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Chapter 3

Early Roman copper-alloy brooch production: a compositional analysis of 400 brooches from *Germaina Inferior.*

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We present here a compositional study of a large number of copper-alloy brooches, undertaken in 2014 using Handheld X-ray Fluorescence Spectrometry (HHpXRF). The brooches, which come from the area of Nijmegen, date from the Late Iron Age until the 2nd c. A.D. Our aim is to explore the ways in which artefact production was organized both in the context of Roman centres and in the countryside. The link between alloys and workshop organization will be elucidated before the methodology and results are presented. The results will then be discussed, leading to the formation of several hypotheses regarding the organization of workshops that produced metal artefacts.

Scientific interest in the composition of ancient artefacts has existed for well over two centuries. Roman brooches in particular have been in the forefront of this research both because of their ease of categorization and because they are found in large numbers on archaeological sites. Much work has been done on how they were made and on the technical choices available to the craftsmen. In particular, the choice of alloying agents (tin, lead, zinc) added to copper demonstrated a complex relationship between composition and typology, especially in the debate over Roman or local production (Dungworth 1997, 902). The technological restraints imposed on these artefacts by different alloy ratios have been studied in some detail (Smythe 1938; Unglick 1991; Bayley and Butcher 1995, 2004; Craddock 1988), especially in terms of casting in liquid form, into a mould, or being wrought through beating with a hammer.

Thanks to the development of X-Ray laboratory-based research since the 1950s, a clearer understanding of the alloying process has been achieved. Until the last decade, however, most of this research has taken place in scientific institutions rather than in museums or places of storage. Not only were there significant cost implications arising from the choice of method or apparatus employed, there was also a hidden cost of safely transporting items to and from their owners and the laboratory. To compound the issue, nearly all methods involved a certain level of damage to the artefact, either by drilling into its centre to remove a sample for testing, or by removing the patina (outer corrosion layer) to gain a clean surface — a requirement plainly at odds with the conservation practices of most museums and other owners, which resulted in a limited availability of objects to study.

X-Ray fluorescence, as a technique for identifying an item’s composition, has been available for a number of decades but, thanks to advances driven initially by the mining and scrap metal industries, the equipment has been miniaturised to a point where it can easily be transported and thereby set up on remote sites, such as on archaeological excavations or in museums and storage depots. Yet it is also necessary to understand the limitations: the X-rays only penetrate a fraction of a millimeter below the surface, which could be especially problematical where surface enrichment has taken place, such as in the gilding or silvering of coins (e.g. Hall 1961; Cowell and Niece 1991; Pollard and Heron 1996). To bypass this limitation, appropriate research questions and qualitative or semi-quantitative approaches should be employed (See Shugar and Mass 2012; Gigante, Ricciardi and Ridülfi 2005 for further reading on HHpXRF approaches). The general advantage of HHpXRF over laboratory apparatus is that it is relatively cheap, quick to use, easily portable, and can be applied in a non-destructive way. Research on brooches found in The Netherlands has until now mainly centred on typological issues and the description of brooches from individual sites (van Buchem 1941; Haalebos 1986; van der Roest 1988). Little is known generally about brooch production in what was the Roman province of Germania Inferior because excavated workshops are very rare. The little research done has been conducted on small numbers of brooches, not least because of the destructive nature of the methods. Fortunately, the recent advances in technology have allowed new approaches to be considered.

When large numbers of objects of a uniform typology are present in the archaeological record, a research opportunity presents itself. One avenue addresses the question: What kind of organization was required to produce and distribute large numbers of these items, to an agreed standard, across a large geographic area? For example, were objects produced in a single, regional or even supra-regional production centre and subsequently distributed along familiar trade routes, or were they made in many dispersed local workshops that copied and distributed new designs as required, to satisfy local demand? An associated question is whether raw materials involved in production were sourced from widely dispersed locations, or from single supply centres (e.g., the long-established mining areas of Cornwall or the Belgian Ardennes).

Even in cases when the source of the raw materials is not known, the complexity of their procurement and subsequent production standards can be implied. In a study of compositional variation across a wide geographic area, a high degree of uniformity is likely to imply that the objects and raw materials were supplied and produced in a centralised fashion. By contrast, significant compositional variation is likely to indicate separate production events, perhaps at many different workshops governed by differing quality standards that in turn were influenced by variations in the sourcing of the raw material. This avenue of research becomes even more useful once it is applied to chronological variation, changes in morphology, and the creation of typologies, especially in relation to the known dating of sites and materials. For example, the typological classification of Roman brooches is well advanced in many countries (Just a few of the main works are: Almgren 1923; Böhme 1972; Riha 1979; Feugère 1985). Less well developed before the recent technological advances has been the study of composition. With good typological dating, variations over time, perhaps combined with changes in production quantity, can be taken as indications of wider economic changes.

For investigating the organization of artefact production the study of composition can provide useful information, but only if large amounts of compositional analyses are available and when the precision of the measurements is sufficient to distinguish between compositional groups. The development of HHpXRF applied especially on large collections resulting from metal-detecting has provided this opportunity. Previous research had already suggested that Roman brooches offered a prime opportunity to study objects in this way due to the uniformity seen in their typologies (See Istenič and Šmit 2007; Drnić 2013).

However, information on the production of brooches in the form of the discovery of workshops or parts from them (e.g. casting moulds) is rare. Only two workshops have been excavated and recognised as such, along with a small number of sites that have turned up recognisable casting moulds (Riha 1979, 37; Böhme 1972, 48)

There are some existing theories on the organisation of brooch production because there are close parallels between some brooch types and items of military gear, in particular sword suspension hooks and armour fittings, as well as other military-related objects such as seal-boxes. The resemblance in form and decoration of such objects suggests that many brooches were produced in military workshops; this is further suggested by the fact that several of these types have been found in military camps. The Aucissa type is seen as the soldiers' brooch during the Early Imperial period (c.20 B.C.–A.D.70), since it is present in large numbers in camps during the expansion under Augustus:at the military site of Haltern, 81% of the brooches recovered (n=361) were of the Aucissa type (Haalebos 1986, 43; Müller 2002, 29). This high amount might be accounted for by the fact that the camp was abandoned in A.D.9 and the type was quite new at that point. At sites with a longer habitation history, for instance the camp at Nijmegen–Kops Plateau, the proportion of Aucissas amounts to 33% (n=567). In contrast, the Aucissas from the contemporaneous civilian town of Nijmegen–Oppidum Batavorum amounts to only 15% of the brooch assemblages, suggesting therefore that the type is connected to the military (Heeren and van der Feijst 2014). Half-finished examples of Aucissa brooches have also been found in several military camps, again suggesting military-related production (See Riha 1979, 37, Abb. 17; Haalebos 1986, 74, fig. 28, no. 1).

The question can be posed as to whether the close relationship between the army and brooch production is valid only for a select group of brooch types. Certain types are widely distributed and therefore associated with the army, while locally distributed types are associated with a specific provincial region or tribe. In Germania Inferior the presence of various types of 'wire brooches' (Draadfibulae or "Nauheim-derivative") is a regional phenomenon.Wire brooches have also been found in small numbers in other provinces (Mackreth 2011, pl.12 for Britain), but percentages as high as 40-60% are common on any given site in Germania Inferior (Heeren and van der Feijst 2014, 99). Thus the question of the provenance of these types (and others such as the Eye brooch, which is contemporary with the Aucissa brooch) remains open. They have been called Soldatenfibeln before (Riha 1979, 59, "Soldatenfibeln") but now large numbers from rural sites are available, so that other options must also be explored (E.g., production in local or 'tribal' workshops. Alloy classification and alloy uniformity can provide further arguments.

In this debate the Roman production of brass artefacts is also of some importance. Apparently brass was first introduced on an industrial scale by the Romans during the 1st c. B.C. (Craddock 1978, 8-9; Istenič 2005, 187-188), and then only through the development of a technique now known as the cementation process (Bayley and Butcher 2004, 13). It has been assumed that the Roman state reserved it for the production of items such as coins and military equipment, at least for a time (Dungworth 1997, 903), but towards the end of the 1st c. A.D. brass appears to have been withdrawn from circulation (Bayley and Butcher 1995, 118), as may be suggested by the increasing use of bronze in brooch production.

In order to study the organisation of Roman brooch production from examples found in various locations across The Netherlands, the following were necessary. First, the metal composition of pre-conquest Iron Age brooches had to be established in order to provide a comparison for Roman-era production. Sufficient brooches of a well-defined typology, such as the Nauheim series, would have to be included. Second, it had to be established whether the alloys used for Roman military types, such as the Aucissa series, were considerably different from the Late Iron Age alloys; and it needed to be shown that the Roman alloys are homogeneous over large areas. If this were to prove the case, they can be considered to be real 'Roman' brooch alloys. Third, sufficient brooches of many different types needed to be measured, so that 'real

Roman' alloys, once established, could be compared to alloys confined to more local or tribal typologies. It would then be possible to say something about the level of compositional control found in different brooch types. By comparing the Dutch results to those from other regions, ideas about the organization of both production and the distribution of finished items could be proposed.

METHODOLOGY

The present study was conducted on 406 brooches recovered from several locations across The Netherlands. The largest group of measurements was taken from bow brooches in the private collection of Harry Sanders and at the Bureau Archeologie & Monumenten, Nijmegen; these brooches were all recovered during archaeological fieldwork in that city or in metal-detecting on ploughed fields in neighbouring municipalities. The remainder were from the northern provinces of Friesland and Groningen (The Zijlstra and Regtop collections, housed at the Northern Archaeological Depot, Nuis.), from the city of Maastricht (From the municipality collections at the Centre Céramique, Maastricht, in the province of Zuid Limburg), and from the province of Zeeland (From collections housed at the Zeeuws Museum and the Cultural Heritage Agency for Zeeland (SCEZ). The brooch types were chosen from a broader selection of material according to the following criteria: they needed to be easily recognisable, they had to be datable, and there had to be enough of them to be significant. A minimum number of 6 brooches was decided upon, and this led to generating the results for each of the types listed below (Future data gathering could add more typologies (e.g. enamelled military and animal brooches), but only when access to further collections with sufficient numbers of brooches becomes possible.).

A Niton XL3t GOLDD XRF analyser was used for the study. It was factory calibrated with standards for metals and alloys; it also had a silicon drift detector with optimised geometry. The electronic metals mode was selected and used throughout the data-gathering phase; the advantage of this mode is that the same metals contained in Roman alloys (copper, tin, silver, zinc, gold) are found in modern electronic equipment, including potentially hazardous metals that need to be identified in the recycling of scrap (lead, mercury, arsenic, selenium). The analyser was mounted on a lead-covered portable test bench so as to provide a consistent operating environment and to protect the user from radiation. After various measuring times were tested, the signal was found to be stable after a reading time of 30 seconds. Following the analyses, the spectra were checked for inconsistencies and an external normalization of the data-set was undertaken. The calibration of the device was further checked for applicability to copper-alloy research against the CHARM - heritage bronze reference set (see Heginbotham et al. 2015, and ternary diagram a in fig. 1). The data was then reproduced as an Excel database to aid further study.

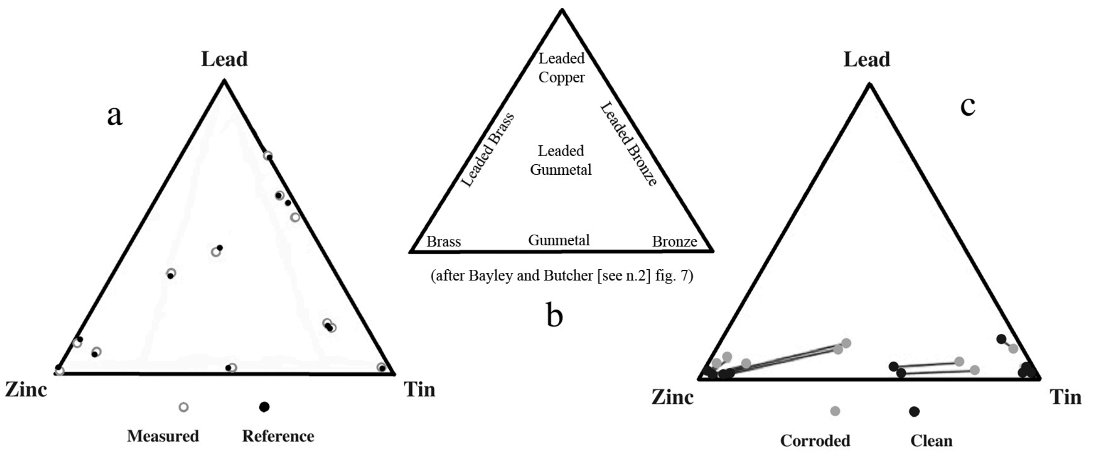

Fig. 1. Ternary diagrams: a) Charm calibration; b) Classifications; c) Corrosion effects.

Corroded metal is one of the most problematic materials to investigate with HHpXRF because the outer corrosion has an altered composition relative to its original (uncorroded) state. The bias introduced due to corrosion was evaluated by studies on a selection of corroded Roman bow-brooch fragments; this revealed that a depletion in copper and zinc takes place, altering measurements recorded on the outer surface of an item (See Fernandes, van Os and Huisman, 2013 for methodology. In our analysis both the patina and altered outer surface were removed to a depth of 1 mm to access a clean inner core for measuring.). Ternary diagram c in fig. 1 shows the difference in graph locations for corroded and non-corroded results. This suggested that decuprification and dezincification are the most probable corrosion processes at work. Depletion in copper content was seen to be the most active change, with the leeching of zinc from brass objects also seen to be common. Yet the effects of corrosion on the alloying elements tin, lead and zinc, when plotted as a ratio in ternary diagrams, did not prevent the measurements from falling into broad compositional groups. Identifying these groups was considered to be of some help in terms of further understanding Roman metal production. This is useful for brooches in particular because they are found in great numbers and variation.

RESULTS

The study of copper alloys in Roman Britain by J. Bayley and S. Butcher (1995 and 2004), already demonstrated the effectiveness of ternary diagrams for visualising their ratios of tin, zinc and lead. Their study identified multiple distinct compositional groups of Roman brooches that matched well the typological data. Because we were interested only in the deliberate addition of alloying metals, copper was not taken into account, as it is present (by definition) in all copper alloys. This type of classification is thus less sensitive to variations in surface copper content resulting from corrosion effects. For our study this was the classification scheme adopted (fig. 1 diagram b). The alloy compositions are presented in the following ternary diagrams (fig. 2) in chronological order, along with the number of each type measured. We start with a common Iron Age variant, the Nauheim brooch, to identify pre-Roman alloy production. The diagrams chart the introduction of brass in the 1st c. B.C. as seen in the Aucissa series, and its subsequent phasing out by the end of the 1st c. A.D., seen in the van Buchem 23 types.

DISCUSSION

The pre-Roman production of Nauheim brooches is in a bronze alloy, demonstrating the widespread lack of brass at this time, but by the time the Spoonbow types appear (late 1st c. B.C.) the data suggest a switch away from bronze to production in brass, an alloy that became widely available during this period. Because we have examples of this type made of both brass and bronze, one explanation could be that the brass examples are later than those cast in bronze.

In the Aucissa series, appearing around 20 B.C., brass appears to be the preferred alloy. Although some Aucissas may have been used in non-military contexts, the Aucissa type is the most frequently used brooch in military camps, and production is known from military centres.

Roman military production fits neatly with the 'industrialisation' of brass production by the Romans in the 1st c. B.C. Note that the alloy measurements for Aucissa brooches are available for other areas too: Bayley and Butcher published laboratory results for Aucissa brooches from Britain (2004, 152, fig.118.), and there are also measurements from Israel (Ponting and Segal 1998). All lie firmly in the brass corner of their ternary diagrams, suggesting that all Aucissas were made in brass, at least in the early period. Two models then arise for the military workshops where the Aucissa brooches were made: either the artisans in these workshops were fully able to control their choice of alloy, or half-products were cast in a central workshop and then widely distributed. Since half-finished products were found in different locations (Riha 1979, 37, Abb. 17; Haalebos 1986, 74, fig. 28, no. 1.), the possibility that finished products were distributed in this way is less likely — or at least not valid for all Aucissa brooches.

The results for the Aucissa series identified two bronze outliers, easily detected in the ternary diagram. These measurements may result from hitting a patch of surface decoration such as tinning, or a solder repair — either could produce a result in the bronze area of the diagram — but there is also the possibility of copying taking place by local workshops, in a non-standard alloy, an option which can now be explored.

Other important brooch types, such as Eye brooches, Knickfibeln, Almgren 19 and 20, the early wire brooches, the Almgren 22a+b series, and Van Buchem 13Ce, the rounded brooch with 4 knobs, are also produced in brass. One curious brass type is related to the early wire series; this can easily be mistaken for one of the more common Almgren 15 types, but closer inspection reveals a moulded shoulder just behind the spring, and the shape of the bow itself also appears cast rather than drawn. The alloy puts this brooch at odds with other morphologically-similar Almgren 15 types. That the Almgren 22a+b series is composed of brass is also an important result, as this type is not very numerous at military sites but present in elevated numbers at rural sites. This probably suggests that brass was also employed in the countryside by traditional workshops, though to a far lesser extent than bronze and gunmetal (the other option, that the Roman army controlled all brass and produced separate types for the native population, is far less likely). This makes it likely that the choice of brass or bronze was related to choices in the production process.

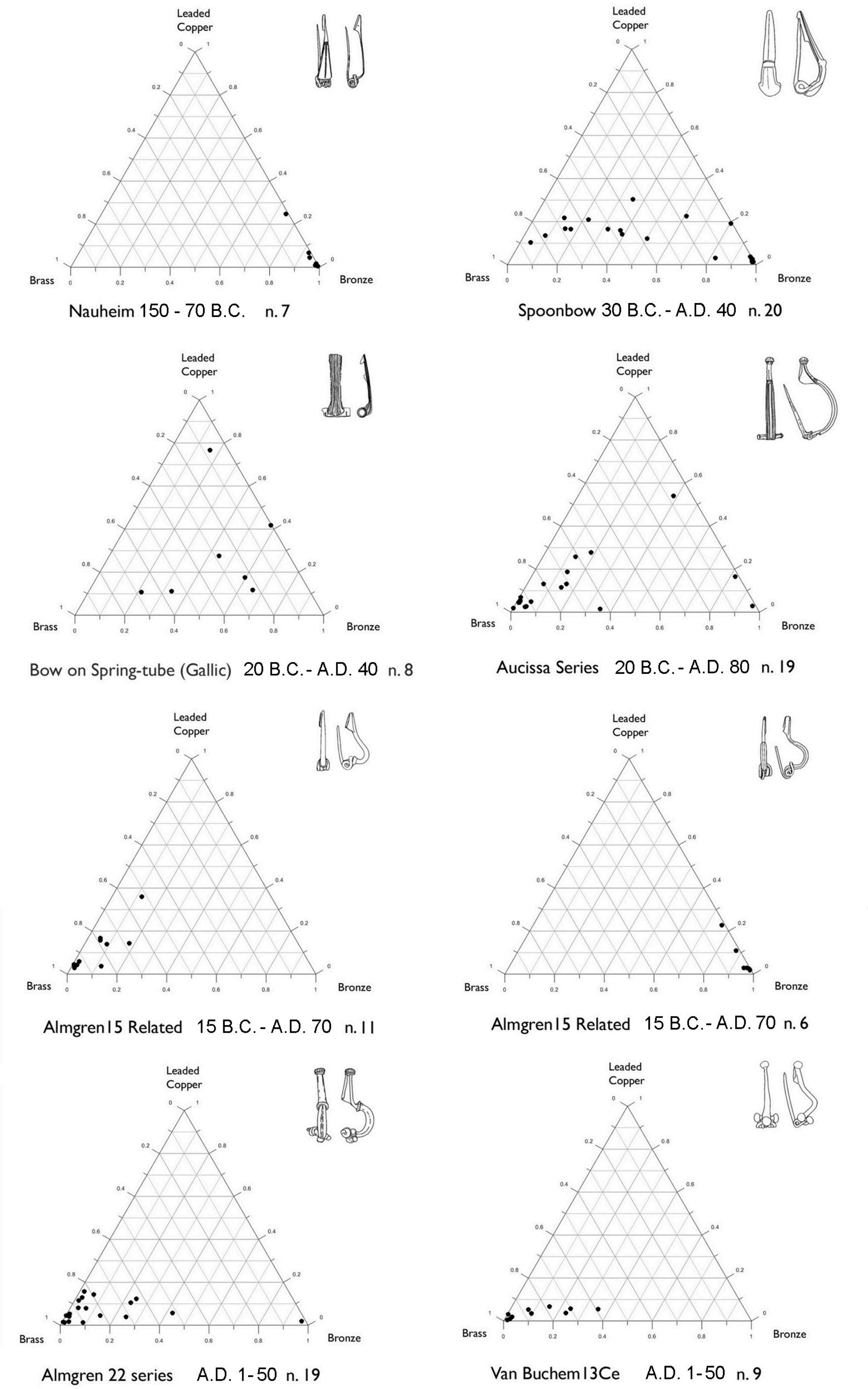

Fig. 2. Compositional results organized chronologically and by type.

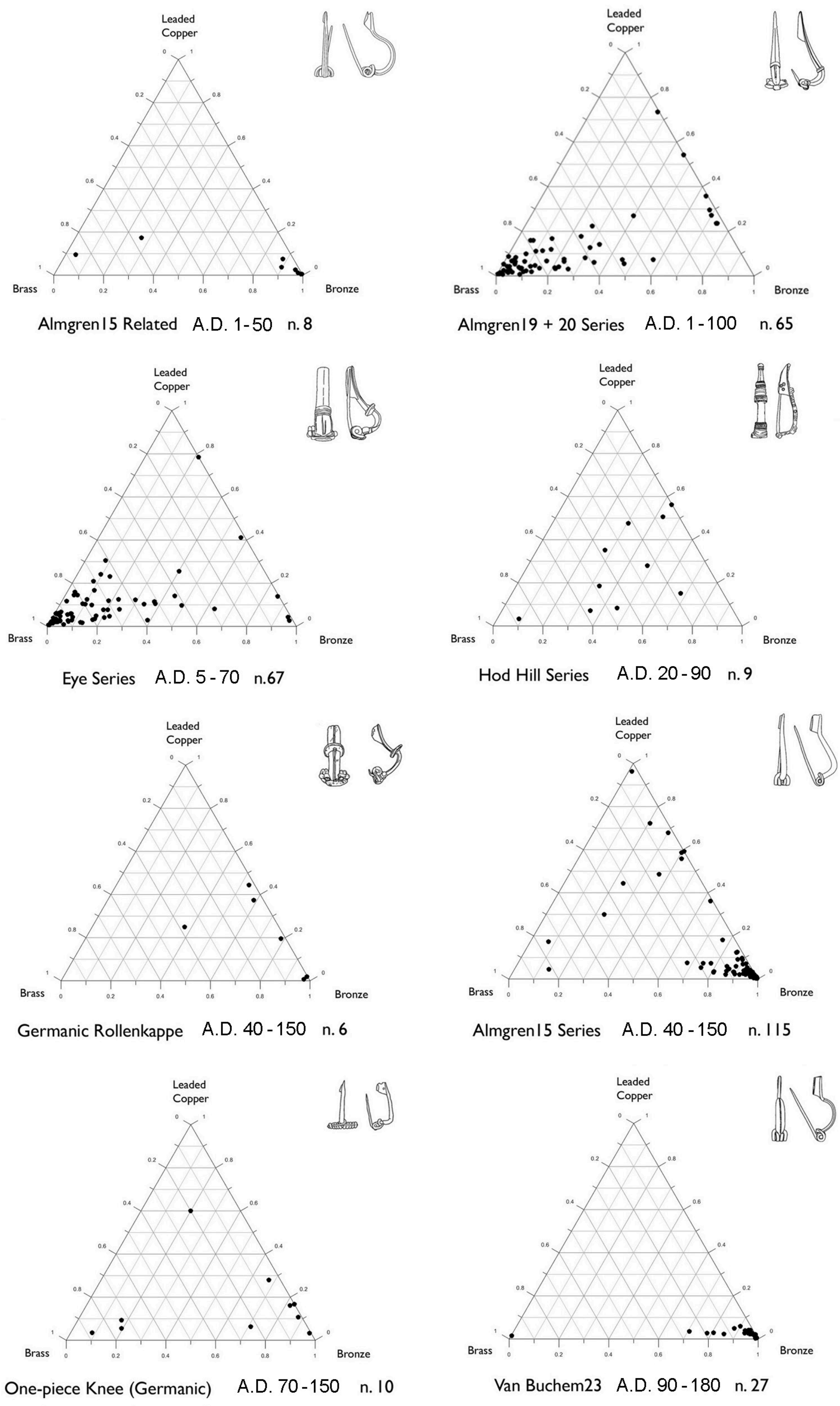

Fig. 2 (continued). Compositional results organised chronologically and by type.

Not all brooch styles, however, converted to brass in the 1st c. B.C.; some Almgren 15 wire types datable between c. 15 B.C. and A.D. 70 remained in bronze. Furthermore, the archetypal Almgren 15 wire brooch, a common find on Roman sites from the mid-1st c. into the 2nd c. A.D., is also in bronze. A further observation is that these wire brooches are drawn and hammered into shape, rather than cast. Bronze could therefore have been chosen for its practical properties in relation to the manufacturing technique, rather than for other reasons.

Two important groups do not conform to either brass or bronze. The Gallic Bow-on spring series, dating to around the same time as the Aucissa series, appears to avoid either option, having leaded gunmetal as a preferred alloy. One plausible explanation is that this series had a tinned surface probably on a brass core, with the result that the surface measurements would include a varying amount of residual tin, pulling the measurements into the gunmetal areas of the ternary diagram. This result also appears in the Hod Hill brooch series, which is quite diverse (it includes many from the British Isles). The results of Bayley and Butcher's study are comparable (2004, 153, fig.120) in that both studies show a scattered spread of alloy compositions in leaded gunmetal; importantly, however, a large concentration of brass and a secondary concentration of leaded bronze, present in the British results, are missing in the Dutch results. Towards the end of the 1st c. A.D., we detect a shift away from brass back to bronze, as shown by the alloy measurements of the Van Buchem 23 and 24 series.

The timing of this change conforms to the notion that brass is withdrawn from circulation around this date (Bayley and Butcher, 1995, 118).

VARIOUS HYPOTHESES

a) Craftsmen control the choice of alloy

Many brooches have a very uniform composition: whether brass or bronze, in many of the types all or most of the readings are of a single alloy category. This probably means that the type of alloy was well controlled by the craftsmen. The other option; that half-products were cast centrally and then distributed, is much less likely (See the discussion of the Aucissa type above.).

b) The choice of alloy relates to the mode of production

Since Nauheim-brooches of the prehistoric period were in almost pure bronze and Aucissa brooches (which are strongly associated with the Roman military, though from their presence in civilian contexts are not entirely reserved to the military) were in an almost pure brass, one explanation could be that traditional workshops retained the use of bronze, and that all brass brooches are produced by the military. The other option is that the choice of material is connected to the production method: alloys for casting require other properties than alloys for smithing (drawing and hammering). It was observed above that a simple wire brooch (Almgren 15) was predominantly in bronze, whereas a wire-related brooch with a broad collar, which requires casting, was in brass. This still leaves open both options: either the casting process determined the choice for brass, or (possible) production in a military camp explains the choice of brass. The same line of argument can be pursued for eye brooches: the massive form needs to be cast, and this might be the reason that it is executed in brass; but it is also possible that it is simply a ‘military’ type, made by the military and later taken home by veterans returning to live in the countryside (explaining why it is also found relatively often in the countryside). An important clue lies in the fact that the brooch type Van Buchem 13 Ce is hardly ever present in military contexts but is fairly common (though not numerous) on rural settlements. The results given above prove that this type is executed in brass. Morphologically, this type with an upper chord and 4 massive knobs had to be cast. We can suggest therefore that the production process was determined to some extent by the choice of alloy. Therefore brass may not have been strictly limited to military supply.

c) Military-based and traditional metalworking existed alongside one another

It is conceivable that all brooches were produced by army workshops; the process of smithing for certain types could have been executed next to the casting for other types. According to a first hypothetical model, rural production will simply have ceased after large quantities of brooches became available in the civilian settlements surrounding army camps. A second hypothetical model is that the military workshops created brooches only for the needs of the military personnel in camps and their families nearby, while rural smiths produced brooches for the local people. The longevity of the selection of bronze alloys for wire brooches based on the Nauheim archetype is an argument for the second model. The first model would imply a highly commercial exchange sector aimed at providing goods for a large market, with profit as the chief motivator. These ‘modernist’ positions however, have been heavily criticised in the past (Finley 2014; Badian 1968; Hobson 2014), and the first model is less likely as the explanation for the observations made above.

SUMMARY AND CONCLUSIONS

The metal composition of pre-conquest Iron Age brooches was first established in order to provide a comparison for Roman-period production. It was shown that alloys used for Roman military types, such as the Aucissa series, were considerably different from Late Iron Age alloys. As a result of comparison with other studies undertaken elsewhere in the Roman empire, such alloys can be considered homogeneous over large areas. This permits an argument to be put forward that this composition can be considered to be a real ‘Roman’ alloy. Sufficient numbers of brooches of sufficient different types were measured so that differences in alloy ratios could be compared. This in turn made it possible to discuss the level of compositional control for the different types of brooch. The results drawn from across the Netherlands could then be compared to published results from other regions, allowing ideas about the organisation of production and the distribution of finished items to be formed. The observation of differences in the alloys of distinct typological groups allows new arguments to be brought to the discussion of the provenance and cultural tradition of certain brooch types found in The Netherlands. Although no direct provenance can be given for any brooch, the identification of a standard alloy for the Aucissa brooch, considered the archetypical military brooch, as well as for other typological groups with alloys that deviate from it, is a useful step forward.

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