (e.g. forging, bending, turning), to turn cast blanks into desired objects, had to have a specific composition, so adding scrap metal of unknown composition was out of the question (Voß et al. 1998, 201–203).

The metallographic studies of Roman brass militaria and the experiments to make similar objects using the techniques known to the Romans have revealed a great complexity of procedures, hence a wide and specialised knowledge of materials that a Roman master metalworker had to possess. In light of that, the hypothesis of large and specialised workshops that mass produced brass billets (e.g. large pieces of sheet metal), seems plausible. These billets were then used by other specialised workshops to make finished products (Brüggler et al. 2012, 142, 144, 148, 149).

It seems reasonable to think that a large part of the military equipment in the Augustan period was produced in a few large workshops with mass production and broad markets. The main factors in the choice of the metals were their mechanical properties, appearance and price. Supporting the hypothesis of mass production is the standardisation of materials, production techniques, forms and appearance of products, while the existence of broad markets is clear from the close similarities in numerous items of Roman militaria recovered from different and even very distant sites. Military equipment was likely also produced in smaller workshops with relatively small markets, which imitated the products of the large workshops; their products differ in details (e.g sword A16 from the Ljubljanica; Istenič 2019, 50, 52, 204, 296, Figs. A16.1, A16.2, Pl. 5: A16).

The Romans had a preference for a gold-silvery appearance of their military equipment. The expensive items of prestige were made of silver alloys and gold, either for objects as a whole or for plating, while all other objects used cheaper materials to achieve this effect, i.e. brass, tin, alloys of tin and lead, copper and tin, as well as iron. Brass and bronze surfaces have a yellow metallic shine when polished, reminiscent of gold, while polished tin surfaces are similar to silver (Istenič 2019, 204).

Suetonius mentions the abuse of these similarities in connection with the Emperor Vitellius, who 'was said to have stolen some of the offerings and ornaments from the temples and changed others, substituting tin and brass for gold and silver' during his proconsulship in Africa (Beagrie 1989, 170).

Of importance regarding the organisation of Roman military equipment production is a hypothesis, put forward on several occasions, on the monopoly of the Roman central authority over the production and use of brass in the early period of its Roman use, i.e. from the mid-1st century BC to the 1st century AD (Craddock and Lambert 1985, 164; Bayley 1990, 20; Jackson and Craddock 1995; Rehren 1999; Ponting 2012, 166). Because of the extremely widespread use of the alloy in this production, such a monopoly would argue for the centralised control over the production of Roman military equipment as a whole.

The beginnings of the Roman use of brass, dating to around 60 BC, are in fact connected with military equipment and rare issues of brass coins (Istenič and Šmit 2007). However, the copper alloys of this time are poorly investigated and it is not possible to speculate on whether the use of brass was limited to military equipment and coins. It seems that pure brass was the prevailing copper alloy for military equipment already at the beginning of its Roman use, but certainly in the Augustan period and the Early Principate (Craddock and Lambert 1985; Ponting and Segal 1998; Istenič 2000a; Istenič 2000b; Šmit and Pelicon 2000; Riederer 2001; Ponting 2002, 559; Riederer 2002a; Istenič 2005; Istenič and Šmit 2007; Ponting 2012, 167, 168). From the monetary reform around 23 BC onwards, pure brass was also used for part of the coins (sestertii, dupondii) minted in Rome (Burnett et al. 1982; Burnett 1987; Cowell et al. 2000). From the Augustan period on, pure brass was in extensive use for objects in civilian use (Riederer 2001; Riederer 2002b, 286–288; Bayley and Butcher 2004, 209, 210; Ponting 2012, 165–169), which shows no signs of a centralised control; the same is true of the two stamps on the brass ingots from Haltern (Müller 2002, 246, Pl. 120: 1488) and Colchester (Musty 1975, 409–410;

Fig. 6). So, the Roman central authority may have exercised control over the production and use of brass in the earliest period, but this was probably not the case from at least the (Middle) Augustan period onwards.

In short, we lack clear indications to support the hypothesis of a state-controlled production of military equipment in the Augustan period. It seems more likely that its production and distribution was organised in the same way as the production of fine tableware, such as terra sigillata and thin-walled wares, which the merchants supplied in great numbers to the Roman soldiers and civilians across the empire. These tablewares were initially produced in workshops in central and northern Italy, with subsidiaries springing up at Lyon in the Early Augustan period and later followed by others. For these workshops, the army was such a great customer that the good communication routes along rivers to the areas along the Rhine, where many army units were stationed in the Middle and Late Augustan periods, must have played a very important role in establishing the subsidiaries at Lyon and Vienne in the Augustan period (Desbat 2000; Roth-Rubi 2006a; Rudnick 2006, 59–63).

Conclusion

An important part of the research into the Roman military equipment from the River Ljubljanica was the systematic examination of the elemental composition of the non-ferrous metals. The results show a great uniformity in the choice of metals (such as brass and silver) and in their elemental composition. This corresponds with the uniformity of construction and production techniques and speaks in favour of a mass production in one or several production centres.

The high uniformity of forms (types) and, inasmuch as researched, of the metals used in the production of the military equipment of the Augustan period and the 1st century AD from different and geographically distant sites suggests that a large part of the militaria from the Augustan period were mass produced in a small number of large workshops supplying vast markets. Military equipment was probably also produced in smaller workshops to supply smaller markets, their products being modelled on those of the large workshops, but differing in details (Istenič 2019, 204, 296, A6).

The choice of metals was determined by their mechanical properties, appearance and price. The desired appearance of militaria was that of silver and gold. For expensive, prestige items, this was achieved by using silver and gold, either to make the objects or to plate them. For the rest, cheaper materials were used: brass, tin, tin-lead and copper-tin alloys, as well as iron; brass and bronze surfaces obtain a yellow metallic shine when polished, while polished tin surfaces have a silvery appearance.

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