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Report 67/96

ASSESSMENT OF NON-FERROUS METALWORKING DEBRIS FROM ELMS FARM, HEYBRIDGE, ESSEX

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Summary

Assessment of the material from this late Iron Age and Roman settlement site showed a wide range of non-ferrous metalworking processes were carried out; the ironworking (mostly smithing) activities at the site were discussed in AML report 40/96. Crucible and mould debris showed that copper alloys, silver and gold were worked at high temperatures. Some of the moulds were for investment casting (lost wax). Copper alloys were also worked as sheet metal. Lead sheet was present, possibly for recycling and a possible pewter 'ingot' was examined. Silver refining (cupellation) was demonstrated by the presence of litharge cakes. Recommendations for further analysis and for sample storage were given.

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ANCIENT MONUMENTS LABORATORY REPORT

Assessment of non-ferrous metalworking debris from Elms Farm, Heybridge, Essex

Catherine Mortimer

Site details

Two phases of excavation were carried out at the site, in 1993 and in 1994/1995, covering a total of 29 hectares. The evidence recovered mainly related to late Iron Age and Roman settlement. Roundhouses, ditches and pits indicated a sparsely-populated and dispersed late Iron Age (*c*50BC-50AD) settlement which was succeeded by a denser Roman occupation. The Roman activity at the site can be divided into four important zones; an area of pits (some of which contained metalworking debris) and hearths, a temple precinct, a possible market place and domestic areas. Investigation of the economic basis of the settlements was amongst the objectives of the original project design, and non-ferrous metalworking was clearly a significant component of the economy.

Material assessed

Six boxes of non-ferrous metalworking material were submitted for assessment. The nature of the material and requirements for further analysis are discussed below. A relatively large proportion of the material is undated because it came from spoil heaps, 'machine clearance' and 'cleaning layer' contexts (especially contexts 3999, 4000, 4004, 11000, 17000); much of this material was probably recovered by metal detecting. Context dates were provided by Mark Atkinson, but no distributional data was available.

Crucibles

All the samples in the box of 'crucibles' have been examined and analysed using surface X-ray fluorescence (XRF). The material totalled about 1.8kg, but only *c.* 273g of it is identifiable as crucible (Table 1). The remainder of the material is mainly fired clay with droplets of copper alloy on it, pieces of fired clay with no evidence connecting them with high-temperature processes or ceramic metalworking debris other than crucibles.

Of the finds which can be identified as crucibles, several are from 1st century BC/AD contexts and two from late Roman contexts. Most of the fragments are too incomplete to attempt a reconstruction. However, the examples from context 11156 are of the shallow triangular form known from Iron Age sites such as Gussage All Saints (Spratling 1979) and one piece from 11343 is also likely to be of this type. In both cases, they are heated from above, with the underside of the crucible having an oxidised colour; this is typical for crucibles of this type. In contrast, other broadly-contemporary examples from contexts 11250, 4433 and 11156 have thinner walls, a much finer fabric and are strongly-reduced throughout; thick layers of clay (now heavily-vitrified) were added to the outside of examples from context 4433, which would have acted as a sacrificial layer and given the crucible extra strength. This crucible type is known from many other Roman metalworking sites.

Where droplets of metal adhered to surfaces or in cracks within the crucibles, these areas were selected for analysis. Where no deposits are visible, the analytical evidence is much more difficult to interpret, since the levels of lead and zinc may be misleadingly high. For example, XRF analysis of a droplet on the crucible from 14573 suggests that the alloy melted was a leaded bronze (Cu-Sn-Pb), but only zinc was detected on the lip of a crucible from 11156, suggesting that the alloy melted contained zinc, but it is impossible to tell whether it was a brass (Cu-Zn) or a quaternary alloy (Cu-Zn-Sn-Pb). The use of these crucibles for melting copper alloys, is however, confirmed.

A fourth century context (21809) contained two fragments of a crucible with a pedestal base (common in the late 1st and 2nd centuries AD (Bayley 1992)) with silver detectable in pale creamy slagging on the inside surface and a 1st century BC/AD context (11343) yielded a crucible fragment (probably of the Iron Age type) with tiny droplets of gold visible within a greenish vitrification on the rim. This confirms melting of precious metals occured on the site.

Two thumb pots were found (contexts 11227 and 11396, both 1st century BC/AD). These are not highly-fired and are rather crudely made, although one of them has pecked decoration running around it. It is possible that they are unused crucibles but they are more likely to have nothing to do with metalworking.

Further analysis is not required on this material.

Precious metalworking debris

The two crucible fragments which had gold or silver detected on them (see above) and the litharge cakes which were found on the site (see below) are evidence for precious metalworking.

Another class of material was found which was initially thought also to be connected with precious metalworking - the fragments of a ceramic vessel of an unusual form, found in context 11156. Certain aspects of their appearance resemble those of parting vessels (used for separating silver from gold), but no silver could be detected on the surfaces, using XRF, so parting can be discounted as an explanation. Another high-temperature oxidising process may have produced the colouration - amongst the possible industries is salt production (more than 200kg of briquetage was found at the site, see Tyrell in Assessment, 3.4). The material excavated includes a pedestal base. These pieces merit drawing and possibly a reconstruction drawing.

Further technical analysis is not required on this material; further study of the material from context 11156 should be undertaken by the pottery specialist, to try to identify its origins. This materials is also rather friable and should be more adequately packed.

Moulds

One box of mould fragments (containing material from 18 contexts) was submitted for examination. A brief survey of about half the bags indicates that there are a number of interesting and relatively well-preserved examples. As noted by the finds staff, some of this relates to casting rings or flat circular plates and there is a very distinctive six-petalled item (sf 408 context 15745) and possibly a piece of drapery (context 23002), the latter can be compared with mould fragments at Gestingthorpe, Essex (Draper 1985). Some of the material does not show any evidence of having been used *ie* the surfaces are not reduced fired. There were no examples with metal droplets attached (*eg* in cracks or voids) so that an XRF survey would be unlikely to give useful data. The total weight of mould material is *c.* 2.2 kg.

This material will require further study, in conjunction with the finds specialist, to determine the range of artefacts cast at the site and the manner in which they were made. It will be important to determine whether both piece mould or investment mould technology were in evidence - at least some of it seems more likely to be from the investment process, also known as lost-wax casting (*eg* context 13446). At least one day of the analysis should be spent working with the finds specialist who will write up the non-ferrous metalwork from the site, as the likely artefact types must be agreed on. A further two days would be necessary to complete the report on this material. The best examples should be drawn, and it may be necessary to consult with the Technology Section about this.

Moulds are friable by nature and should be carefully packed; the current packing is probably sufficient, if the material is not moved frequently.

Other fired clay

A number of the samples submitted are not, as described in the catalogue, 'crucible' or 'mould' but other types of fired clay. Some of this material was not subject to any great temperature and has no copper alloy metal associated with it, so it may be from domestic activities. The occurence of copper alloy droplets on some fired clay may be accidental (*eg* copper alloy objects being melted during a household fire) and not part of an industrial process. It is normally impossible to distinguish these material types, although association with other metalworking finds may suggest an industrial process (metal melting and casting). Some further research into distribution patterns might be beneficial in this respect, but the amount of fired clay submitted is small.

XRF analysis of copper alloy deposits on five pieces of fired clay indicate that they are leaded bronzes.

Litharge cakes

Three pieces of litharge cake were submitted for analysis, two of which had already been identified as such, sf7014 from a machining layer 17000 and sf6078 from a late Roman context 8747, and one of which was described as 'lead slag', sf5180 from an undated context, 11000. Litharge cakes are primarily lead oxides, and are the product of a silver-refining technique known as cupellation. Debris from this process has only relatively-recently been identified but many sites from the Roman period and later now produce evidence. Visually, the Elms Farm examples conform to other Roman examples, although only sf5180 has a diagnostic feature, part of the edge of a central depression (where the silver would have solidified). XRF confirmed that these items are lead-rich with traces of copper and silver. Further analysis is not required as a current AML project is underway on litharge cakes. However, if more 'lead slag' is listed under 'lead and lead waste', this should be checked visually to determine how much of it is litharge. Further advice on identifying litharge can be sought from the Technology Section.

Litharge should be handled and stored with care, as lead oxides are toxic.

Lead and lead waste

A 4.2kg sample from the 75kg of lead objects and lead waste was examined and weighed (Table 2, below), although the litharge cake (sf5180 from 11000) was discussed above.

Context	SF	Type	Weight (g)
5448	2256	Waste,spillage of molten metal	328
5448	2105	Ditto	178
5448	2109	Disc, possibly blank, seal or weight?	20
11000	5180	Litharge cake	541
11000	5169	Sheet waste, ?ingot	3112

Table 2: Sample of 'lead waste'

The spillage indicates that the lead was heated to above its melting point, 327°C if it is pure lead, below this if it is alloyed with tin. The material therefore indicates a relatively-low temperature melting process, which could have been carried out without special furnace structures or crucibles. Some of the waste in sf 5169 has a laminated appearance; this has been identified as pewter (lead-tin alloy) and some pieces are so substantial that they may be parts of an ingot. Pewter tends to be even more deeply corroded than lead. Other pieces seem to be sheet offcuts which may indicate the manufacture of lead objects.

Smelting (mentioned in the assessment of the lead objects, R Tyrrell) is the extraction of a metal from its ore; it is possible that some of the litharge was at the site to be used as a source of lead metal, but more likely that it was there as a byproduct of precious metal refining. Lead ores (*eg* galena) were not seen in the sample submitted, so there is no evidence for lead smelting.

The remainder of the lead should be checked to assess whether there is more litharge present (as noted above) and to see if any more of the material is pewter. It might also be useful to determine whether any of the pewter comes from dated contexts, since pewter is thought to be found only in late Roman contexts.

Corroded lead should be handled and stored with care, as lead oxides are toxic.

Non-ferrous metal 'waste'

A *c.* 25% sample from the two boxes (total weight = *c.* 3.4kg) of non-ferrous 'waste' has been examined and analysed using surface XRF (Table 3). Unfortunately a lot of material from context 4000 (a machined layer) was studied before the phasing information was received so it is unclear what interpretation should be placed on the results from this material. Overall, more than half the contexts with non-ferrous metal 'waste' are undated.

The non-ferrous 'waste' examined from the site includes drops and dribbles of metal (some very corroded), a casting sprue, offcuts from sheet metal working and part-formed or miscast artefacts. A thick, block-like fragment of copper alloy (4000, 815) could be an offcut from a very thick object or may possibly be an ingot (*c.* 40x26x18mm). Much of the material consists of very small pieces (less than 5g) and it is difficult to identify it in any detail. Some of the waste may be (finished) objects which have accidentally been heated, but others may be broken objects, miscasts, offcuts or accidental spills. It is difficult, often impossible, to tell which is the case and a 'best guess' is given here. Given the existence of crucibles and moulds at the site, at least some, if not much, of the non-ferrous metal waste is likely to have been deliberately melted metal.

Amongst the dated 'waste' material that has been analysed, leaded bronzes (Cu-Sn-Pb) were by far the most common, but there were a few examples of leaded brasses (Cu-Zn-Pb) and quaternary alloys (Cu-Sn-Zn-Pb). All these alloy types are known in the Roman period, with leaded bronzes being the most common alloy used overall.

If the material examined is typical of the site as a whole, no further analysis is required other than typological identification, as far as possible, of the remainder of the material. This material is generally in a good condition and has been well packaged.

Other material

A sample originally identified as litharge (from context 6848) is a piece of ironworking slag (hearth bottom). The fired ceramic 'mould' from 13446 does not appear to have been heated to a high temperature; there is no evidence of vitrification or slagging. There is at present nothing to connect it with metalworking.

Conclusions

The non-ferrous metals worked at the site were copper alloys, lead alloys, silver and gold. Leaded bronzes and some zinc-containing copper alloys were melted and cast, to make various types of artefact. At least some of the casting was by investment moulds and may be from high-prestige artefacts, such as statuettes. Additionally, copper-alloy sheet metal artefacts were made. It is not known what purpose the pewter ?ingot had on site. The evidence for precious metalworking is less frequent, with a very small amount of gold and silver melting indicated. Artefact types associated with parting (separating silver from gold), were originally identified, but these now seem more likely to be associated with a non-metallurgical process. In addition, silver refining by cupellation took place, although it is not yet known how intense this activity was.

Recommendations

- Three days for a technologist working on the moulds.
- Technology input on illustrations of the unusual vessel form from 11156 and some of the moulds.
- Re-examination of the rest of the 'lead waste' to see if any of it is litharge or pewter.
- Visual identification of the copper alloy 'waste', as far as possible.
- Comparison of material identifications given here and by Dave Starley with distributional information.

References

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Spratling M G 1979 'The debris of metalworking' in Wainwright G W *Gussage All Saints: An iron age settlement in Dorset* (Dept of Environment Report no 10), 125-149.

Acknowledgement: Lynn Keys carried out some of the XRF analysis in this study.

Table 1: Identification and XRF analysis of 'crucible' fragments

Context	SF	Phase	Dating	XRF	Identification	Comments, area analysed	Wt (g)
20041	7353	9-10	1st BC/AD	Cu Pb Sn	CA waste on FC		32
14995	6277	11	early R	Cu Pb Sn	CA waste on FC	copper alloy deposits	19
10922	5728	16-18	4th C AD	Cu Pb Sn ?Zn	CA waste on FC	copper alloy deposits	28
11743	6304	nd		Cu Pb Sn	CA waste on FC	copper alloy deposits	25
14573	6231	nd		Cu Pb Sn	CA waste on FC	copper alloy deposits	38
11306	none	9-10	1st BC/AD	?Cu ?Zn	Ceramic vessel	Shallow, thick walled 'heating tray'?	26
11156	none	9-10	1st BC/AD	none	Ceramic vessel	Bleached walls, originally 'parting vessel?'	181
11343	none	9-10	1st BC/AD	Cu Pb ?Zn	Crucible frag		8
11343	none	9-10	1st BC/AD	?Cu	Crucible frag, Au droplets	Analysed away from Au	8
14573	6249	nd		Cu Pb Sn	Crucible frag, CA inside	copper alloy deposits	12
11250	none	9-10	1st BC/AD	Cu Zn Ti	Crucible frag?	V reduced fired, upright	20
4433	none	9-10	1st BC/AD	Zn ?Cu	Crucible fragment	Lip analysed	
4433	none	9-10	1st BC/AD	Cu ?Zn	Crucible fragment	Outside analysed (Zn detected inside)	71
11156	none	9-10	1st BC/AD	Zn	Crucible fragment	Fine fabric, outer layer added, lip analysed	11
21809	none	17-18	4th C	Ag Cu Zn Pb	Crucible fragment	Pedestal base and wall sherd	22
8000	none	nd	late R?	?Cu	Crucible fragment	overfired	2
11156	none	9-10	1st BC/AD	Cu Sn and Cu Sn Pb ?Zn	Crucible fragments	Handmade, triangular type, two frags analysed	119
9515	3304	nd		?Cu ?Zn ?Pb	FC	low fired, not metalworking	554
4974	6105	nd	mid R?	?Cu	FC , with vitrification		32
11269	none	9-10	1st BC/AD	Sn ?Cu ?Pb	FC with slagging	sample B	10
6848	5728	11-12	early R	?Cu	Fe slag - hearth bottom		323
4691	4680	15-16	3rd C	not analysed	Geological		18
4840	none	9-10	1st BC/AD	Cu ?Zn ?Pb	Hearth lining	High-temp, but not necess. non-ferrous MW	162
11227	5813	9-10	1st BC/AD	?Cu ?Zn	Low-fired thumb pot	Decorated, prob. not non-ferrous MW	36
11396	6991	9-10	1st BC/AD	none	Low-fired thumb pot	Probably not metalworking	51
11269	none	9-10	1st BC/AD	Pb Ti ?Cu ?Sn	Mould?	sample A	20

Iron was detected in all cases.
SF = small finds number, where available
Cu = copper, Zn=zinc, Pb = lead, Sn= tin, Ag= silver, Au = gold, Mn = manganese
FC = fired clay, CA = copper alloy, MW = metalworking.

Total weight 1828g

Table 3: Identification and XRF analysis of 25% sample of non-ferrous metal waste

Context	SF	Phase	Dating	Fe	Cu	Zn	Pb	Sn	Other	Comments	Wt (g)
4273	1832	9-10	1st C BC/AD	18316	474419		1818	8729		casting waste	7
4273	1832/2	9-10	1st C BC/AD	3820	218834		1171	22476		casting waste	6
4273	1832/3	9-10	1st C BC/AD	1638	417317		252	38980		casting waste	1
4273	1832/4	9-10	1st C BC/AD	5868	139020		71	18082		casting waste	1
4336	6443	9-10	1st C BC/AD	18198	320163		8040	17164		waste	44
4336	6443	9-10	1st C BC/AD	31932	476282		9106	17175		waste	
4336	6443	9-10	1st C BC/AD	26873	455530		35292	14867	Sb?	obj?	5
4699	1937	9-10	1st C BC/AD	4721	11135	41	142418	51727		lead waste	39
4699	1937	9-10	1st C BC/AD	13236	106811		46328	37188		fired clay	9
4699	1937	9-10	1st C BC/AD	16849	117964		81449	51302	Sb?	casting waste	59
4699	4162	9-10	1st C BC/AD	7106	169023	44	7214	90885	Sb?	casting waste	22
4699	4162	9-10	1st C BC/AD	27872	450351		5840	48337	Sb?	dribble	57
4794	4176	12-13		31663	150924	tr.	4346	78174		partformed obj? bar	4
4918	7298	11-13?	1st/2nd cent	116778	198134		2540	21160		waste	22
4918	7298	11-13?	1st/2nd cent	27130	748501		1648	23885		waste	
4937	4193	9-10	1st C BC/AD	3488	74853		3461	29474		droplets/waste	33
4937	4193	9-10	1st C BC/AD	4069	115347		5700	21062		dribble	
4994	4200	14-15	L2nd/mid 3rd	31207	405379		14617	24822		object?	3
5307	2010	18-19	latest Rom.	52358	366793	445	20534	56415		object	2
5307	2476	18-19	latest Rom.	22557	251665		5976	65875		sheet offcut	1
5385	2036	18-19	latest Rom.	58316	124732		35522	28784		casting waste	4
5387	2029	17-18	4th cent	24716	84404		43011	21769		miscast object?	7
5427	2755	18-19	latest Rom	1424	64441		9373	67170		miscast object?	10
5491	2267	9-10	1st C BC/AD	23440	248802		401	43906		object frag	1
5562	2314	16-17	3rd/4th cent	40858	524799		2890	24326		offcuts	
5630	6408	11-12	Early Rom.	18837	406468		14272	24382		casting waste	4
5662	2314	16-17	3rd/4th cent	21838	662793		2966	41281		offcuts	6
5807	2252	18-19?	?latest Rom.	31560	435399		47292	54893		object frag?	2
6181	1669	14-15	L2nd/mid 3rd	56657	424126		20214	49753		waste	6
6269	2736	15-16	3rd cent	5149	72293		147693	51162		waste	7

Table 3 cont.

Context	SF	Phase	Dating	Fe	Cu	Zn	Pb	Sn	Other	Comments	Wt (g)
9178	1550	10-11	Earliest Rom.	19105	437916		649	48590		obj. frag	3
9178	1550	10-11	Earliest Rom.	8778	212032		562	28148	Sb?	obj?	3
9491	3306	13-14	2nd cent	6985	525480		19051	59687		droplet	1
10262	7295	16-17	3rd cent	25276	251020		50865	21568		casting waste	19
10280	2246	15-17	3rd cent	53917	443272	3100	28686	16316		object	1
10296	3478	18-19	latest Rom.	31318	318560	tr.	34537	55400		waste	3
4000	284	undated		55647	87871		90991	23827	Ag?	waste	4
4000	376	undated		29450	194369		59205	106479		dribble	15
4000	667	undated		18365	200036	323	11414	160491		sheet/offcut	1
4000	673	undated		35097	277459	2981	64124	91201		casting sprue	15
4000	682	undated		7968	872346		22229	669	Sb	casting waste	21
4000	690	undated		42320	473172		19206	23891		waste	1
4000	815	undated			92613		27615	23412	Au?	ingot?	93
4000	1063	undated		31667	371429	1555	54232	9883		bracelet frag	20
4000	1064	undated		17921	127277		100101	114166		object	9
4000	1720	undated		23246	292287		27525	16838		casting waste	181
4000	2500	undated		40828	158986	1988	88578	33556		distorted mount	2
4000	2501	undated		10674	70990	873	1253	572		waste	3
4000	2507	undated		29017	83813	986	134116	559		object frag?	4
4000	2509	undated		11305	187817		17724	28063		dribble	2
4000	2515	undated		7522	203788		1829	359		dribble	2
4000	2775	undated		12223	120089		69031	29504		waste	2
4000	2777	undated		7011	57727		72843	125632		dribble	15
4000	2793	undated		48570	166341	48	96790	20924		waste	8
4000	6592	undated		43308	76013		20171	10215		waste	21

Notes: Total weight 811g. Where several samples were analysed from one context, each sample was not weighed seperately. The samples are listed in context and small find order, undated material listed last. SF= small find, Fe = iron, Cu = copper, Zn = zinc, Pb = lead, Sn=tin, Au = gold, Ag = silver, Sb = antimony. Analysis was carried out at 35kV, 100μA for 100s, using a 2mm collimator.