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Summary

Crucibles, moulds and copper alloy objects from medieval and post-medieval contexts were examined. The casting of copper alloy buckles during the 13th and 14th centuries is confirmed by the presence of ceramic moulds and part-made buckles or failed castings. The examination of the contemporary crucibles included the analysis of copper alloy droplets trapped in their vitrified surfaces. The chemical composition of these droplets differed significantly from the buckles and other contemporary copper alloy artefacts. The examination of the 16th–17th century crucibles showed that they were manufactured from a different clay source to that used in the 13th and 14th centuries. These crucibles are unlikely to be residual and may relate to the 16th–17th century casting of copper alloy candlesticks.

Keywords

Metal Working-non Fe
Post Medieval
Medieval

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Introduction

Excavations at the Guildhall Yard, London (NGR TQ 3250 8135) by the Museum of London Archaeology Service (1985–95) took place as part of a proposal for the construction of the new Guildhall Art Gallery (site codes GAG87 and GYE92). Following the discovery of the Roman amphitheatre in 1987 the site was scheduled. The amphitheatre was overlain by a sterile deposit of 'dark-earth' and above this was a long sequence of medieval and later development up to the Great Fire and beyond. The medieval deposits (Period 13) included evidence for copper alloy working (hearths, crucibles, moulds and part made artefacts). There was a later post-medieval phase (Period 16) of copper alloy casting when the products were candlesticks.

Table 1. Dates for periods of activity

Period 9	Post dark earth–1050
Period 10	1050–1140
Period 11	1140–1230
Period 12	1230–1270
Period 13	1270–1350
Period 14	1350–1425
Period 15	1425–1550
Period 16	1550–1666
Period 17	1666–1790

Description of Samples

The samples submitted for examination and analysis included crucibles, moulds and copper alloy artefacts relating to two periods of copper alloy casting: the manufacture of buckles in Period 13 and of candlesticks in Period 16. Several other artefacts were submitted for examination, including a Winchester style strap end and a piece of lead used as a support for stamping sheet metal.

Crucibles

Crucibles were recovered from a range of contexts. A selection of the those with the most vitrified surfaces (i.e. those where it was most likely that droplets of metal would be trapped in the vitrified surfaces of the crucibles) was submitted for examination and analysis (Table 2). This included 88 fragments of crucible, 1 fragment of cupel, 2 fragments of copper alloy slag and 2 fragments of vitrified ceramic hearth lining. Most of the crucible fragments (78% by weight) derived from period 13 (1270–1350) contexts, in particular Open Area 219 (a series of hearths and industrial deposits).

The single cupel is made from clay (rather than bone ash) and is likely to be Roman in date (all of the dateable artefacts from period 9 contexts were residual Roman objects).

Some of the crucibles (and all of those from pre phase 13 contexts) were rather small, thin-walled (<10mm) and of rounded or hemispherical form with a small lip (Jacqui Pearce personal communication). The Period 13 and later crucibles are fairly large (rim diameters of ~100mm) and thick-walled vessels (10–20mm thick) with straight sides and rounded bases. These crucibles could have held up to 5kg of molten copper alloy. The outer surfaces of these

crucible fragments were often heavily vitrified and in many cases had added outer layers applied (cf. Bayley 1992: 3–4). Such outer layers were added to protect the crucible fabric from thermal shock and help insulate the contents. This insulation would help keep the contents of the crucible molten when the vessel was taken out of the hearth and the metal poured into moulds.

Table 2. Crucible fragments from each context (+ other materials). All from site GYE92. NB. only a selection of all the crucibles were examined.

Accession	Context	Period	Land Use	Group	Comments	Frags	Weight
3291	20266	9	OA100	1108	Cupel	1	23
6312	23419	10	OA105	1273	Small, thin-walled crucible fragments	1	15
2185	13910	11	OA109	1181	Small, thin-walled crucible fragments	1	25
566	11346	12	OA211	678	Small, thin-walled crucible fragments	1	47
2782	19255	13	OA200	56	Highly vitrified crucible fragments	6	73
4047	19307	13	OA200	57	Large thick-walled crucible fragments	16	365
4648	21000	13	OA202	93	Large thick-walled crucible fragments	1	109
4883	21035	13	OA202	93	Large thick-walled crucible fragments	2	137
5757	21515	13	OA202	1527	Large thick-walled crucible fragments	9	887
219	10638	13	OA219	414	Large thick-walled crucible fragments	39	2779
3774	19208	14	B204	67	Large thick-walled crucible fragments	2	124
156	10636	14	B224	1601	Small, thin-walled crucible fragment (no vitrification)	2	9
2757	19025	16	B205	81	Large thick-walled crucible fragments	1	149
2723	19040	16	B205	81	Large thick-walled crucible fragments	6	805
6896	19040	16	B205	81	Large thick-walled crucible fragments	1	62
Total						89	5609
2782	19255	13	OA200	56	Vitrified ceramic hearth lining	2	69
5757	21515	13	OA202	1527	Copper alloy slag	2	152

The small number of crucible fragments from pre-Period 13 contexts indicates only occasional or small-scale casting activity. Relatively large numbers of crucible fragments were recovered from Period 13 contexts. The size of the Period 13 crucibles suggests the casting of fairly large objects (or large numbers of small objects). The crucibles from Period 14 contexts are generally of the same form and fabric as those from period 13 and might be residual. The Period 16 crucible fragments appear to derive from vessels of the same size and shape as those of Period 13. These crucibles might be residual or they could have been used for melting the copper alloys used in the manufacture of Period 16 candlesticks in Building 205.

Vitrified ceramic hearth lining

Two fragments of vitrified ceramic hearth lining were included with the crucible fragments. The ceramic structure of the hearth would in places have been subjected to temperatures in

excess of 1000°C which has resulted in a black glassy inner surface. The outer surface remains an oxidised maroon colour.

Copper alloy slag

Two fragments of copper alloy slag were included with the crucible fragments. Such slags form as a result of reactions between the fuel ash, crucibles, molten metal and any fluxes that may have been used. The morphology of the slags shows that they are **not** connected in any way with the smelting of copper ores but result from the melting and casting of copper alloys.

Ceramic moulds

Three samples of mould were submitted for examination. The first consisted of one half of a two piece mould (GYE92 <203>) which had been used to cast a sub-rectangular object (30 by 55+ mm). The size and shape of this mould is similar to the Winchester style strap end recovered from the site (GYE92 <3268>). The second ceramic mould sample submitted was a small fragment of a mould used to cast large numbers of buckles (GAG87 <939>, Egan & Pritchard 1991: 122–3, fig 80). The fragment examined appears to have been a part of a mould which cracked during casting, trapping small amounts of metal. The third sample of possible mould resembled a small plug of ceramic material with vitrified surfaces.

Copper alloy objects

A range of copper alloy objects were submitted for analysis. These included examples relating to the Period 13 manufacture of buckles with oval frames and ornate outside edges (Figure 1, cf. Egan & Pritchard 1991: 72–4, fig 44) and included both finished and part-made examples. Other copper alloy objects examined included scrap metal from Period 13 contexts and the Winchester style strap end (GYE <3268>).

Figure 1. GYE92 accession <5581>. Three joining buckles.

Lead

A lead object (GYE 92 <1868>) submitted for examination consists of a piece of sheet (48 by 36 by 1–2mm) which bears a stamped impression. This object had been used as a supporting medium while designs were stamped onto non-ferrous sheet metal (repoussé). The impression

of the stamped motif on the lead was reproduced using silicone rubber (Figure 2). This shows the hind leg and tail of an animal such as a lion (cf. Egan & Pritchard 1991: 112, fig 72).

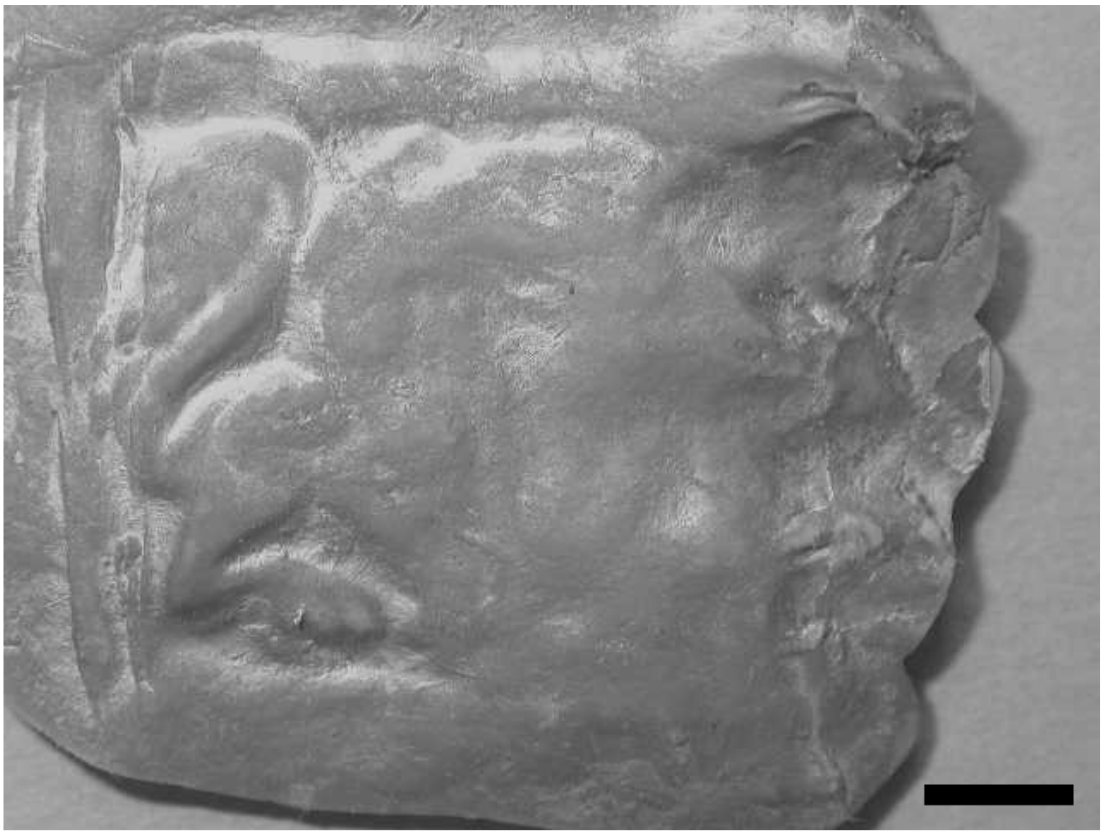

Figure 2. Silicone rubber copy of the impression on a piece of lead (scale bar = 5mm).

Chemical analysis of samples

A selection of the artefacts submitted for examination were analysed to determine their chemical compositions. Thirteen crucibles were examined to determine if the same clay sources were used in Period 13 and Period 16. In addition, where copper alloy droplets remained trapped in the vitrified surfaces of the crucibles, these were analysed. Thirty-five copper alloy artefacts (mostly from Period 13 contexts or typologically similar to those manufactured in Period 13) were analysed to characterise the range of alloys used in the manufacture of buckles.

Sample preparation and chemical analysis

The samples of crucible and of copper alloy artefact selected for analysis were mounted in cold-setting resin to expose a cross-section. The crucible samples were selected to include regions of ceramic fabric and vitrified surfaces. The copper alloy samples were generally $<2mm^3$. The mounted samples were polished to a 1-micron finish. The samples were examined with a scanning electron microscope and areas analysed using the attached energy dispersive spectrometer (for further details of the procedures used see Dungworth 2001).

The analysed copper alloy samples were assigned to the four main alloy types (brass, gunmetal, bronze and copper) according to the levels of zinc and tin present (Bayley 1991).

Pure copper is only used very rarely during the medieval period but 'more-or-less pure copper' (i.e. alloys containing <8% zinc and <3% tin) are more common.

Chemical composition of the ceramic fabric of the crucibles

The six crucible samples from Period 13 contexts (as well as the examples from Period 12 and Period 14) all have very similar compositions and are likely to have been manufactured using clay from a single source (Table 3). The three crucible samples from Period 16 contexts all share a similar composition but this can be distinguished from that used in Period 13 by the relatively high alumina and lime contents and low silica content. The Period 16 crucibles are unlikely to be residual from Period 13 activity. The Period 14 crucible sample has the same composition as the Period 13 crucibles and is likely to be residual. The period 10 and 11 crucible samples have compositions which do not closely match those of Period 13 or 16.

Table 3. Chemical composition of the ceramic fabric of the sampled crucible fragments. All from site GYE92.

Sample	Accession	Period	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Fe_2O_3
4	3612	10	<0.5	1.3	15.9	73.8	<0.3	<0.2	3.8	0.5	0.8	4.0
6	2185	11	<0.5	0.6	13.1	81.8	0.3	<0.2	1.0	0.4	0.7	2.1
7	566	12	<0.5	0.8	19.9	73.0	0.5	<0.2	2.3	0.4	0.7	2.5
1	219	13	<0.5	0.9	19.2	73.8	<0.3	<0.2	1.7	0.8	0.8	2.8
2	219	13	<0.5	1.2	18.8	73.2	<0.3	<0.2	2.3	0.4	0.9	3.3
9	5757	13	<0.5	0.7	14.8	80.4	<0.3	<0.2	1.7	0.3	0.6	1.6
10	2782	13	0.5	0.9	19.2	72.9	0.4	<0.2	2.1	0.5	0.8	2.7
11	4648	13	<0.5	0.8	18.1	75.6	<0.3	<0.2	2.3	0.3	0.7	2.2
16	4883	13	<0.5	0.9	20.5	71.2	<0.3	<0.2	2.7	0.5	1.0	3.3
14	3774	14	0.7	0.9	17.2	74.9	<0.3	<0.2	1.8	0.5	0.8	3.2
12	2757	16	<0.5	0.9	21.3	66.4	2.3	0.5	3.0	1.9	1.1	2.5
13	6896	16	<0.5	1.0	23.0	67.2	0.6	0.3	2.9	0.9	0.9	3.3
17	2723	16	<0.5	1.0	22.7	68.0	0.6	0.3	3.1	1.0	1.0	2.4

Chemical composition of metallic droplets trapped in the vitrified surfaces of the crucibles

Ten of the crucible samples had small droplets of copper alloy trapped in the vitrified surfaces (data in Appendix 1). Metal droplets were also identified in a piece of slag and a possible piece of mould.

The copper alloy droplets trapped in the vitrified surfaces of the crucibles contain varying levels of copper, zinc, tin and lead. Not all copper alloy droplets in a single crucible share the same chemical composition, for example, crucible 16 contains three copper droplets, one bronze droplet and one gunmetal droplet. The degree of vitrification on the surface of many of the crucibles illustrates that they were re-used many times. If the composition of the copper alloys melted varied with each re-use then the copper alloy droplets would also vary. In addition, a copper alloy droplet trapped in a vitrified layer would be subjected to heat and oxidation with each re-use of the crucible. While the thermochemical properties of many of the elements in a copper alloy vary widely, zinc, tin and lead are all more volatile and more easily oxidised than copper. Thus, copper alloy droplets maintained at high temperatures

under oxidising conditions will tend to be transformed into more-or-less pure copper (and into copper oxide if these conditions are maintained, see Dungworth 2000a for further data).

The copper alloy droplets in the crucibles generally contain more copper and less tin, zinc and lead than the contemporary artefacts. While 61% of the droplets are more-or-less pure copper, only 17% of the artefacts were composed of more-or-less pure copper. The only copper alloy artefacts with chemical compositions comparable to the droplets trapped in the crucibles (i.e. more-or-less pure copper) are two buckles and the samples of wire. The high proportion of copper (as opposed to copper alloy) droplets in the crucibles can be explained by reference to the thermochemical behaviour of molten copper alloys. Nickel is one of the few elements present in copper alloys which has almost identical thermochemical properties to copper and so would be neither enriched nor depleted by exposure to hot oxidising conditions. However, nickel was detected in 13 out of 35 copper alloy droplets trapped in the crucibles (37%) but in only 1 out of 34 copper alloy objects (3%). The differences in the nickel contents suggest that the Period 13 crucibles were not used to manufacture the buckles submitted for analysis. One of the Period 13 crucibles (<4883>) contains copper alloy droplets with levels of arsenic and antimony that are commonly seen in large castings, such as cauldrons, e.g. Dungworth 2000b.

The copper alloy droplets in the Period 16 crucible and mould show much less variation than the copper alloy droplets from Period 13 crucibles. The composition of these droplets (gunmetal) may provide an indication of the composition of the metal that was cast.

Scanning EDXRF examination of a mould fragment

One of the mould fragments (GYE92 <203> was examined using scanning EDXRF analysis (cf. Scott 2001). This technique has been used successfully to determine the shape of copper alloy objects cast in ceramic moulds even where relatively little relief survived on the mould (e.g. Dungworth 2001: 16–17, fig 13). Zinc in the copper alloy that had been poured into the mould would have diffused into the ceramic mould and be concentrated in those parts of the mould that were in contact with the metal. Scanning EDXRF analysis allows the mapping of element distribution across the surface of an object. The analysis of mould GYE92 <203> showed the presence of small amounts of copper and zinc. Scanning EDXRF of the zinc showed that it is evenly distributed across the surface of the mould (the copper levels were too low to allow scanning EDXRF). The mould fragments examined were parts of one half of a two-piece mould. The surviving fragments probably came from the undecorated reverse side of an object.

Chemical composition of the copper alloy objects

Thirty-five samples were taken from copper alloy objects including buckles, strap loops, bar mounts and waste (data in Appendix 2). Five of the samples are likely to relate to the Period 13 manufacture of buckles with oval frames and ornate outside edges (Figure 1, cf. Egan & Pritchard 1991: 72–4, fig 44): sample 19 was taken from three buckles cast together and never separated, sample 21 from waste metal inside a buckle mould, sample 29 from a buckle with ceramic mould still adhering to the metal, and samples 27 and 143 were from buckles typologically identical to the three joining buckles. Two of the samples came from Period 13 contexts while the others are residual in later contexts. All five samples have very similar chemical compositions with moderate amounts of zinc, tin and lead (a gunmetal or leaded gunmetal). Such an alloy is well suited for the casting of small items such as buckles and was used in the manufacture of many medieval dress accessories (Heyworth 1991).

The samples of wire (copper alloy samples 139.1–139.3) were all composed of more-or-less pure copper, which would have the ductility necessary for the manufacture of wire. The only other artefacts composed of copper were two buckles: a crude probably unfinished buckle (sample 138) and a buckle (sample 140.1, and its pin, sample 140.2) which appears to have been hammered to shape rather than cast.

The other copper alloy artefacts are (with one exception) composed of brass or gunmetal. This accords with previous work which has established that three-quarters of 14th century copper alloys used for small decorative objects are gunmetals or brasses (Heyworth 1991).

The only bronze artefact among the copper alloy artefacts sampled is the Winchester style strap end (sample 146). During the late Saxon period, bronze was an extremely popular alloy type and accounted for around 60% of all copper alloys (Blades 1995).

Discussion

The materials examined provide evidence for the casting of copper alloy artefacts in Periods 13 and 16. The small quantities of crucible from pre-Period 13 contexts provide evidence for only limited copper working.

The copper alloy artefacts and moulds provide good evidence for the casting small buckles during Period 13. The unfinished buckles and mould fragments indicate that buckles would have been cast together in larger numbers before being separated. In the initial publication of the GAG87 accession <939> mould, Egan & Pritchard suggest that 'it is appropriate to think in terms of hundreds of these objects being manufactured at any one time' (Egan & Pritchard 1991: 123). Similar moulds for the mass-production of base metal strap loops (Armitage *et al*. 1981: 364) were recovered previously, 250m to the east in Copthall Avenue.

The pre-Period 13 crucibles were all rather small while the Period 13 and onwards crucibles were larger vessels (~100mm diameter) with rounded bases and straight sides (the few examples from Period 14 contexts are likely to be residual). The crucibles from Period 16 are of a similar form and fabric to those of Period 13 but have slightly different chemical compositions. They are unlikely to be residual and probably relate to the manufacture of candlestick holders (Jacqui Pearce personal communication).

The compositions of the metal droplets trapped in the vitrified layers of the Period 13 crucibles differed from those of the copper alloy buckles and the crucibles may not have had anything directly to do with the manufacture of the buckles.

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Appendix 1: chemical composition of copper alloy droplets trapped in crucibles, moulds and slag

Sample	Area	Site	Context	Accession	Period	Cu	Zn	Sn	Pb	Fe	Ni	As	Sb	Total	Alloy Type
Crucible 4	Droplet 1	GYE92	23419	6312	10	78.6	1.4	16.5	2.4	0.2	0.2	0.6	<0.5	99.9	Bronze
Crucible 4	Droplet 2	GYE92	23419	6312	10	90.5	0.6	6.9	<0.5	0.8	<0.1	<0.5	<0.5	98.8	Bronze
Crucible 6	Droplet 1	GYE92	13910	2185	11	99.0	<0.1	<0.5	1.1	0.4	<0.1	<0.5	<0.5	100.5	Copper
Crucible 6	Droplet 2	GYE92	13910	2185	11	98.1	<0.1	0.6	<0.5	0.5	<0.1	<0.5	<0.5	99.2	Copper
Crucible 6	Droplet 3	GYE92	13910	2185	11	98.4	0.3	<0.5	<0.5	0.4	<0.1	<0.5	<0.5	99.0	Copper
Crucible 6	Droplet 4	GYE92	13910	2185	11	77.5	11.1	4.4	7.4	0.6	<0.1	<0.5	<0.5	100.9	Leaded gunmetal
Crucible 10	Droplet 1	GYE92	19255	2782	13	99.1	<0.1	<0.5	<0.5	<0.1	<0.1	<0.5	<0.5	99.1	Copper
Crucible 10	Droplet 2	GYE92	19255	2782	13	99.9	<0.1	<0.5	<0.5	<0.1	<0.1	<0.5	<0.5	99.9	Copper
Crucible 10	Droplet 3	GYE92	19255	2782	13	100.5	<0.1	<0.5	<0.5	0.1	<0.1	<0.5	<0.5	101	Copper
Crucible 10	Droplet 4	GYE92	19255	2782	13	99.2	<0.1	<0.5	<0.5	0.1	<0.1	<0.5	<0.5	99.3	Copper
Crucible 11	Droplet 1	GYE92	21000	4648	13	99.5	<0.1	0.7	<0.5	0.2	0.4	<0.5	<0.5	100.7	Copper
Crucible 11	Droplet 2	GYE92	21000	4648	13	99.2	<0.1	1.1	<0.5	0.1	0.5	<0.5	<0.5	100.9	Copper
Crucible 11	Droplet 3	GYE92	21000	4648	13	99.6	<0.1	0.5	<0.5	<0.1	0.2	<0.5	<0.5	100.4	Copper
Crucible 11	Droplet 4	GYE92	21000	4648	13	99.1	0.6	0.5	<0.5	0.3	0.3	<0.5	<0.5	100.8	Copper
Crucible 16	Droplet 1	GYE92	21035	4883	13	95.2	<0.1	2.6	<0.5	<0.1	0.2	0.9	0.9	99.8	Copper
Crucible 16	Droplet 2	GYE92	21035	4883	13	90.2	6.5	2.6	<0.5	<0.1	<0.1	<0.5	0.6	99.9	Copper
Crucible 16	Droplet 3	GYE92	21035	4883	13	90.4	<0.1	6.3	<0.5	<0.1	<0.1	1.3	2.5	100.5	Bronze
Crucible 16	Droplet 4	GYE92	21035	4883	13	94.6	<0.1	1.6	<0.5	<0.1	0.2	1.8	1.6	99.8	Copper
Crucible 16	Droplet 5	GYE92	21035	4883	13	95.2	0.3	2.9	<0.5	<0.1	0.3	0.9	1.3	100.9	Copper
Crucible 9	Droplet 1	GYE92	21515	5757	13	97.9	<0.1	1.3	<0.5	0.8	<0.1	<0.5	<0.5	100.0	Copper
Slag 36	Droplet 1	GYE92	21515	5757	13	78.7	8.6	5.6	6.4	0.9	<0.1	<0.5	<0.5	100.2	Leaded gunmetal
Crucible 1	Droplet 1	GYE92	10638	219	13	94.1	<0.1	5.8	<0.5	<0.1	<0.1	<0.5	<0.5	99.9	Bronze
Crucible 2	Droplet 1	GYE92	10638	219	13	97.2	<0.1	1.8	<0.5	<0.1	0.3	<0.5	0.6	99.9	Copper
Crucible 2	Droplet 2	GYE92	10638	219	13	98.7	<0.1	<0.5	<0.5	<0.1	<0.1	0.6	<0.5	99.3	Copper
Crucible 2	Droplet 3	GYE92	10638	219	13	98.9	<0.1	<0.5	<0.5	0.1	<0.1	<0.5	<0.5	99.0	Copper
Crucible 2	Droplet 4	GYE92	10638	219	13	99.6	<0.1	<0.5	<0.5	0.1	<0.1	<0.5	<0.5	99.7	Copper
Crucible 14	Droplet 1	GYE92	19208	3774	14	96.1	<0.1	3.7	<0.5	0.2	<0.1	<0.5	<0.5	100.0	Bronze
Crucible 14	Droplet 2	GYE92	19208	3774	14	95.9	0.2	2.2	<0.5	0.1	0.1	<0.5	1.0	99.6	Copper
Crucible 14	Droplet 3	GYE92	19208	3774	14	98.5	<0.1	<0.5	<0.5	0.1	<0.1	<0.5	<0.5	98.6	Copper
Crucible 12	Droplet 1	GYE92	19205	2757	16	83.7	9.2	4.6	<0.5	1.0	<0.1	<0.5	1.7	100.2	Gunmetal

Sample	Area	Site	Context	Accession	Period	Cu	Zn	Sn	Pb	Fe	Ni	As	Sb	Total	Alloy Type
Crucible 12	Droplet 2	GYE92	19205	2757	16	82.4	11.9	3.6	<0.5	1.3	<0.1	<0.5	<0.5	99.2	Gunmetal
Mould 144	Droplet 1	GYE92	19040	12950	16	87.2	5.7	4.0	1.4	0.6	<0.1	<0.5	<0.5	98.9	Gunmetal
Mould 144	Droplet 2	GYE92	19040	12950	16	84.9	6.0	5.7	1.1	0.3	0.2	<0.5	0.6	98.8	Gunmetal
Mould 144	Droplet 3	GYE92	19040	12950	16	82.7	7.0	5.3	2.1	0.7	0.5	<0.5	0.7	99.0	Gunmetal
Mould 144	Droplet 4	GYE92	19040	12950	16	83.8	7.3	4.4	2.7	0.5	0.2	<0.5	0.6	99.5	Gunmetal

Sample	Area	Site	Context	Accession	Period	Cu	Zn	Sn	Pb	Fe	Ni	As	Sb	Total	Alloy Type
Copper alloy 136	Wire	GYE92	10679	94	13	97.1	0.4	1.7	0.7	<0.1	<0.1	<0.5	<0.5	99.9	Copper
Copper alloy 139.1	Wire	GYE92	10679	95	13	95.3	0.9	1.7	1.3	<0.1	<0.1	<0.5	<0.5	99.2	Copper
Copper alloy 139.2	Wire	GYE92	10679	95	13	94.3	0.6	3.5	0.9	0.3	<0.1	<0.5	<0.5	99.6	Bronze
Copper alloy 139.3	Wire	GYE92	10679	95	13	99.5	<0.1	<0.5	<0.5	<0.1	<0.1	<0.5	<0.5	99.5	Copper
Copper alloy 146	Strap end (Winchester style)	GYE92	20403	3268		86.2	0.4	10.5	2.0	<0.1	<0.1	<0.1	<0.1	99.1	Bronze

Appendix 2: chemical composition of copper alloy artefacts

Sample	Area	Site	Context	Accession	Period	Cu	Zn	Sn	Pb	Fe	Ni	As	Sb	Total	Alloy Type
Copper alloy 19	Buckle (3 joining examples)	GYE92	23086	5581	17	86.2	6.3	3.8	1.8	1.3	<0.1	<0.5	<0.5	99.4	Gunmetal
Copper alloy 21	Waste metal from buckle mould	GAG87	4625	939	13	83.8	6.2	5.6	4.1	0.7	<0.1	<0.5	<0.5	100.4	Leaded Gunmetal
Copper alloy 29	Buckle and mould (cf. <5581>)	GYE92	20735	6154	13	77.7	6.9	6.6	7.4	1.0	<0.1	<0.5	<0.5	99.6	Leaded Gunmetal
Copper alloy 27	Buckle (type cf. <5581>)	GYE92	21518	5535	17	84.0	7.7	4.3	2.8	0.9	<0.1	<0.5	<0.5	99.7	Gunmetal
Copper alloy 143	Buckle fragment (cf. <5581>) or waste	GAG87	385	421	14	77.2	9.7	6.0	5.0	0.6	<0.1	1.0	0.6	100.1	Leaded Gunmetal
Copper alloy 138	Buckle (unfinished?)	GAG87	353	307	14	99.2	<0.1	<0.5	<0.5	<0.1	<0.1	<0.5	<0.5	99.2	Copper
Copper alloy 140.1	Buckle (rectangular, wrought ?)	GAG87	297	445	13	98.8	<0.1	<0.5	1.4	<0.1	<0.1	<0.5	<0.5	100.2	Copper
Copper alloy 140.2	Buckle pin	GAG87	297	445	13	99.4	<0.1	<0.5	1.2	<0.1	<0.1	<0.5	<0.5	100.6	Copper
Copper alloy 20	Buckle fragment	GYE92	23605	6605	13	79.6	14.7	3.9	1.2	0.7	<0.1	<0.5	<0.5	100.0	Brass
Copper alloy 22	Buckle fragment	GYE92	23611	6633	13	79.8	13.0	4.0	2.3	0.6	<0.1	<0.5	<0.5	99.6	Brass
Copper alloy 35	Buckle (two rectangles)	GAG87	us	189		79.7	11.2	4.9	2.3	1.1	<0.1	<0.5	<0.5	99.2	Gunmetal
Copper alloy 32	Buckle (rectangular, cast)	GYE92	19150	2424	14	85.9	8.2	4.4	1.1	0.8	<0.1	<0.5	<0.5	100.3	Gunmetal
Copper alloy 28	Buckle (rectangular, cast)	GYE92	20945	5560	10	83.0	9.3	4.9	1.2	0.9	<0.1	<0.5	<0.5	99.3	Gunmetal
Copper alloy 23	Strap loop (failed casting)	GAG87	us	458		79.4	15.0	3.6	0.8	0.7	<0.1	<0.5	<0.5	99.5	Brass
Copper alloy 145	Strap loop (failed casting ?)	GYE92	21518	5536	17	75.4	14.1	5.4	3.3	1.2	<0.1	<0.5	<0.5	99.4	Gunmetal
Copper alloy 25	Strap loop fragment (or waste ?)	GYE92	10676	129	13	78.3	16.5	2.4	1.9	0.7	<0.1	<0.5	<0.5	99.7	Brass
Copper alloy 34	Strap loop	GYE92	10676	124	13	85.2	7.3	3.8	3.1	1.0	<0.1	<0.5	<0.5	100.4	Gunmetal
Copper alloy 26	Strap loop ?	GYE92	23601	6623	13	81.4	5.6	8.1	4.1	0.4	<0.1	<0.5	<0.5	99.6	Leaded Gunmetal
Copper alloy 30	Bar mount	GYE92	19329	2863	13	77.3	16.4	2.9	2.2	1.0	<0.1	<0.5	<0.5	99.8	Brass
Copper alloy 31	Bar mount	GYE92	20735	6164	13	86.0	8.0	3.7	0.8	1.1	<0.1	<0.5	<0.5	99.5	Gunmetal
Copper alloy 142.1	Mounts	GYE92	19307	2811	13	82.5	13.6	2.1	1.1	0.2	<0.1	<0.5	<0.5	99.5	Brass
Copper alloy 142.2	Mounts	GYE92	19307	2811	13	82.2	12.1	2.4	1.8	0.1	0.2	0.8	<0.5	99.6	Brass
Copper alloy 142.3	Mounts	GYE92	19307	2811	13	77.2	10.2	2.6	7.9	0.3	<0.1	1.2	<0.5	99.4	Gunmetal
Copper alloy 142.4	Mounts	GYE92	19307	2811	13	84.9	9.9	1.9	2.1	0.4	<0.1	<0.5	<0.5	99.2	Brass
Copper alloy 142.5	Mounts	GYE92	19307	2811	13	84.8	11.5	1.7	1.6	0.3	<0.1	<0.5	<0.5	99.9	Brass
Copper alloy 142.6	Mounts	GYE92	19307	2811	13	85.0	10.8	1.9	1.9	0.5	<0.1	<0.5	<0.5	100.1	Brass
Copper alloy 135	Arched purse holder fragment	GYE92	20995	5748	15	82.2	8.5	4.5	2.9	1.0	<0.1	<0.5	<0.5	99.1	Gunmetal
Copper alloy 137.1	Sheet (with punched holes)	GYE92	17131	2166	13	84.7	11.6	1.3	1.0	0.4	<0.1	<0.5	<0.5	99.0	Brass
Copper alloy 137.2	Sheet (with punched holes)	GYE92	17131	2166	13	83.8	12.0	1.2	2.2	0.5	<0.1	<0.5	<0.5	99.7	Brass
Copper alloy 33	3 joining rivets?	GYE92	10679	101	13	79.3	16.8	2.1	<0.5	1.2	<0.1	<0.5	<0.5	99.4	Brass