Characterising copper-based metals in Britain in the first millennium AD: a preliminary quantification of metal flow and recycling

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Online supplementary material

Caple (1986) analysed 445 copper alloy pins dated between AD 400–1600 from 14 sites in England, ranging from Whitby and Ribchester in the north to Faversham in the south. Analysis was conducted by X-ray fluorescence (XRF) on metallographic specimens (i.e. cut, mounted and polished sections). The elements copper (Cu), zinc (Zn), lead (Pb), tin (Sn), nickel (Ni), iron (Fe), manganese (Mn) and antimony (Sb) were measured quantitatively; silver (Ag), arsenic (As) and gold (Au) were measured semi-quantitatively. Dating of the pins was very variable—some were quite accurately dated, others only to a general range. Broadly speaking, the material analysed covered the following periods: Roman (72 samples, mostly from Ribchester); Saxon (52 samples—mostly unspecifically dated, from Whitby, but a few later samples from York and Lincoln with more precise dates); early medieval (eleventh–thirteenth century AD, 33 samples); later medieval (thirteen–fifteen century AD, 120 samples); and post-medieval (105 samples).

Dungworth (1995) published *c.* 2600 analyses of copper alloy objects from 83 sites across northern Britain (from Manchester to Edinburgh), analysed by XRF either on polished surfaces or on drillings removed from the object. He quantified Cu, Zn, Pb, Sn, Fe, Ni, Mn, As and cobalt (Co). Antimony (Sb) was similarly recorded but subsequently deemed to be unreliable because of changes to the stripping and deconvolution routine used over the course of the analytical programme. The samples came from a range of sites, most commonly military (*c.* 30% of samples analysed), but also including *vici* (*c.* 14%), large rural sites (*c.* 12%), and villas (*c.* 10%). Typologically, they were classified as personal ornamentation (*c.* 25%), household objects (*c.* 27%), military equipment (*c.* 8%), transport-related objects (*c.* 13%), waste (*c.* 5%) or ‘other/uncertain’ (*c.* 22%). Dungworth’s material was dated to cultural periods with varying degrees of specificity, codified as shown in Table 1 of the main article.

Blades (1995) reported analytical data on 1235 samples from 18 sites in England, south of West Heslerton in North Yorkshire, using inductively coupled plasma optical emission spectroscopy (ICP-OES) on solutions made from 5–10mg samples removed from the object.

He reported data for Cu, Zn, Pb, Sn, Fe, As, bismuth (Bi), cadmium (Cd), Sb, Co, Ni, chromium (Cr), phosphorus (P), sulfur (S), manganese (Mn), Ag, Au and vanadium (V). The objects are classified into more than 30 forms, the most frequent of which are brooches (*c.* 19% of all objects analysed), pins (*c*. 12%) and sheets (*c*. 12%). The sites date from *c.* AD 400–1600. His chronological classification is as shown in Table S2 (Table S2).

<TABLE S2>

Bayley and Butcher (2004) published data on *c.* 3500 Roman brooches found in Britain, including quantitative chemical analyses of 1062 brooches from 39 sites for the elements Cu, Zn, Pb, Sn and Ag. Of these, 1018 were analysed by atomic absorption spectrometry (AAS), based on samples of 10–20mg of clean metal removed by drilling from the back of each brooch, with the remainder of the quantitative data derived from Dungworth (1995: see below). The remainder of the database by Bayley and Butcher consists of attributions of each brooch to an alloy type based on qualitative XRF analysis on uncleaned surfaces. We discuss the identification of these alloy types below, but have not used these qualitative data in our analysis. The quantitative analyses published are unnormalised, and the analytical totals show occasional low or high values (assuming that Cu, Zn, Pb and Sn represent the bulk of the components), which Bayley and Butcher attribute to errors in the measurement of copper by AAS on the basis of re-analysis by XRF (Bayley & Butcher 2004: 21). As was the case with the original data interpretation, this uncertainty in Cu would not affect the allocation of a sample to alloy type using the methodology described below, so we have accepted the data as published. Specific dates are not given for each brooch analysed, although each is described according to a standard typology, so that a date range can be allocated to many of the analyses. The majority fall into the date categories of Late Iron Age (pre-conquest: 100 BC–AD 50, 10 samples), AD 1–70 (Late Iron Age to Roman conquest, 368 samples), AD 43–70 (conquest, 91 samples) or AD 70–170 (post-conquest, 296 samples).

Given that the traditional alloy categorisation such as that used by Bayley and Butcher (or similar) is so widely used in archaeometallurgy, we have compared the relationship between the classifications derived by Bayley and Butcher and those proposed here (Table S3). Some categories are effectively unchanged, e.g. 100% of the brooches described by Bayley and Butcher as ‘leaded gunmetal’ are classified as leaded gunmetal (LG) by our scheme, but the main (simple binary) alloy types are significantly shifted. For example, objects in Bayley and Butcher’s category ‘brass’ are reclassified into either gunmetal (G) or LG (accounting for *c.* 65% of the ‘brass’ when combined), with only 31% being classified as brass (BR). ‘Bronze’ is likewise shifted to G and LG (together *c.* 27%), but with 37% remaining as Bronze (B) and

37% re-defined as leaded bronze (LB). The overall effect, as expected, is to move the alloys away from the simple binary categories, such as brass and bronze, which imply deliberate alloy design, towards more complex categories, especially gunmetal and leaded gunmetal, which we believe highlights the mixed nature of these alloys.

<TABLE S3>

In order to provide reassurance that the datasets we are using are broadly comparable, Table S4 shows the four sets of data for the Roman period in terms of the types of alloys represented using our definitions (Table S4). For the purposes of this comparison, we have combined all of Dungworth's Roman data (C1AD, C2AD, C3AD, C4AD, EROM, MROM, LROM and ROMN) into a single category. Given that there are significant variations in the typology of the objects analysed in the geographical spread represented and the precise chronologies covered, there is a reasonable amount of agreement between these three datasets in terms of the alloy types used. Using our definitions, it might be reasonable to suggest that a 'typical' Roman assemblage from Britain contains *c.* 10% bronze objects, 20–30% leaded bronze, 10% brass, 10–20% gunmetal and 30–40% leaded gunmetal (remembering, however, that a 'bronze' could contain as little as 1% Sn on these definitions).

<TABLE S4>

References

BAYLEY, J. & S. BUTCHER. 2004. *Roman brooches in Britain: a technological and typological study based on the Richborough Collection*. London: Society of Antiquaries of London.

BLADES, N.W. 1995. Copper alloys from English archaeological sites 400–1600 AD: an analytical study using ICP-AES. Unpublished PhD dissertation, University of London. Available at: http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.261778(accssed 18 February 2015).

CAPLE, C. 1986. An analytical appraisal of copper alloy pin production: 400–1600 AD. Unpublished PhD dissertation, University of Bradford.

DUNGWORTH, D.B. 1995. *Iron Age and Roman copper alloys from northern Britain*. PhD dissertation, Durham University. Available at: http://etheses.dur.ac.uk/1024/ (accessed 21 January).

Table S1. Date categories used in Dungworth (1995).

Date category	Expansion	Definition	Number of samples
LBA	Late Bronze Age/Early Iron Age		8 samples
EIA	Early Iron Age		59 samples
IA	Iron Age		56 samples
LIA	Late (Roman) Iron Age		37 samples
C1AD	First century AD	Roman, post AD 42	261 samples
C2AD	Second century AD	Roman	248 samples
C3AD	Third century AD	Roman	148 samples
C4AD	Fourth century AD	Roman	78 samples
EROM	Early Roman	First–second century AD	134 samples
MROM	Middle Roman	Second–third century AD	32 samples
LROM	Late Roman	Third–fourth century AD	174 samples
ROMN	Roman	First–fourth century AD	235 samples

Table S2. Date categories used in Blades (1995).

Date category	Definition	Number of samples
Roman	First–fourth century AD	94 samples
Early Saxon	AD 430–650	377 samples
Middle Saxon	AD 650–850	149 samples
Late Saxon	AD 850–1066	73 samples
Early medieval	Eleventh–thirteenth century	58 samples
Late medieval	Thirteenth–fifteenth century	272 samples
Post-medieval	After AD 1600	212 samples

Table S3. Comparison of the alloy classification of Roman brooches using Bayley and Butcher's scheme with that obtained using the definitions proposed in Table 2, showing percentages of objects in Bayley and Butcher's categories (left-hand column) that fall within each of our categories (top row). Major differences are highlighted. Data from Bayley and Butcher (2004).

	C	LC	B	LB	BR	LBR	G	LG	Number
Copper	50		16.7	16.7			16.7		6
(Leaded) copper		100							1
Leaded copper				100					1
Copper/brass		12.5					62.5	25	8
Bronze			36.7	36.7			13.3	13.3	128
(leaded) bronze				67.6				32.4	68
Leaded bronze				84.6			0.3	15.1	298
Bronze/gunmetal							39.1	60.9	23
(Leaded) Bronze/gunmetal							100		19
Leaded bronze/gunmetal				7.7				92.3	26
Brass					31.3	3.4	50.4	14.9	355
(Leaded) brass						9.1		90.9	11
Leaded brass								100	1
Brass/gunmetal							29.2	70.8	24
(Leaded) brass/gunmetal								100	12
Leaded brass/gunmetal								100	1
Gunmetal							48.7	51.3	39
(Leaded) gunmetal								100	19
Leaded gunmetal								100	21

Table S4. Comparison of copper alloy types from the three datasets for the Roman period. Data recalculated from Blades (1995), Dungworth (1995) and Bayley and Butcher (2004).

	Copper	Leaded Copper	Bronze	Leaded Bronze	Brass	Leaded Brass	Gunmetal	Leaded Gunmetal	Total
Bayley & Butcher (all)	0.3	0.1	4.6	32.5	10.5	1.4	21.7	29	1062
Dungworth Roman	1.3	0.2	14.7	21.7	11.2	1.2	17.2	32.6	1274
Blades Roman	1.1	1.1	6.4	33	6.4	3.2	9.6	39.4	94
Caple Roman	8.3	0	1.4	15.3	8.3	3.2	26.4	38.9	72

Colour key:	5-20%	>20%