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Ancient Monuments Laboratory
Report 32/99

X-RAY FLUORESCENCE ANALYSIS OF NON-FERROUS METALWORKING DEBRIS FROM THE ROYAL OPERA HOUSE SITE, LUNDENWIC, 1995

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Summary

This Saxon site produced a wide range of non-ferrous metalworking debris including crucibles, other vessels, ingots, blanks, moulds, slag, scrap, waste, wire, unidentifiable fragments and objects. The crucibles, industrial vessels, ingots, blanks and moulds were analysed by X-ray fluorescence. The results show that both silver and copper alloy were being melted and cast on the site, although no foci of activity could be identified. Analysis of the slag, scrap, waste, wire, unidentifiable fragments and objects carried out by Sophie Julien were interpreted.

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X-ray fluorescence analysis of non-ferrous metalworking debris from the Royal Opera House site, Lundenwic, 1995

Megan Dennis

Introduction

The site at the Royal Opera House was excavated in 1995 by the Museum of London Archaeology Service. The excavations revealed a series of structures - buildings and open areas dating from 7th to the 10th century AD. Finds from these areas included evidence of non-ferrous metalworking. This was not abundant but was more diverse than on many sites within Lundenwic, being present in the form of crucibles, moulds, ingots, wire, blanks, scrap for recycling and debris from casting. Possible metalworking tools were also recovered from the site including tongs, a chisel, punches, awls and stone hones. The assemblage has elements in common with finds from Fishergate (Rogers, 1993, 1232-9) and Hamwic (Hinton, 1996), although much smaller in size. Most of the copper alloy finds were analysed qualitatively by Sophie Julien using energy dispersive X-ray fluorescence (XRF). A number of the crucibles, industrial vessels, partly worked ingots, blanks and moulds were also analysed using the same system.

Description of the crucibles, other vessels, partly worked ingots, blanks and moulds

These items were all examined visually. They provide evidence (together with the copper alloy objects) that non-ferrous metalworking was taking place on the site during the Saxon period.

Crucibles

The 18 crucible sherds are all derive from small vessels, rim fragments from <468> reconstructed with a diameter of approximately 80 mm. The wall thickness of the sherds varies from 1-6 mm (<1364>) to 3-19 mm (<469>). The sherds are all of dark clays, often highly vitrified and reduced. They often have a lighter area of clay on the outer edge where the firing conditions have been more oxidising. Some have clear evidence for added layers (for example <1674>). Brownish residues can be seen on some of the crucible fragments - these are thought to be post-depositional deposits (for example <1362>). Some crucible fragments also have green and red-brown coloured residues characteristic of copper corrosion (for example <1674>).

The sherds were all from thumb pots (for example <1677>) though some had a slightly flared rim (described by Blackmore (1997) as open rimmed vessels, for example <1362>). These slightly different rim forms have been seen at both Fishergate and Hamwic See figure below).

Figure One

0 30 mm

Thumb pots with flared rims (open vessels) (after Rogers, 1993, Figure 608, 1232)

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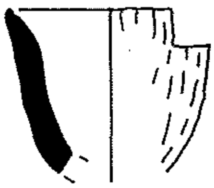

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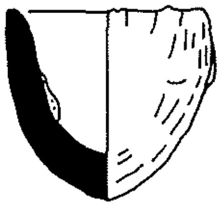

Thumb pots (closed vessels) (after Rogers, 1993, Figure 603, 1232 and Hinton, 1996, Figure 35, 87)

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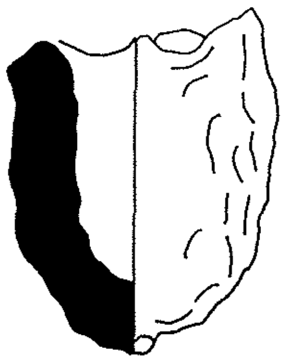

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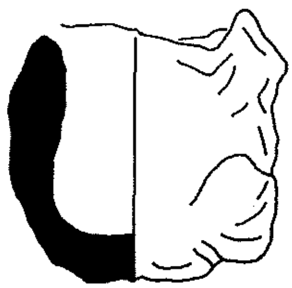

Those thumb pots described by Blackmore (1997) as closed vessels have a thicker wall at the rounded base (as can be seen in <1677>).

Two sherds (<470> and <471>) may have come from a lidded crucible. <1676>, <1364> and <468> are rim fragments. At least five of the sherds have had extra layers of clay added to the outer surface (<469>, <471>, <1365>, <1368>) and in one case this is now missing (<572>). One small fragment differs from the others in the thinness of the wall and the glassy dark greenish outer surface (<1363>).

One fragment (<1678>) comes from a crucible that was quite different in form to the rest represented in the assemblage. This is a small knop that appears to be a waisted pedestal base from a miniature vessel. Crucibles of this form are not unknown in the Saxon period but it is more likely that this was a lid (it does not appear to have been exposed to any great heat), or a small lug handle (Bayley, pers comm) like that from Fishergate (Rogers, 1993, figure 608, number 4605).

Other Vessels

One sherd was described as being from an industrial vessel (<1372>), but not a crucible as it has not been exposed to high temperatures (it is not vitrified or reduced). This is a small base fragment from a thick walled vessel with black charcoal like internal deposits which have a high iron content (see XRF results). There are a series of scratches on the outer surface. The fragment is probably of brickearth.

Partly Worked Ingots

Five ingots were examined. All could be coin stock rather than an ingot in the true sense of the word as they all appear to have been worked (hammered) to some extent. Two of bullet-shaped form (<821> and <621>) are approximately 24 mm long and 9 mm in diameter and made of silver. Two others are rectangular strips of bronze (<359> and <1390>). <359> appears to be made out of a number of thin sheets and measures 47 x 10 x 3.5 mm. <1390> has rounded corners and measures 35 x 8 x 3 mm. The largest ingot, a rectangular block (<809>) measuring 47 x 12 x 8 mm was unstratified, but seems likely to be of Saxon date, being made of debased silver (see XRF results)

Blanks

Two blanks (or small ingots) originally identified as copper alloy were also submitted for analysis. One of these (<774>) comprises two blank *sceatta*-sized discs between which is a thinner metal layer. Another fragment is also thought to be a coin blank (<763>). Silver is the main element in both.

Moulds

Three moulds were found. The first (<492>), for a brooch, is made from an antler pedicle; a similar brooch from Hamwic suggests that the castings may have been made in a lead alloy (Hinton, 1993, 3 and Newman, 1993). The second of ceramic (<142>) is incomplete, but appears to be for the back of a curved object with expanded terminal which resembles a penannular brooch. This mould looks very clean and free of any surviving metal or corrosion. Two fragments (<1366>) are rather friable but may have been used for an ingot or a straight-sided object such as a spoon or key.

Analytical Method

The samples were analysed using X-ray fluorescence. X-ray fluorescence (XRF) analysis provides a non-destructive method of identifying the alloys represented in the samples. It involves the excitation of atoms within the sample by X-rays. The atoms then give out characteristic X-rays of their own. The energy of these secondary X-rays is measured which identifies the elements present in the sample. Results are given in graphical form with energy of the X-rays being plotted against number of X-rays of that energy (counts). Each element present will be represented by one or more peaks in the graph. The larger the peak the more of that element is present in the sample. The results of the analysis were recorded as the height (in counts) of the peaks of interest within the spectrum: copper (Cu), zinc (Zn), lead (Pb), tin (Sn) and silver (Ag). Any other detectable peaks were also recorded. The counts are not directly proportional to the abundance of the elements present in the sample. They are also dependent on other effects produced within the sample (such as absorption of secondary X-rays, the shape of the fragment, its position within the XRF machine and the effects of burial conditions (Bayley, 1992)). Different metals also react differently in contact with the ceramic and so are represented in different ways. For example unreactive elements such as silver or gold are not detectable unless they are trapped in the item as discrete drops of metal but lead and zinc are enhanced as they are volatile and become chemically bound into slags, waste and ceramic. Therefore the identification of metal alloys is not always easy. In some cases no more can be stated than the object has been "used" as the overall levels of metals are low and the relative proportions not diagnostic. The results for the samples are presented overleaf.

Key for All Tables

*** - element strongly present
** - element present
* - element detectable
tr - element detectable in trace amounts
? - interpretation uncertain

Table One: XRF Analysis of Crucibles and Other Vessels

Context No	Find No	Object	Cu	Zn	Pb	Sn	Ag	Other	Interpretation
1939	1677	crucible	*	***					used
1592	1365	crucible	*	***					used
1994	1367	crucible	*	***					used
1705	469	crucible	*	***					used
1399	1676	crucible	*	***			tr		silver?
762	1674	crucible	**	*			tr		silver?
504	1363	crucible	**	**	***		***	Br	silver
1301	1675	crucible	***	**			**		debased silver?
2657	1370	crucible	*	***					used
1591	470	crucible	*	***					used
1597	572	crucible	*	***					used
2886	1368	crucible	*	***					used
1560	471	crucible	*	***			tr	Br	silver?
3190	1678	crucible?	*	*					not a crucible
-	1364	crucible	***	***	*	tr	*		debased silver?
-	1369	crucible	*	***	*	tr	*		silver
-	1362	crucible	*	***	*				used
-	468	crucible	*	***	tr		*		silver
4362	1372	other vessel	tr	tr					not a crucible

Table Two: XRF Analysis of Ingots and Blanks

Context No	Finds No	Object	Cu	Zn	Pb	Sn	Ag	Other	Interpretation
1706	821	ingot	***		*		**		silver
+	809	ingot	***	**	**		*		debased silver
1705	621	ingot	***		*		***	Br	silver
1705	1390	ingot	***	tr	*	*			bronze
2874	359	ingot	***	tr	*	*			bronze
2886	763	blank	**		*		***	Au Br	silver
2651	774	blank	*		*	*	***	Au Br	silver

Table Three: XRF Analysis of Moulds

Context No	Find No	Object	Cu	Zn	Pb	Sn	Ag	Other	Interpretation
1592	1366	mould	*	***	**				used
805	142	mould	tr	*					used
3254	492	antler mould	*	**	*				used

The XRF analysis of the copper alloy objects, slag, scrap, waste, wire and unidentified objects was carried out by Sophie Julien. These are presented in Appendix One, with interpretations given by Megan Dennis.

Discussion

It is clear from the analysis of the assemblage that copper alloy melting and casting was occurring on the site, alongside the melting and working of silver and lead (Blackmore, 1997). The diversity of the finds rules out the possibility that they form part of the background level of deposition from a non-metalworking site. The presence of almost all forms of characteristic non-ferrous metalworking debris, excluding cupels, suggest that the site was a well established, if somewhat small, industrial centre. The assemblage has elements in common with Fishergate (Rogers, 1993) and Hamwic (Hinton, 1996), which produced a greater quantity of material of a similar kind. The size of the assemblage suggests that small workshop activity was taking place, not a large scale industry.

By identifying the areas the finds come from interpretation of the foci of activity may be possible (see Table Four overleaf). Open area (OA) 16 has been interpreted as an area of debris deposition (Blackmore, 1997). Waste from iron working was also relatively abundant here. The mixing of ferrous, copper alloy and silver working debris suggests that these came from a variety of areas and were transported here to be disposed of. The relative abundance of debris here suggest that this was a regular dumping ground. The other areas (OA 19, 22, 12 and 3) have much lower levels of metalworking debris. This suggests that these fragments were deposited here by accident or on an irregular basis.

Building (B) 31 has only 2 fragments in it, one of these (<821>) found within the destruction debris. This suggests that the building was not used for metal working. The debris may have been deposited during destruction, or become incorporated into domestic occupation deposits. It is also possible, however, that this low level of debris may be fragments left in their original locations following collection and disposal of the bulk of the material.

B28 has been described as an area of copper alloy metalworking with B11 being interpreted as a silversmiths workshop (Blackmore, 1997). The analysis of the debris from B28 shows that it is more likely to have been used for silver working. Three crucible fragments and one ingot from the area were analysed. Two of the crucible fragments could only be interpreted as being "used", but the ingot was made of debased silver and the remaining crucible was used to melt silver. It is, however, possible that copper alloy working was also being carried out in the same area as identical techniques and tools would have been employed. No debris was analysed from B11, so there is no evidence to support Blackmore's interpretation (1997) of it as a silversmiths workshop.

Table Four: Location of Analysed Materials

OA - open area
B - building
R - alley

Area	Context No	Finds No	Object	Interpretation
OA16	1705	621	ingot	silver
OA16	1705	1390	ingot	bronze
OA16	1705	469	crucible	used
OA16	1301	1675	crucible	debased silver?
OA16	1591	470	crucible	used
OA16	1560	471	crucible	silver?
OA16	-	1364	crucible	silver
OA19	805	142	mould	used
OA22	762	1674	crucible	silver?
OA12	504	1363	crucible	silver
OA3	4362	1372	ceramic	not a crucible
B31	1706	821	ingot	silver
B31	1994	1367	crucible	used
B28	2651	774	coin blank	silver
B28	2657	1370	crucible	used
B28	2886	1368	crucible	used
B28	-	1369	crucible	silver
B27	3190	1678	ceramic	not a crucible
B27	-	1362	crucible	used
B29	-	468	crucible	silver
R10	2874	359	ingot	bronze
R13	1592	1366	mould	used
R13	1592	1365	crucible	used
R13	1597	572	crucible	used

The remaining areas (B27, B29, R10 and R13) cannot be interpreted fully because they do not contain enough debris. B27 and 29 do not have large enough assemblages to identify the processes being carried out within them - the finds may have been accidentally deposited out of their original contexts or be remnants of the work that used to take place inside the buildings. With the evidence available it is impossible to hypothesise on their function.

It is unlikely that any metalworking would be carried out in the alleyways (R10 and 13) where access would be required to travel from one area to another as any metalworking would obstruct this. The debris found in R10 and R13 was probably accidentally deposited as it is also unlikely that a deliberate dump would be positioned where access would be required.

The low levels of metals on the crucibles means that the craftsman was very skilled. To get the best results from heating copper and silver, with little waste, requires careful control of temperature and other conditions. This has been achieved and therefore there are no residues remaining on the crucibles to enable easy identification of the metals that were melted in them. For those crucibles where the metal melted could be identified, there was no correlation of form with metal (see Table Five overleaf). It is probably that the metalworkers were using whatever was available.

The absence of cupels in the assemblage has been noted (Blackmore, 1997). This does not, however, necessarily argue the absence of gold and silver melting from the site. It has been noted in Hamwic (Bayley, 1996, 89) that the distribution of cupels and other silver working debris is mutually exclusive. This has been interpreted as indicating that the testing and refining of metals was not carried out by those who actually worked them. At the Royal Opera House site there is plenty of evidence for the working of silver has but the assaying and refining of the metal presumably took place somewhere else.

The industrial vessel analysed contained high levels of iron and some copper and zinc. Archaeological objects often contain high levels of iron from post-depositional reactions and adhering soil particles, but it is unlikely that this would explain the presence of copper or zinc. It is not entirely clear what this would have been used for. It may be that was not used for an industrial process, but as a domestic vessel which came into contact with these metals before being discarded.

There is no evidence for copper smelting at the site in the debris analysed, but this was not expected as smelting is normally thought to be carried out near the mine. The raw material would then be transported to the Royal Opera House site for production of finished products. Raw materials for the casting of copper may not have been needed at the site - there is some evidence for recycling. Many of the objects analysed by Sophie Julien were unidentifiable (see Appendix One). It is possible that these were awaiting recycling and would have provided the raw material for the metalworking.

Table Five: Form of Analysed Crucibles

Context No	Find No	Form	Interpretation
3190	1678	crucible handle?	not a crucible
-	1362	open	used
-	1369	open	silver
2657	1370	open	used
-	468	open	silver
-	1364	open	debased silver?
1939	1677	closed	used
2886	1368	closed	used
1399	1676	closed	silver?
1994	1367	closed	used
1301	1675	closed	debased silver?
1597	572	closed	used
1592	1365	closed	used
504	1363	closed	silver
762	1674	closed	silver?
1705	469	closed	used
1591	470	lidded	used
1560	471	lidded	silver?

The antler brooch mould (<492>) and several coin blanks (<763> and <774>) show that brooches and probably coins were produced on the site. It is likely, however, that these were not the only products made on the site and that a wide range of smaller copper alloy and silver objects were produced.

Conclusion

The diverse assemblage of non-ferrous metalworking debris at the Royal Opera House site show that it was an area of metalworking during the Saxon period. This would have included the processes of melting, casting and smithing metals. There is no evidence of metal smelting or cupellation of gold or silver taking place on the site. The output of the site included brooches and coins, but probably also incorporated a wide range of other products.

Acknowledgements

I would like to thank Lyn Blackmore who provided me with draft copies of her report "The Evidence for Non-Ferrous Metalworking at the Royal Opera House (ROP95)" from which sections of text in this report have been copied.

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Appendix One

Results of the XRF analysis of the gold and copper alloy objects carried out by Sophie Julien (interpretation added by Megan Dennis).

Key

y = element detected
t = element detected at trace level

Context No	Find No	Object	Cu	Pb	Sn	Zn	As	Ag	Au	Interpretation
2154	1528	wire					t	t	y	gold
3621	475	awl?	8861	184	641					bronze
0	311		y	y	y				y	?debased gold?
3400	453	buckle plate?	16606							copper
804	18	dress hook	24108	1127	1896					bronze
1525	116	finger ring	8440	146	230					bronze
1155	49	handle	5863	t	139					bronze
2244	265	key?	10270		262					bronze
1847	206	mount?	6931	257	726					bronze
2725	357	mount?	6465	426	1490					bronze
3248	1316	mount	5923		510					bronze
3248	1317	mount	9837	207		1260				brass
0	527	pin	4154	307	427					bronze
453	559	pin	5660	592		2762				brass
749	25	pin	4198	272	303					bronze
823	27	pin	10785	506	440					bronze
903	21	pin	2994		326	154				bronze
947	51	pin	4273	436	686		t			bronze
965	50	pin	5442	1116						leaded copper
970	16	pin	3885	293	254					bronze
1319	1527	pin	2947	683	332	129				(leaded) bronze
1550	117	pin	1948	461	372	t				bronze
1569	173	pin	3047	130	443					bronze
1605	114	pin	3341	202	298	t				bronze
1619	366	pin	3457	253		976				brass
1807	139	pin	14613	140						copper
1821	174	pin	6273	812	146					bronze
1926	171	pin	4450	390	612					bronze
1939	201	pin	7452	605	398	477				gunmetal
3115	346	pin	3654		560					bronze
1852	183	ring	14863							copper
1070	61	strap end	5112	279	205	216		626		?debased silver?
1685	133	strap loop	2365	183	595					bronze
3044	428	tweezer?	9931	188	1143					bronze

Context No	Find No	Object	Cu	Pb	Sn	Zn	As	Ag	Au	Interpretation
1705	621	ingot	5766	t	t					(impure) copper
2874	359	ingot	20688	246	817	t		2035		?debased silver?
669	20	slag	6694		t					copper alloy
1570	190	slag	6272	t	t	t		881		?debased silver?
1570	189	slag	5914							copper
2651	476	slag	4656							copper
2744	678	slag	3903	452	839	t		487		?debased silver?
1705	186	scrap	6910	6470	964	1301				gunmetal
453	561	waste	7966	2833	798					leaded bronze
453	567	waste		8249				t		lead
1503	229	waste	14497							copper
1847	203	waste	4544	2192	528					leaded bronze
2309	387	waste	12759	143				1168		?debased silver
3102	430	waste	28405			1874				brass
1705	172	wire	13495	673	697	607				bronze
1709	328	wire	2453	t	284	t				bronze
1938	180	wire	15487	219	634					bronze
2051	230	wire	8040	1480	209	687				(leaded) gunmetal
2083	223	wire	3566	1337	317	274				leaded bronze
2137	257	wire	1839	2238	1214					leaded bronze
2884	344	wire	12188	256	643					bronze
0	97	unidentified	4977							copper
840	1529	unidentified	1489	761	667	223				bronze
3091	353	unidentified	6731	832	1863					bronze
3263	454	unidentified	7657	3602	2128	t				leaded bronze
504	1363	crucible	99	256		256		199		debased silver
4362	1372	crucible	90			113				copper alloy
2651	1370	crucible	205	128		2561				brass