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Summary

116 sherds and 16 fairly complete crucibles of 3 different fabrics were examined and the metal-rich deposits on them analysed by XRF. Evidence for the melting of silver was found mainly, but not exclusively, on Stamford ware and small London ware crucibles while the larger London ware and EMCW crucibles were used mainly for a wide range of copper alloys.

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Introduction

All the crucible sherds found in recent excavations in the City of London were submitted to the A M Lab for examination and analysis of the metal-rich deposits on them (AML 842022 and 861885-90). They had been divided into three major groups on the basis of their fabrics; ie Roman, Saxo-Norman and later medieval. There were also a few sherds which could not be assigned definitely to any one of these three groups. The Saxo-Norman group was considered first as this material is to be included in a Finds volume which is nearly ready for publication.

At the same time a number of complete or nearly complete crucibles from the Museum of London's collections were also examined and the metal-rich deposits on them analysed to provide comparative data (AML 858505-7). These complete vessels came mainly from 19th century building works in the City and provide a far better idea of the vessel forms than can be reconstructed from the sherds from the recent excavations.

A single ingot mould from Milk Street (AML 861891) was also analysed to see if the metal cast in it could be identified; the results were inconclusive. Apart from the crucibles, this was the only material evidence for metal working in the City in the early medieval period.

The Saxo-Norman crucibles were made of three distinct fabrics, Stamford ware, London ware and early medieval coarse ware (EMCW). In some cases there was uncertainty in the fabric identifications as the high temperatures at which the crucibles had been used caused vitrification which obscured some of the diagnostic features. A total of 116 sherds and 16 crucibles were examined, a few of which had not been used to melt metals despite being of typical crucible form and fabric.

Methods used

All the crucibles and sherds were examined under low magnification (x10 - x30) and all those with visible traces of vitreous deposits or metals were analysed semi-quantitatively by X-ray fluorescence (XRF). Some of the remaining sherds were also analysed but as these all produced non-diagnostic results (see below) it was not considered worth analysing the remainder of the pieces which are marked n/a in Tables 1-4. These sherds however had almost certainly been used as crucibles.

The XRF results were initially recorded as the height of the major peak produced by each element of interest. These were copper (Cu), tin (Sn), zinc (Zn), lead (Pb), silver (Ag) and

gold (Au). Antimony (Sb) was also detected on a few sherds and mercury (Hg) on one complete pot, though this latter case was probably post-excavation contamination. The height of the iron peak was also recorded as this element is present mainly in the clay of the crucible fabric and can be considered as an internal standard. It is almost impossible to directly compare the absolute peak heights as the numbers recorded depend not only on the duration of the analysis, but also on the size of the sherd, the proportion of its surface covered by metal-rich deposits and the varying sensitivities of the individual elements to XRF analysis.

To allow easy comparison of the results the data has been processed and the presence of an element is shown in Tables 1-4 by one of a series of symbols. Major, minor and trace amounts are represented by +++, ++ and + respectively and a possible trace is denoted by ?. By comparing the heights of the other peaks to that of the iron peak it was possible to say whether the elements they represented were present in significant amounts. Where the peaks were very weak an asterisk was entered in the 'metal melted' column which indicates that the crucible had been used to melt non-ferrous metal of some sort but that its nature cannot now be determined.

Once the sherds had been analysed and the data presented as described above, it was necessary to interpret the results to provide information on the nature of the metals being melted. This is at least a partly subjective judgement as a number of different, almost unquantifiable factors have to be taken into account. The information sought is the composition of the metal but what has been recorded is the average composition of the crucible slag and any corroded metal droplets trapped in it. Extrapolating from one to the other is not an exact science and it is this uncertainty that introduces the subjectivity to the interpretation.

One element that is notable for its almost universal presence is zinc. This is because of its chemical nature which means that it both diffuses into the crucible fabric and becomes chemically bound in the slag layer. Because of its volatility it is often detected at apparently significant levels even where it only formed a very minor component of the alloy being melted. For this reason crucibles where major or minor amounts of zinc were detected but no other elements were present at significant levels have also been marked with an asterisk in the tables.

Discussion of results

Tables 1-3 present the analytical results for the crucibles made of the three fabrics, Stamford ware, London ware and EMCW. The results are summarised in Table 5 which shows all types were used to melt both silver and copper alloys but in different proportions. (The results for the crucibles from Milk St are presented separately as no data is available as to their

fabric. Judging by the analytical results they are most likely to be Stamford ware or London ware.)

Table 5: Summary of analytical results

Alloy	Stamford	London	EMCW	Milk St
silver	6	3	1	2
copper			6	
brass			5	
gunmetal		1	2	
bronze			2	
leaded bronze			1	
leaded gunmetal	2			
leaded brass			2	
leaded copper		4	3	
lead		1		
alloy identifiable	8	9	22	2
alloy unknown		2	18	8
not analysed	1		43	
not used		5		6
Total sherds seen	17	16	83	16

Table 5 shows that Stamford ware was preferentially selected for melting silver, London ware was used for both silver and copper alloys, while the EMCW crucibles were used mainly for copper alloys. This choice may reflect the qualities, real or imagined, of the vessels. Stamford ware was an import to London so it is unlikely to have been used unless it was superior to the locally produced fabrics in some way. Its almost exclusive use for silver, a more valuable metal than copper alloys, reinforces this suggestion of higher quality.

All the fabrics were sufficiently refractory to withstand the temperatures to which they were exposed and, as the melting points of silver and copper are very close, there is unlikely to have been any significant difference in the operating temperature used for melting most of the metals noted here. The only exception is the single sherd which came from a vessel used to melt lead which has a far lower melting point. Some of the crucibles have an added outer layer of less refractory clay which is usually deeply vitrified and vesicular. This is a common feature on wheel-thrown crucibles of Roman and early medieval date. The reason for this extra layer is unknown but it would have protected the vessel from thermal shock as it was removed from the fire and would have increased its thermal capacity, keeping the metal molten for a little longer, allowing more time to pour it into a mould. In a few cases the added clay has been extended up over the rim of the crucible to make a bar across the top of the vessel, just behind the pouring lip. (This feature is noted in the Tables by the ^ symbol in the 'extra outer layer'

column.) This bar would have kept back any crucible slag floating on the molten metal when pouring it into a mould which would have helped produce cleaner castings.

One factor which is difficult to judge from small sherds is the overall size of the vessel. In general larger crucibles will not have been used for melting precious metals which were more expensive and hence tended to be used in smaller quantities. Stamford ware crucibles are often quite small with diameters typically in the range 3-7 cm though larger examples are known (Bayley 1982). The one complete vessel from Watling House had a maximum diameter of 9 cm.

The more complete London ware and miscellaneous London ware crucibles fell into the same size range with the exception of two vessels from the Bank of England (Nos 14711 and 14713) which had diameters of 14-16 cm and had been used to melt leaded copper. The two sherds with similar metal deposits were both from thick-walled vessels which must have been of similar diameters. This suggests two distinct sizes of crucibles were made from London ware, the first with diameters of 4-8 cm which were, like Stamford ware crucibles, mainly used to melt silver and the second, with diameters of around 15 cm which were used mainly to melt copper alloys (but note No 1013 from Watling House which is of the larger size but was used for silver). The larger vessels can be seen as a development towards the very large-volume, thick-walled vessels that are common in the later medieval period.

The EMCW crucibles show a considerable range of sizes, from 7 cm up to over 15 cm diameter with no particular favoured sizes. The sherds which are too small to suggest vessel diameters have very variable thicknesses (3 to 10 mm) and thus also indicate a considerable range of crucible sizes. There is some correlation between sherd thickness and the composition of the alloy melted in the vessel; leaded alloys were melted in medium or large vessels while unleaded alloys were found on small or medium sized crucibles. This makes sense as leaded alloys were used for relatively massive castings where the lack of strength of the metal was not important. Wrought metalwork and smaller castings tend to be made of unleaded alloys as they have the necessary physical properties. The vessels where XRF suggested unalloyed copper was melted are of all different sizes which can be interpreted as showing copper was used in both large and small quantities or that the XRF results are misleading and that these crucibles originally contained both leaded and unleaded copper alloys. The larger vessels are comparable in size with the larger London ware crucibles but even the smaller EMCW crucibles are larger than most of the Stamford ware and smaller London ware ones. One EMCW crucible from St Thomas' Hospital (No 13177) had an external diameter of 9 cm and contained 120 ml up to the slag 'tidemark' inside. This is equivalent to about 1 kg of metal.

References

Bayley J (1982) Non-ferrous metal and glass working in Anglo-Scandinavian England: an interim statement. PACT 7(2), 487-96.

Table 1: Analytical results for Stamford ware crucibles

site	context	Accn No	extra outer layer	Cu	Zn	Au	Pb	Ag	Sn	metal melted
BIG 82	3073	5663			+++					*
BIS 82	547	432	yes	++	++		+	+++		silver
BIS 82	662	429	yes	+	++		+			*
GPO 75	420	3701		?	++					*
Paternos	ER 751	1		+	+++		+			*
PDN 81	638	250		++	+++		+	+++		silver
PDN 81	682	254			+++					*
SWA 81	2119	3712	yes	++	++		+	+++		silver
WAT 78	0	34	yes	++	+++		+++		+++	leaded gunmetal
WAT 78	2549	1068		+++	+++		+++		+++	leaded gunmetal
WAT 78	3559	217		+	+++					*
Watling House		20235								not analysable
Probably Stamford ware										
	ER 1151	2		+	++		+	+++		silver
BIG 82	3801	5672		+			+++		?	*
GPO 75	1148	3760		++	+++		?	+++		silver
GPO 75	1195	4146			++					*
SM 75	222	458		++	++			+++		silver

Table 2: Analytical results for London ware crucibles

site	context	Accn No	extra outer layer	Cu	Zn	Au	Pb	Ag	Sn	metal melted
BIG 82	4330	4278								*
Guildh	ER 1076B	18	yes^	+++	+++		++		+++	gunmetal
OPT 81	54	1329		++	++		+++	+++		silver
WAT 78	2195	1013		+	++		?	+++		silver
POM 79	2275	510								not used
Miscellaneous London ware										
ACW 74	2	276		+++	+		+++			leaded copper
ACW 74	2	277		+++	?		+++			leaded copper
EST 83	126	109		?	+					*
Gresham	ER 460	3								not used
Bank of England		14711		++	+		++			leaded copper
Bank of England		14713		++			+++			leaded copper ?
Poultry		22010								not used
Blomfield St		13183		?	?					not used
London Wall		13182		?						not used
Gresham House		A24618		++	+		++	+++	+++	silver ? (+ Hg)
Salters Hall		24392					++			lead ?

Table 3: Analytical results for early medieval coarse ware crucibles

site	context	Accn No	extra outer layer	Cu	Zn	Au	Pb	Ag	Sn	metal melted
	ER 425	1		+++	+++		+		?	brass
BIG 82	3516	5669								n/a
BIG 82	3558	4447								n/a
BIG 82	3738	4279								n/a
BIG 82	3831	5674	yes	++	++		++	+++		silver
BIG 82	3884	5675								n/a
BIG 82	4285	4448		++	+++					brass ?
BIG 82	5400	5687		+++	+		+++			leaded copper
BIS 82	401	421		+++	+		+++		?	leaded copper/bronz
BIS 82	600	385								n/a
BIS 82	630	430		+++			++			copper
BIS 82	724	424								n/a
BIS 82	805	386		+	+					*
BIS 82	925	428								n/a
C.C.C.	ER 1167	7		+++	++		+		?	copper/? brass
CLE 81	166	109								n/a
CLE 81	395	407								n/a
Dyers A	ER 1205	1		+++	?		++			copper
GPO 75	585	1144		+	+++					*
GPO 75	585	4584								n/a
Guildh	ER 1069C	16								n/a
HOP 83	22	37								n/a
HOP 83	222	34								n/a
HOP 83	226	30								n/a
IME 83	160	88		+++	++		++			leaded brass
IRO 80	119	11		++	++		++			leaded brass
LH 74	102	591		+++			++		+++	bronze
MLK 76	3087	979			++					*
OPT 81	58	1489		+	++		?			*
OPT 81	69	1319		+	+++			?		*
OPT 81	74	1463	yes	+	++		+			*
PDN 81	1143	1222								n/a
PDN 81	1173	1220		+	+++					*
PDN 81	1191	1224								n/a
PDN 81	1252	1221		+	+		+			*
PDN 81	1943	1226	yes							n/a
PDN 81	1947	1225								n/a
PDN 81	2371	1953		+	+++					*
PDN 81	32	172								n/a
PDN 81	579	181								n/a
PDN 81	58	173								n/a
PDN 81	618	286		+	++		+			*
PDN 81	635	285		+	++					*
PDN 81	643	255								n/a
PDN 81	644	257		+	+++					*
PDN 81	645	358								n/a
PDN 81	673	360		+	+					*
PDN 81	684	311								n/a
PDN 81	698	361								n/a

Table 3 (cont)

site	context	Accn No	extra outer layer	Cu	Zn	Au	Pb	Ag	Sn	metal melted
PDN 81	84	169		?	+++					*
PDN 81	91	256								n/a
PDN 81	1995	1223								n/a
POM 79	1272	315		?	++					*
RAG 82	97	658		++	++					brass ?
SLO 82	335	76								n/a
SSL 84	7	58								n/a
SWA 81	2277	3716								n/a
SWA 81	2279	3718								n/a
TR 74	201	562								n/a
WAT 78	2091	1014								n/a
WAT 78	3891	749								n/a
WAT 78	3901	1048								n/a
HOP 83	223	47		+	+		+			*
POM 79	688	141		+	+					*
POM 79	1318	312								n/a
SH 74	451	703								n/a
PDN 81	569	178								n/a
Bishopsgate		26423		+++	?		+++		?	leaded copper (+ Sb
Bank of England		14708		+++	?		+			copper (? Sb)
Bank of England		14712		+++	+		+++		++	leaded bronze (+ Sb
In Thames		13173		+++	++		+		++	bronze
Lombard St 1865		6192		++			+			copper
St Thomas' Hosp		13177		+++	++		+		++	gunmetal
		13175		+++	+++		+		+	brass ?
		13178	yes^	+++	++		+			brass
Probably early medieval coarse ware										
C.C.C. ER 1180		2		++	+++		+		+++	gunmetal ?
C.C.C. ER 1142		2								n/a
GuildhalER 1238		4		++	?					copper ?
PDN 81	579	183								n/a
PDN 81	602	252								n/a
WAT 78	2086	363		+	+++					*
WAT 78	2215	774								n/a
WAT 78	2548	1066								n/a

Table 4: Analytical results for Milk Street crucibles

site	context	Accn No	extra outer layer	Cu	Zn	Au	Pb	Ag	Sn	metal melted
MLK76	224	89		?	+++					*
MLK 76	1056	287	yes	+	++					*
MLK 76	3067	365		+	+++		+	++		silver
MLK 76	262	531		?	+++		+			*
MLK 76	3084	860		+	++					*
MLK 76	3143	867		++	++		++	++		silver
MLK 76	224	963		?	++		+			*
MLK 76	3104	1563		+	+++					*
MLK 76	33	1651		++	++					*
MLK 76	1080	1655		+	+		+			*
		1657								not used
		1653								not used
		874								not used
		859								not used
		520								not used
		215								not used