Ancient Monuments Laboratory
Report 4/99

ASSESSMENT OF SLAG AND OTHER METALWORKING DEBRIS FROM ELY FOREHILL, CAMBRIDGESHIRE, 1995

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Summary

This site dating from the 13th - 19th century produced very small amounts of iron smithing slag and non-ferrous alloys. There is evidence of small scale iron smithing on the site, using a mineral fuel. There is no evidence for the working of non-ferrous alloys. No further work is required on the debris.

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Assessment of Slag and Other Metalworking Debris from Ely, Forehill, Cambridgeshire, 1995

David Starley and Megan Dennis

Introduction

Ely, Forehill (TL 545 802) was excavated in 1995 by Cambridge Archaeological Unit. The excavations revealed evidence of human activity from the 10th century, with structural evidence from the 13th century until the present day. These were a series of tenement buildings that stretched back from a route between riverside wharves, market and the monastic centre at Ely. The debris came from Phases 4 - 20, dated by the typology of the pottery finds to the 13th to the 18th century.

The aim of the examination was to provide a brief overview of the types of material present in the debris and assess the potential for further analysis.

Assessment of the Debris

The assessment of the debris first involved an initial visual examination and classification of material, shown in Table One.

Table One: Metalworking Debris from Ely, Forehill

Area	Context No	Find No	Phase, Century	Weight	Interpretation	Comment
1 'X'	[620]	<1642>	9, 14th	2 g	undiagnostic ironworking slag	very cindery
4	[788]	<1039>	9, 14th	13 g	cinder	
3	[419]	<1640>	20, 16/17th		flake hammerscale	
				504 g	smithing hearth bottom	weights and measurements of individual pieces: 205 g 105*75*35 mm 175 g 80*75*45 mm 66 g 60*65*30 mm 57 g 50*55*25 mm
				156 g	undiagnostic ironworking slag	
				86 g	iron rich cinder	
				53 g	partially burnt and slagged shaley coal	
154	[1265]	<799>	9, 14th	105 g	lead	
?	[904]	<985>	4, 13/14th	20 g	lead	
1	[714]	<797>	13, 15th	319 g	lead	
	[284]	<989>	22, 17/18th	112 g	iron	
125/185-90	[330]	<1032>	12, 15th	1 g	copper alloy	
1	[543]	<1030>	20, 16/17th	3 g	copper alloy?	

Explanation of Classification

The assemblage from Ely, Forehill was of very small size. On examination it contained a mixture of both ferrous metalworking debris and non-ferrous waste material.

Ferrous Metalworking Debris

Visual examination of the ferrous debris allowed the material to be classified from a set of criteria: morphology, density, colour and vesicularity. Many of the "classes" of slags overlap and therefore classification can be difficult. Only some of the classes are diagnostic of a particular activity. Many waste products cannot be used to identify the processes taking place. The classes used in this assessment and currently used by the Ancient Monuments Laboratory are defined below.

Smithing *i.e.* hot working of iron, produces two types of slags: bulk slags and micro slags. The only bulk slags diagnostic of smithing are **smithing hearth bottoms**. These are formed at the base of the hearth as a result of a high temperature reaction between the iron, iron scale and silica from the clay hearth lining or sand used as a flux by a smith. They are recognisable by a rough convex base and smooth vitrified upper surface. This upper surface may be hollowed by the action of air being blown into the hearth through a tuyère onto the slag. The hearth bottoms usually have a plano-convex form that fits easily into the palm of the hand. Compositionally hearth bottoms are predominantly fayalitic (made of iron silicate; $2FeO.SiO_2$) with some other minor components. Fayalitic compounds leave a grey mark when scratched across a white ceramic tile, but are present in other slags as well as smithing hearth bottoms.

Two types of micro slags are produced by smithing - **flake hammerscale** and **spheroidal hammerscale**. Flake hammerscale is small flat fragments of the oxide and silicate skin of the iron, dislodged as it is worked. Spheroidal hammerscale is formed as small droplets of slag solidify after being expelled during the working of iron. Spheroidal hammerscale occurs particularly when two components are being fire welded together or when an iron bloom is first consolidated and worked into a bar or billet. Hammerscale is highly diagnostic of smithing and can be used to identify particular areas where smithing was taking place; hammerscale is not removed from the site for disposal, as many other slags are.

Other slags were recognised from the site but these are not diagnostic - they could be formed during many different high temperature processes. The assemblage from Forehill also includes **undiagnostic ironworking slags**. Undiagnostic slag is often classified as such because the fragments are too small to be identifiable. The composition of these slags are predominantly fayalitic, but their morphology is irregular and similar materials can be made during several ironworking processes. **Cinder** is a hard, brittle, porous and lightweight material; similar to the vitrified surface of hearth and furnace linings. It occurs where these linings have reacted with alkali fuel ashes at high temperatures. However, unlike vitrified hearth linings, which show a transition from clay to the porous zone, cinder comprises only the latter. It is often formed when lining falls away from the hearth. It can also result from similar reactions with another source of silica, for example the sand often used as a flux by smiths. **Iron-rich cinder** is a slag that is unusually rich in iron, generally visible as iron hydroxide or hydrated iron oxide deposits on the surface. The last class of debris from the site is **partially burnt shaley coal**. This is a layered silicaceous material, partially vitrified and heated to high temperatures. This indicates the use of a mineral fuel during the processes occurring on site.

Possible Non-Ferrous Metalworking Debris

The non-ferrous material was submitted as possible evidence of non-ferrous metalworking. It consisted of two broad categories - lead alloy and copper alloy. These were identified visually on site and checked during the visual examination in the laboratory. To identify the alloy type correctly the non-ferrous items were analysed by X-ray fluorescence.

X-ray fluorescence (XRF) analysis provides a non-destructive method of identifying the alloys present in the samples. 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), antimony (Sb) and arsenic (As). 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 and its position within the XRF machine. The elements present in the sample will not be the same as in the original alloy - this is partly due to the effect of burial conditions.(Bayley, 1992). Therefore the identification of metal alloys requires careful interpretation. The results for the samples are presented in Table Two.

Table Two: XRF Analysis of the Non-Ferrous Metal from Ely, Forehill

*** - strong signal
** - present
* - weak signal
? - identification uncertain
+ - traces of copper and tin found, but in insignificant levels

Area	Context	Finds No	Phase, Century	Cu	Fe	Pb	Sn	Interpretation
154	1265	799	9, 14th	*	*	***	tr	lead+
unknown	904	985	3, 13/14th	*	*	***	tr	lead+
1	714	797	13, 15th	*	*	***	*	lead+
	284	989	22, 17/18th	tr	***	*	**	iron block with lead attached
				*	**	***	tr	
125 185-90	330	1032	12, 15th	***	**	***	*	leaded bronze/bronze
1	543	1030	20, 16/17th		*	*		stone?

Find <1030>, a small sphere of 14 mm diameter, appeared too light to be copper alloy- its density was therefore calculated. It is too dense, at approximately 6 g/cm, to be a ceramic and may be a polished stone or fossil.

Conclusions

The diagnostic components of the ferrous material were exclusively associated with smithing - the secondary working of iron. There were no slags characteristic of iron smelting. Therefore the undiagnostic slags can be presumed to also derive from this small scale iron smithing. The slag weighs less than 1.5 kg - it should be noted that this amount of debris cannot be related to long term or large scale ironworking. It could be the product of an ironworker connected with the construction or modification of the buildings on the site, or possibly an itinerant worker. These processes involved the use of a mineral fuel.

The non-ferrous debris is not diagnostic of metalworking. The low melting point of lead means that the melted lumps could have been formed in a household hearth or be due to an accidental fire. The cylindrical form of find <989> is suggestive of the remains of a metal that has been melted in a crucible. However, even if this is its origin, a single object cannot be used as evidence for more than a very limited scale of operation.

Potential for Further Work

The debris assemblage does not warrant further examination. If soil samples are to be wet sieved or floated for archaeobotanical remains then checking the sieve and flotation residues with a bar magnet would detect any hammerscale present that might help achieve closer dating of the smithing activity taking place on the site.

Storage of Debris

The debris should be kept, but requires no special storage facilities.

Bibliography

Bayley, J., 1992, *Anglo-Scandinavian Non-Ferrous Metalworking from 16-22 Coppergate*, York Archaeological Trust, Council for British Archaeology, London, 817-8.