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Roman Copper Alloys: Analysis of Artefacts from Northern Britain

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A survey of the range of Roman copper (Cu) alloys is offered. This is based primarily on the analysis of almost 1200 Roman artefacts from sites throughout northern Britain. This large body of data is examined from a number of different perspectives (e.g. typological, cultural, chronological). A full list of the data as an ''interactive database'' is to be published separately in *Internet Archaeology*.

Keywords: ROMAN, BRONZE, BRASS, COPPER ALLOY, XRF, ANALYSIS, BRITAIN.

Introduction

This paper illustrates some of the current knowledge on Roman copper (Cu) alloys, based on the compositional analysis of finished artefacts. Considerable research has already been carried out in this field but this has tended to focus on relatively simple issues related to the technology of Cu alloys. The ever increasing size of the data set and its sophistication (especially information concerning the archaeological context of samples) make possible a more wide-ranging examination of Roman copper alloy use.

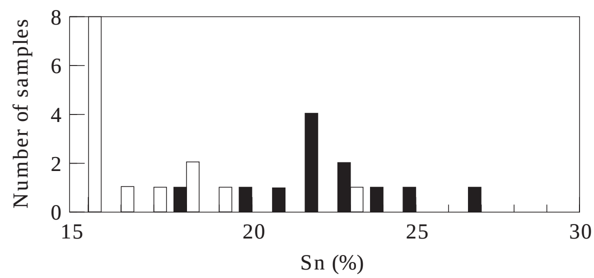

Figure 1. Tin content of Roman mirrors compared with other artefacts. Only those artefacts with at least 15% Sn are shown here (data from Dungworth, 1995). ■: Mirrors; □: non-mirrors.

Previous Research

Roman Cu alloys have been subjected to scientific analysis for almost 2 centuries and a large data set now exists. Most research to date has aimed to investigate two themes: the relationship between alloy composition and the mode of manufacture, and the use of recipes when making ancient alloys. A limited amount of work has also focused on chronological changes and the role of undifferentiated ''stock'' metal. This section summarizes this previous research, while following sections set out the contributions made by the present research project.

Analyses have been carried out by a number of researchers in this field (Smythe, 1938; den Boesterd & Hoekstra, 1965; Picon, Condamin & Boucher, 1966, 1967, 1968; Condamin & Boucher, 1973; Lindberg, 1973; Riederer, 1974; Riederer & Briesse, 1974; Craddock, 1975, 1978; 1986*a*, 1986*b*; Laurenze & Riederer, 1980; Bayley & Butcher, 1981, forthcoming; Bayley, 1985; Rabeisen & Menu, 1985; Beck *et al.*, 1985; Caple, 1986; Rabeisen, 1990; Unglick, 1991; Stos-Gale, 1993; Bollingberg & Lund Hansen, 1993; Jackson & Craddock, 1995; Hook & Craddock, 1996). In particular, Craddock's analyses of hundreds of Roman artefacts are published as British Museum occasional paper (Craddock, forthcoming) and Bayley's analyses of brooches are to be published in an English Heritage monograph (Bayley & Butcher, forthcoming).

This research has shown that a variety of different Cu alloys were in use in the Roman empire. The traditional tin (Sn) bronze, which had been in use in the Mediterranean for 2 millennia, continued in use but with increased variation in the exact level of Sn added depending on the nature of the product, e.g. Cu alloy mirrors were made from a very high Sn alloy (20% or more Sn—see Figure 1). In the late 1st century BC bronze was joined by brass (Craddock, 1978) and these two alloys were mixed together to produce mixed alloys containing Cu, zinc (Zn) and Sn (these alloys are often known by the modern term gunmetal). The simultaneous variation of two different additions to the Cu has led many to represent bronzes, brasses

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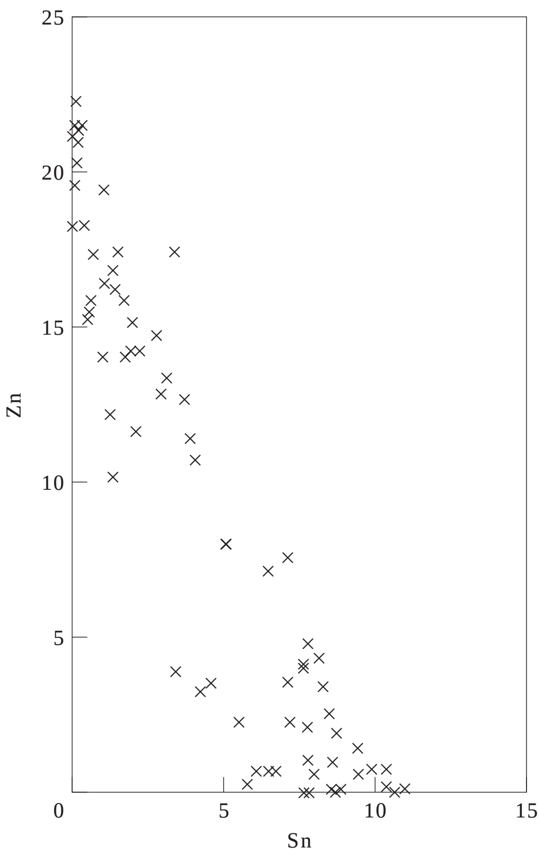

Figure 2. Two-dimensional plot of Sn and Zn content of a selection of Roman Cu alloys (data from Dungworth, 1995).

and gunmetals through two-dimensional x–y plots (Figure 2). Occasionally, lead (Pb) was added to all of these alloys, especially where the alloy was to be used in the casting of large and complex objects such as statues. In cases where the three alloy elements (i.e. Zn, Sn and Pb) vary, a two-dimensional plot such as Figure 2 no longer suffices. This problem has been overcome to a certain extent by the use of ternary diagrams (Bayley, 1988, figure 9). These are able to indicate simultaneously the difference between brasses and bronzes and between leaded and unleaded alloys (Figure 3).

Existing research on Roman Cu alloys has provided considerable insight into the relationships between alloy choice and *technological constraints*. Technological constraints can be seen most clearly in the levels of Pb present in Roman alloys. Unlike Zn and Sn, Pb is not present in Cu alloys in solid solution. Instead the Pb forms discrete droplets throughout the metal. This makes leaded alloys more likely to crack when hammered and forged, and so sheet and wire almost never have more than 1% Pb. Lead does, however, lower the melting point of Cu and produces a more fluid molten alloy. This makes it a useful addition to alloys which are to be used in the manufacture of large or complex castings, such as statues. Almost 60 years ago Smythe

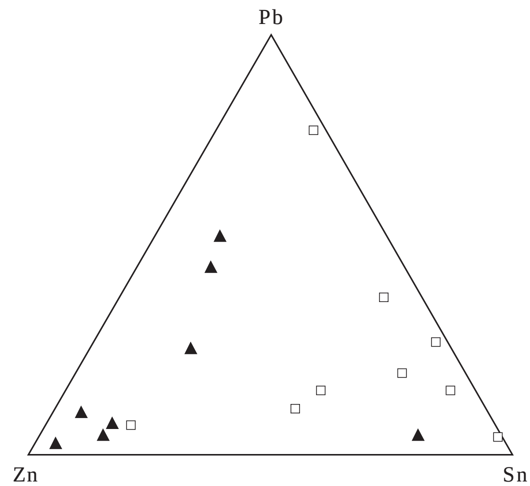

Figure 3. Ternary diagram showing the Zn, Sn and Pb contents of Roman dragonesque brooches (data from Dungworth, 1995). P and R types (□) are early while S and L types (▲) are late.

showed that most wrought artefacts had higher Zn contents and lower Pb contents than cast ones (Smythe, 1938). These findings have been confirmed by more recent research (e.g. Unglick, 1991). Clearly the *technical* properties of leaded and unleaded Cu alloys were understood and utilized by Roman copper workers.

A number of researchers have shown that there were more complex links between the form of artefacts and the alloys used in their manufacture (e.g. Bayley & Butcher, 1981; Craddock, 1975, 1996). One of the clearest examples of this phenomenon in the Roman period is the large number of bronze vessels produced in Campania and elsewhere (den Boesterd, 1956). The analysis of a large number of these by den Boesterd & Hoekstra (1965) demonstrated that the vast majority were made of leaded bronze. Craddock also showed that a wide range of Cu alloy artefacts (e.g. large statues and musical instruments) produced in the late Republican and early Imperial periods in the Mediterranean area were made from a similar alloy (Craddock, 1975, forthcoming). This does not appear to be a single homogenous alloy type, however, and Craddock (1988) has attempted to relate levels of Sn and Pb in different categories of artefacts to the recipes given in Pliny's *Natural History* (34.20.94–98).

More recently, the analysis of a large number of Romano-British brooches (Bayley, 1992) has illustrated even more complex relationships between alloy composition and typological categories. Some of these relationships are quite clear (e.g. the use of brass for Colchester A brooches and leaded bronze for Colchester B brooches, Bayley, 1985) while others have required the analysis of large numbers of brooches and a careful examination of existing typologies (Bayley & Butcher, forthcoming). Some of these variations between different types of brooches are subtle but highly consistent, which implies the careful blending of

Table 1. Average alloy compositions (percentage) of some early Roman brooch types, using atomic absorption analysis. (Source: Bayley, 1990, table 1.)

	Zn	Sn	Pb
Colchester A	20·1	1·6	0·3
Aucissa	19·5	1·7	0·2
Rosette, Langton Down, etc.	17·9	2·6	0·9
Hod Hill	16·3	2·4	0·9

different raw materials according to traditional recipes (a few examples are given in Table 1).

Relatively little attention has been paid to chronological changes in the alloys used during the Roman Empire. Craddock's (1975) study of Roman Cu alloys was restricted by the nature of the samples (most were from museums and did not come from securely datable archaeological contexts). An earlier examination of Roman brass coins (Caley, 1964) used a small number of samples but each was easily dated by their legends. Caley observed that imperial brass coins suffered from a gradual diminution of their Zn content until the early 3rd century AD when these coins contained almost no Zn (Caley, 1964; but see Dungworth, 1996*c*, for a reconsideration of this problem). Caley suggested that this was the result of an economic or technological problem: either supplies of Zn ore were no longer obtainable or the (relatively obscure) cementation process was ''lost''. Neither of these explanations has seemed very attractive as Zn ores are found extensively throughout Europe and the sheer scale of brass production in the 1st centuries BC and AD argues against any ''loss'' of the cementation technique. Craddock (1975: 221–223) argued that while brass may have become less common in the late Empire, gunmetal became more common and so *average* Zn levels would remain constant.

The relatively obscure method of manufacture of Roman brass (the cementation process—see Craddock, 1978; Bayley, 1990) and its speedy adoption for the manufacture of large numbers of Roman coins and military fittings has suggested to some that the Roman state exercised a monopoly of the manufacture and distribution of brass (Grant, 1946: 88; Caley, 1964: 92; Bishop & Coulston, 1993: 191).

In some cases, no clear relationship between artefact typologies and alloy composition has been detected. This has led some to the conclusion that many everyday artefacts were manufactured from whatever scrap or ''stock'' metal was available regardless of its composition (e.g. Riederer & Briese, 1974; Caple, 1986: 476). While the mixing of scrap metal has been viewed by some archaeometallurgists as a barrier to understanding metal use, Caple (1986) stressed that the composition of these mixed alloys might actually provide information about the overall availability of different alloying elements in the past. In this approach metal supply is viewed as a whole and the changing composition of ''stock metal'' can be seen as reflecting wider social and economic influences on metallurgy (such as supply and demand, status, and even politics, as well as technology).

The methodology of previous investigations into Roman Cu alloys and the results obtained are closely related. Most previous programmes of analysis have examined just one type of artefact (e.g. brooches or statuettes) or just one archaeological site and so the results have been largely limited to discussions of technology involved.

Present Work—Methodology

A recent programme of analysis was devised to address these limitations (Dungworth, 1995). In particular, it was hoped that the systematic analysis of samples from a range of artefacts from different archaeological contexts and different sites would provide a more detailed picture of Roman Cu alloy use as a whole. The sites selected for study included forts, associated civilian settlements (vici), towns, smaller roadside settlements, villas, hillforts, farmsteads, caves, a temple, ritual hoards, and a cemetery. The Roman occupation of northern Britain was achieved with the use of a small number of soldiers and administrators compared to the indigenous population. Despite this, most archaeological excavation and research (including archaeometallurgy) has focused on Roman forts and towns. One of the principal aims of the present research project was to examine the ways in which the existing alloying traditions of northern Britain were affected by the Roman Conquest. In order to redress this imbalance, samples were especially sought from indigenous farmsteads and the like. Similar biases in the known archaeological record have ensured that most archaeological contexts available for examination belong to the 1st century AD of Roman occupation. Again the sampling strategy was geared to redressing this imbalance. While a study of Cu alloys in relation to artefact typology was not a principal aim of this research project, artefact typology was considered to ensure that all artefact types were represented. Samples of artefact types normally ignored (e.g. sheet, wire, and droplets) were actively sought. It was hoped this would provide a range of samples as representative as possible and so would provide a ''global'' view of Roman Cu alloys.

The analytical results were obtained by energy dispersive X-ray fluorescence (EDXRF). The EDXRF facility used was a Link Analytical XR200 in the Department of Archaeology, University of Durham. The source of the X-rays used was rhodium (Rh) with the primary X-ray beam set at 20 KeV and 250 μA (no filter was used). A 2 mm diameter collimator was used to direct the X-rays on to the sample analysed and the fluorescent radiation from the sample was measured in a Li-Si detector for 100 s ''live time''. The spectra were deconvoluted using the software provided and the counts per s totals for each element were compared

Table 2. Minimum detectable levels and analytical errors (absolute rather than relative) for each of the elements analysed by EDXRF

	Zn	Pb	Sn	Fe	Ni	Mn	As
Minimum detectable level	0·10%	0·15%	0·10%	0·04%	0·05%	0·01%	0·10%
Error (SD)	± 0·45%	± 0·50%	± 0·35%	± 0·02%	± 0·06%	± 0·02%	± 0·36%

with 21 standards of known composition. The results are therefore comparable with those obtained using other analytical techniques, although minimum detectable levels (see Table 2) may not be as low as those found with more recent techniques, such as ICPS. The range of elements which could be determined using this method was limited to those which were present in the standards and so some ''trace elements'' determined by other researchers (such as Sb, Au, and Ag) could not be determined.

As EDXRF analyses the outer 0·1 mm or so of a Cu alloy, the analysis of a corroded surface can be misleading (Hall, 1961; Condamin & Picon, 1965). This problem can only be overcome by obtaining a sample of uncorroded metal. Two methods were used to prepare samples; mounting specimens in resin, and drilling. For the first method, a fragment (typically 0·25 g) of the artefact was isolated, the corrosion products were removed by air abrasion (Carter, 1964) and the remaining uncorroded metal was mounted in resin. For the second method a drill was used (1 mm diameter drill bit) to obtain a sample of swarf (up to 5 mg). The drillings were then analysed by placing them in a sample cup fitted with a Mylar film base.

The programme of analysis produced a large data set: 1163 different samples; nine elements; and 22 variables describing the nature of the artefact and its archaeological context. This full data set would be too extensive to publish here, instead they form the core of an article in the new *Internet Archaeology* journal (Dungworth, 1997).

Roman Copper Alloys: a ''Global'' View

The selection of samples of Cu alloy from a wide range of artefact types and from a wide range of archaeological contexts in northern Britain has provided a data set which is as representative as possible. This allows the characterization of Roman Cu alloys free from the biases due to considering just one site or just one artefact type. While this picture is described as ''global'' it is only strictly valid for the northern part of the Roman province in Britain. The sheer size of the present data set, however, poses problems of description and representation. The usual method of two-dimensional plotting (whether with two axes or with a ternary diagram) loses some of its visual impact when over 1000 points are plotted. This can be avoided by using a ''three-dimensional'' x–y chart. The two ''horizontal'' x and y axes represent two elements (in this case Zn and Sn) while the ''vertical'' axis indicates frequency. A virtual three-dimensional view is achieved by using an isometric (or similar) projection. Figure 4 shows the distribution of Zn and Sn contents for around 1200 Cu alloy samples from northern Roman Britain. This figure was originally produced using the UNIMAP computer programme which has partially smoothed the data and allows rotation of the chart in all three dimensions. Only two elements may be shown simultaneously (unlike the ternary diagram) but a fuller picture of Cu metallurgy as a whole may be gained.

A close examination of the peaks and troughs in Figure 4 reveals a number of aspects of Roman Cu alloys. Figure 4 shows two major peaks, a ridge running between the two major peaks and one minor peak. One of the major peaks rests up against the Zn axis (i.e. little or no Sn) with its peak in the region of 18% Zn and represents brass. The other major peak rests up against the Sn axis with its peak in the region of 9% Sn and represents bronze. The low ridge which runs between these two peaks represents those alloys having intermediate compositions (i.e. gunmetals). The remaining, minor peak rests up against the Sn axis with its peak in the region of 2% Sn and represents a very low Sn bronze.

This three-dimensional chart of Zn and Sn contents provides a detailed picture of Roman Cu alloys as a whole (typological, chronological and cultural aspects are considered below). This shows some features which have previously been recognized as well as some new details. The two major peaks show that brass and bronze are the most prominent of the Roman copper alloys. The existence of these two peaks indicates that these two alloys were preferred alloys and may have been made to recipes. The ridge running between the brass and bronze peaks covers gunmetals with a fairly wide range of compositions (2–8% Sn, 3–15% Zn) and does not show any preferred composition: there is no peak within the ridge. The lack of a peak within the gunmetal region implies that there was not one preferred type of gunmetal in the same way as there is a preferred bronze and preferred brass. From this it might be thought that gunmetals were formed by using whatever scrap metal was available to hand and so had a random composition. A closer examination of the relationship between the typology and exact compositions of some gunmetal artefacts (discussed below) suggests that more care was taken over the composition of gunmetals than first impressions might indicate.

The position of the brass peak (centred on 18% Zn) is noteworthy as the Roman cementation method of

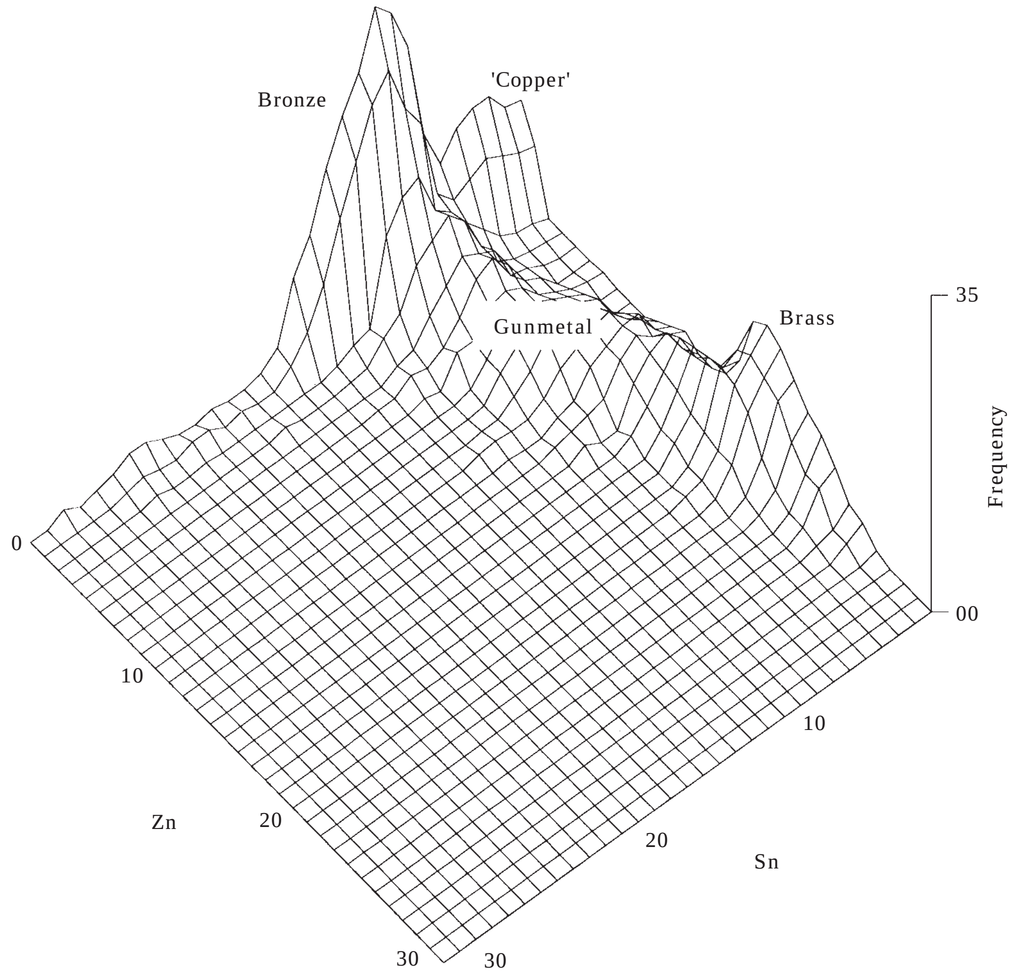

Figure 4. Three-dimensional plot (smoothed) of Sn and Zn content of 1163 Roman Cu alloys (data from Dungworth, 1995).

brass production should have produced brass with 23–28% Zn (Werner, 1970). Less than 1% of the artefacts analysed from northern Britain had more than 23% Zn (Dungworth, 1995: 122). The relatively low Zn content of many Roman brass artefacts may have arisen due to the loss of volatile Zn during the melting of fresh cementation brass prior to casting (Dungworth, 1995: 127–128).

The absence of a peak at the intersection of the Zn and Sn axes (i.e. pure Cu) is of interest, especially as large circular ingots (10–20 kg) of pure Cu are well known (Tylecote, 1962, table 10). Pure Cu, therefore, was available but was rarely used on its own to manufacture artefacts. Other times and places (e.g. India, see Lahiri, 1995) have seen considerable use of pure Cu alongside alloys of Cu. The minor peak in Figure 4 noted above represents a very low Sn bronze (1–5% tin) which would have had a similar colour and mechanical properties to pure Cu (i.e. pinkish colour and malleable). This alloy was widely used in the production of sheet and wire objects.

While the peaks within the Zn-Sn distribution have been considered (e.g. brass and bronze), attention should also be paid to the troughs in the distribution (Caple, 1986: 532). The most significant of these is the area beyond the gunmetal ridge (mentioned above). The lack of Cu alloys with high levels of Zn and Sn (and the shape of the gunmetal ridge) indicates that brass was not mixed directly with Sn but with bronze. If pure Sn was directly mixed with brass then Cu alloys with high levels of Sn *and* Zn would be encountered (e.g. 20% Zn, 10% Sn, and 70% Cu; analysed Roman artefacts do not have such compositions).

A very few Roman Cu alloy objects have high levels of Zn *and* Pb; these are usually military (e.g. Jackson & Craddock, 1995) and indicate the fairly restricted use of this particular alloying technique. Most of the Pb in gunmetals, however, was introduced by the use of leaded bronze rather than the addition of Pb to brass.

Another equally important trough in the three-dimensional chart is that between the gunmetal ridge, the intersection of the axes and the Zn axis (i.e. alloys with 2–10% Zn *and* 0–5% Sn). This gap shows that brass was not recycled on its own—if cementation brass (23–28% Zn) was repeatedly recycled then the volatile Zn would be progressively driven off producing low Zn brasses. The absence of these alloys shows that if brass was recycled then it was always mixed with scrap bronze. It is possible that this constituted a recipe similar to those given in Pliny (Craddock, 1988).

The peaks and troughs in this Zn-Sn graph have been used to define alloy types which are used in discussions below. Brass refers to alloys with at least 15% Zn, bronze refers to alloys with at least 5% Sn but no more than 5% Zn, ‘‘copper’’ refers to alloys with less than 5% Zn and Sn (although few of these have more than 1% Zn and most have at least 1% Sn), and gunmetal covers the remaining alloys (mostly 2–8% Sn and 3–15% Zn). In addition, those alloys containing at least 1% Pb are referred to as leaded.

The analysis of a large number of Roman copper alloy artefacts has provided the opportunity to examine the nature of such alloys as a whole. The large number of results, however, makes many simple graphical representations inappropriate. A three-dimensional chart allows the investigation of the relationship between two elements in considerable detail. This provides a vivid picture of the practices and traditions of Roman coppersmiths. The following sections describe the variations in alloy use in relation to typological, chronological and cultural frameworks. All of these threads are then brought together in a discussion of the operation of a symbolic or ideological code in the manufacture and use of Roman Cu alloys.

Typology and Alloy Composition

The present research has not been aimed primarily at examining the relationships between artefact typology and alloy composition. Nevertheless the large number of artefacts analysed has revealed some links between artefact typology and alloy composition. The most significant of these links are perhaps amongst small everyday artefacts. As mentioned above, it has usually been assumed that many ‘‘ordinary’’ objects were made from whatever scrap metal was available (regardless of its composition). Only a few examples (dragonesque brooches, ‘‘toilet implements’’, and lock bolts) of this phenomenon will be presented here to demonstrate the prevalence of the links between typology and alloy composition.

The large number of Roman brooches analysed by Bayley (1992) are from southern Britain. One type of brooch, however, is found almost exclusively in northern Britain: the dragonesque brooch (Feachem, 1968). Those analysed are made of quaternary alloys containing Cu, Zn, Sn and Pb. At first sight such alloys seem to offer little opportunity for distinguishing different types based on their alloy composition. Nevertheless it has been possible to relate alloy composition to style of decoration. The earlier and plainer types (P and R) are usually made of bronze, while later ornate types (S and L) often have higher levels of Zn (Figure 3).

Amongst the wide range of Roman artefacts made from Cu alloys is a group often referred to as toilet

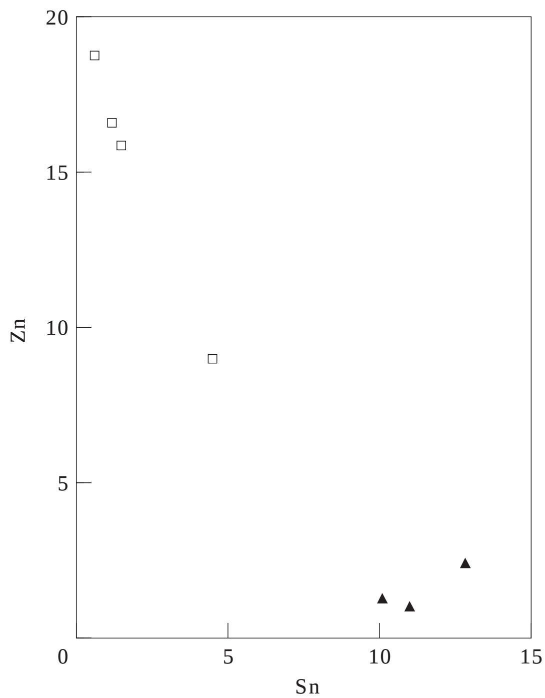

Figure 5. Two-dimensional plot of Sn and Zn content of two types of Roman toilet implements (data from Dungworth, 1995). □: Long handle; ▲: short handle.

implements. This includes tweezers, nail cleaners, spoons and probes. Some of these artefacts may have been used as tools during surgery (Jackson, 1986) but most are assumed to have been used for personal cleaning and grooming. Two different types of toilet spoons can be distinguished: those with long thin handles which are usually decorated (e.g. bead and reel mouldings); and those which appear to be formed from a simple strip of metal (the bowl being simply a small depression in the sheet). The longer and more ornate toilet spoons are made of brass, while shorter simpler ones are usually made of bronze (Figure 5).

Roman doors were sometimes fitted with locks. One popular locking mechanism relied on a sliding lock bolt which contained a series of triangular and rectangular holes which were matched by protrusions on the key (British Museum, 1958, figure 41). The analysis of seven slide lock bolts has shown that these were made from a quaternary alloy (average composition: 4·9% ± 2·9 Zn, 6·2% ± 2·3 Sn, 8·5% ± 5·5 Pb, remainder Cu). While it is possible that no care was taken over the composition of the alloys used for these artefacts, the lack of brasses, bronzes, or unleaded alloys suggests that a preferred alloy was used for these slide lock bolts. A similar phenomenon can be observed with 2nd and 3rd century AD military equipment. The vast majority of these artefacts are made from quaternary alloys characterized by a lack of extremes (i.e. intermediate Zn, Sn and Pb contents). This suggests that some care was taken *always* to use a very mixed alloy.

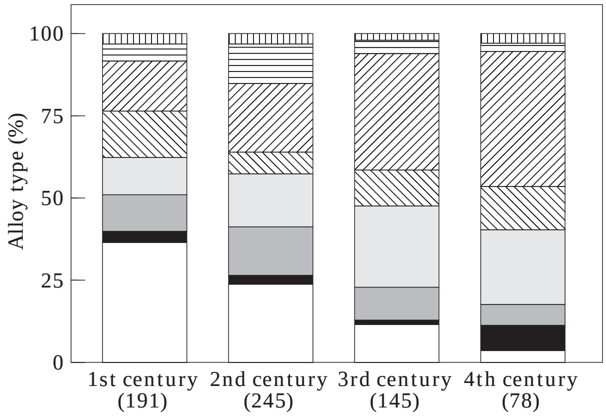

Figure 6. Proportions of Roman alloy types used, by century (actual number of samples given in brackets, data from Dungworth, 1995). ▥: Leaded Cu; ⊟: Cu; ▨: leaded bronze; ▧: bronze; ☐: leaded gunmetal; ⬚: gunmetal; ■: leaded brass; □: brass.

It can be seen that there were at times very subtle associations between artefact typology and alloy composition. While scrap metal may have been a frequent source of raw material for the Roman coppersmith it would appear that some care was taken over its use. Alloys would have been recognizable by their colour (and possibly other properties) and may have been ''blended'' together to produce deliberately mixed alloys. A recent review of the Zn content in Roman coins (Dungworth, 1996*c*) concludes that the decline in Zn was due to the progressive and deliberate mixing of brass and leaded bronze to produce an alloy of desired composition. The emerging picture, therefore, is one of quite subtle control of raw materials. Recipes and tradition were as powerful constraints on alloy composition as the limits of physical metallurgy. Even more important may have been the symbolic meaning attached to certain metals and alloys (discussed below).

Chronological Changes in Roman Copper Alloys

Little study has been made of chronological change in Roman Cu alloys. Caley's (1964) claim that the art of brass manufacture was lost has been denied by Craddock (1975; 1986*a*). Almost half of the analyses of Cu alloys from northern Britain could be dated by associated archaeological context. An examination of the alloys from each century shows the overall changes in the use of alloys over time (Figure 6). Many of the alloy types depicted are present at relatively low levels throughout the Roman period (e.g. leaded brass and leaded Cu) or show relatively little change over time (e.g. gunmetal and bronze). The significant chronological changes in the alloy types are the decline in unleaded brass and the increasing use of leaded bronze and leaded gunmetal. In the 1st century AD brass accounted for 37% of the alloys used while leaded bronze and leaded gunmetal together accounted for 27%. By the 4th century AD, brass had declined to just 4% while leaded bronze and leaded gunmetal had increased to 64%. Craddock argued that while brass may have been less common in the 4th century AD, *average* Zn levels remained constant (the Zn was increasingly contained in gunmetals) and there was no overall decline in Zn (Craddock, 1975: 221–223). While the proportion of gunmetals increases over time in northern Britain, the average Zn content does decline (Table 3). Despite the decline in Zn content and in the use of brass this alloy did not disappear. A limited number of certainly 4th century AD artefacts (defined on typological grounds) were produced from cementation brass (i.e. at least 23% Zn, see also Lindberg, 1973; Bishop & Coulston, 1993: 183).

Table 3. Average alloy element content of Cu alloys from northern Roman Britain broken down by century (Dungworth, 1995)

	Number of samples	Zn	Sn	Pb
1st century	191	10	4·2	2·2
2nd century	245	7·8	4·8	4·4
3rd century	145	5·3	6·4	5·1
4th century	78	4·8	7·4	4·4

The chronological changes in the compositions of Roman alloys analysed should, however, be viewed cautiously as the proportions of samples from different categories of sites changed over time; no villas are known in the 1st century AD, while no *vici* are known in the 4th century AD. The changes in the analysed alloys may reflect changes in the archaeological record rather than changes in ancient Cu metallurgy. In addition, the types of artefacts produced and the methods used in their manufacture also changed, e.g. many early Roman military fittings were made from riveted sheet metal while most late fittings were cast in moulds. It is not clear to what extent changes in the alloys available forced changes in fabrication techniques or if, on the other hand, changes in typology encouraged changes in alloy composition.

Culture, Settlement and Alloy Composition

Little attention has been paid to inter-site differences in the use and deposition of Cu alloys. The selection of samples from sites in northern Britain was carried out specifically with inter-site comparisons in mind. Potentially the most interesting area of inter-site difference would be the incidence of brass. As discussed above, the obscurity of its production technique and its use for Roman coins and military equipment has suggested to some that brass was produced and supplied by a ''state monopoly''. If brass was produced and supplied by a ''state monopoly'' then the largest proportion of brass artefacts would be expected on highly Romanized settlements such as towns and forts. The range of alloys (including brass) used on different types of

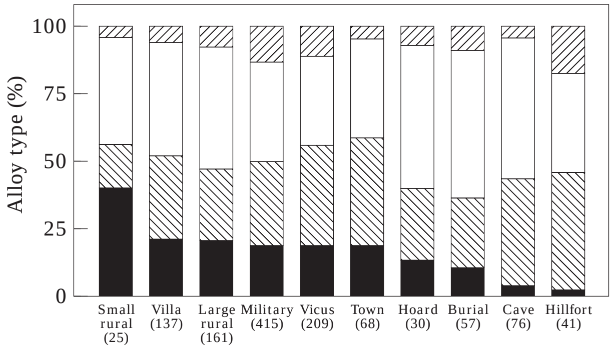

Figure 7. Proportions of Roman alloy types used on different sites in northern Britain (actual number of samples given in brackets, data from Dungworth, 1995). ▨: Cu; □: bronze; ▧: gunmetal; ■: brass.

Roman-period sites in northern Britain is shown in Figure 7. It can be seen that the proportion of brass on a range of Romanized sites (forts, *vici*, towns, and villas) is broadly similar (about 20% of alloys from these sites are brasses). This suggests that there was little differentiation between these types of sites in terms of the availability of brass. The proportion of brass on these sites does not seem to reflect any military–civil or urban–rural settlement hierarchy.

There is one category of site which does display a much higher incidence of brass—the small isolated rural farmstead. The high proportion of brass on small rural sites seen here is similar to that seen in late Iron Age and ''Celtic'' metalwork (Dungworth, 1996*a*: 10–11). Late Iron Age sites such as Dragonby (Dungworth, 1996*b*) and hoards of Late Iron Age metalwork, such as Melsonby (Dungworth, 1995) all have higher proportions of brass artefacts than are found on Roman-period sites. The widespread use of brass in the early Empire suggests that there was not an official monopoly on the production. Brass was widely available throughout northern Britain, even for indigenous manufacture (for a broadly similar picture from a contemporary Polish site, see Stos-Gale, 1993). The high proportion of brass on indigenous sites is the opposite of what might be expected from traditional explanations of the Roman occupation of Britain. The indigenous inhabitants of northern Britain should not be seen as passively receiving those elements of Roman culture offered them: they apparently had more access to one ''Roman'' resource than many Romanized communities. It should be noted, however, that the actual number of brass artefacts from these sites is small. Limited excavation of small indigenous sites compared to villas, towns and forts, and possible differences in artefact curation and disposal between indigenous and Roman sites makes direct comparison of the numbers (as opposed to the proportions) of brass artefacts meaningless.

There are a few classes of sites, especially hillforts and caves, where much lower proportions of brass (i.e. less than 20%) are found. It seems most unlikely that the low proportion of brass on these sites reflects a lack of Romanization as those sites with a high proportion of brass mentioned above were amongst the least Romanized. A more likely explanation may be sought in the nature of deposition on such sites. It has become increasingly accepted that the material culture of the Iron Age which survives in the archaeological record is highly influenced by active selections made by the depositors and so ''cannot be taken at face value'' (Hill, 1994; Pollard, 1995). The low levels of brasses from some Roman-period sites in northern Britain may reflect similar structured deposition. Sites which have produced low proportions of brass artefacts include Traprain Law, the Settle Caves, Coventina's Well, and the Brougham cemetery. All four of these sites can be easily interpreted as arenas for ritual activities. Millett (1993) has demonstrated that the artefacts deposited in an early Roman cemetery were carefully selected and did not reflect the full range of artefacts available. A similar process would seem to be operating in the deposition of copper alloys on a range of Roman-period ''ritual'' sites. Brass may have been seen as an inappropriate metal for deposition in some circumstances. Alternatively, some artefacts (which were only incidentally made of brass) may have been regarded as inappropriate.

The differences in the range of Cu alloys deposited on different Roman period sites in northern Britain shows that this action was meaningful rather than unconscious. The use and deposition of metals may have formed part of a wider scheme of ideological and symbolic meanings. The next section explores this issue further in the light of the above findings.

Diversity in Alloy Choice: the Role of Symbolic Meaning

The varying levels of three different alloying elements (Zn, Sn and Pb) in Roman Cu alloys offers the opportunity to examine in detail the ways in which one Cu alloy was selected over others. Most previous archaeometallurgical research into Roman Cu alloys has focused on the ways in which alloy choice has been constrained by *technological* factors. Some variations in alloy composition do not, however, appear to be related to the physical properties of the alloys and the large data sets now becoming available make possible the examination of non-technological, that is *economic*, *social*, and *symbolic*, constraints. This evidence consists of the compositions of alloys as a whole and their relationship with artefact typology and deposition on different sites.

The use of a three-dimensional plot of Zn and Sn compositions of all Roman Cu alloys from northern Britain has shown a series of peaks, troughs and lacunae. The lack of a Cu peak (i.e. zero Sn *and* zero Zn) is curious given that other cultures have used pure Cu alongside Cu alloys (Lahiri, 1995). There is a "copper" peak which centres on 2% Sn. This Cu-like alloy would have had similar properties to pure Cu and was used for wire and sheet work. The lack of Cu alloys with high Sn *and* Zn levels suggests that pure Sn was never added to brass. The shape of the gunmetal ridge between the brass and bronze peaks confirms that brass and bronze were mixed with each other. The addition of Pb to brass seems to have been more complex. In a few cases Pb was added directly to brass, but in most cases Pb was added indirectly as leaded bronze to produce leaded gunmetals. The lacuna corresponding to low Zn brasses (<10% Zn) shows that brass was not recycled on its own. If it was recycled then it was always mixed with scrap bronze. The relationship between Sn and Zn is complex and restricted by more than simply technology.

While scrap metal may have been a frequent source of raw material for the Roman coppersmith, it would appear that some care was taken over its use. Alloys would have been recognizable by their colour (and possibly other properties) and may have been "blended" together to produce deliberately mixed alloys. A recent review of the Zn content in Roman coins (Dungworth, 1996*c*) suggests that the decline in Zn was due to the progressive and deliberate mixing of weighed amounts of brass and leaded bronze to produce an alloy of desired composition. The emerging picture, therefore, is one of quite subtle control of raw materials. Recipes and tradition were as powerful constraints on alloy composition as the limits of physical metallurgy.

The variations in alloy composition of different types of artefact would have been apparent at (at least) two different levels: the user and the manufacturer. Gross differences in alloy composition produce differences in a range of properties, e.g. colour, texture, taste and sound (Hosler, 1995). These properties would have carried social and symbolic meanings for the wearers and users of the artefacts. Spiral rings, for example, can be divided into the larger types which would have been worn as finger rings and the smaller types which were earrings. The finger rings are composed of brass while the earrings are made from bronze. The use of material culture such as jewellery for the negotiation of identity (gender, class, ethnicity, etc.) is well established (Hodder, 1982). The selection of different copper alloys will have formed an important part of this process.

Wide variations in the composition of Roman alloys have been identified. In some cases the use of a particular alloy, or the mixing of different metals in particular ways, may have simply amounted to "what was done before". It is likely, however, that attitudes to the production and use of Cu alloys will have grown out of wider symbolic and ideological schemes. Some metals may have been "inappropriate" for some purposes. The blending of different metals and alloys may have been governed by a complex belief system only fleetingly exposed in this study.

The Publication of Compositional Data

The use of spectrometric techniques of analysis has allowed the compilation of enormous numbers of compositional analyses for archaeological materials. Large tables of data are not popular with editors and publishers (and the readership would, in any case, never be large) and so large quantities of scientific data remain unpublished. Even where large numbers of analyses are published in table form, the sheer size of many data sets makes them unwieldy. Data are manipulated and conclusions drawn using various computer applications such as databases and statistical packages. This would be a more appropriate form of publication and would allow readers to interrogate the data in any way they saw fit (including ways that never occurred to the original author). The increasing use of the World Wide Web offers just such an opportunity to place large and complex data sets in the public domain. In an attempt to achieve this, the full data set of Cu alloy analyses and associated archaeological data (provenance, context, etc.) are published by the *Internet Archaeology* Journal (Dungworth, 1997). It is hoped that this will ensure that the data set is used to its full potential.

Summary

Most archaeometallurgical research continues to focus on the early stages of metallurgy and it is often assumed that the analysis of artefacts from later periods is of less use because of the mixing and recycling of scrap metal. A careful study of the different Roman alloys used shows that the smiths had a great understanding of the raw materials they used. It is clear that there were complex rules governing the use of alloys as a whole (e.g. brass was always mixed with bronze when it was recycled) and in particular cases (the use of recipes for distinct artefact types).

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