AML Rpt. FILE 1023

Ancient Monuments Laboratory
Report 176/87

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Summary

Examination of the residues showed that iron smithing had been carried out on or close to the area of excavation during the Saxo-Norman Period. The deposits were disturbed and re-deposited during the Medieval Period. Background levels of slag were present in later contexts. Analysis of a slag sample showed that it had a typical smithing slag morphology, mineral texture and chemical and phase composition.

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REPORT ON THE SLAG RECOVERED FROM EXCAVATIONS (1978-79) AT WALTHAM ABBEY, ABBEY MEAD, ESSEX

1 INTRODUCTION

Excavations within the Abbey Precinct revealed occupation layers dating from the Saxo-Norman Period until the present day. Ironworking residues were recovered from contexts belonging to all periods, but the main concentration was of Saxo-Norman Date. These deposits are therefore distinct from the Monastic Forge Site excavated in 1972-3[1].

The ironworking process and associated residues have been discussed, in detail, elsewhere[2,3]. The manufacture of iron artefacts was a two stage operation. Firstly, the metal was extracted from the ore by the smelting process, and secondly it was refined and worked into artefacts by the smithing process. Both processes generated residues as by-products, and these have been divided into diagnostic and non-diagnostic residues. The former are those that derived only from the ironworking process, and comprise the silicate slags. The latter may have been generated by other high temperature processes, and include fuel ash slag and hearth or furnace lining.

2 The Residues Recovered From The Abbey Mead Excavations

The residues were derived only from the iron smithing process and they were classified into four types:

1 Iron Smithing Slag - randomly shaped pieces of iron silicate slag generated in the hearth during the smithing process. The totall amount recovered was 53.677 kg..

2 Smithing Hearth Bottoms - if the smithing slag was retained in the hearth for a sufficient amount of time, it

developed the characteristic plano-convex form. The hearth bottoms formed in-front of the tuyere (air inlet), often attaching themselves to the hearth lining. Eleven hearth bottoms were identified (14.200 kg, 20%of the total smithing slag plus hearth bottoms), and had mean dimensions of:

	Mean	Standard Deviation	
Weight	1291	902	(gms)
Major Diameter	265	161	(mm)
Minor Diameter	213	125	(mm)
Depth	110	67	(mm)

These results show that the hearth bottoms recovered from the Abbey Mead Site are large, for example, results from Raunds Furnells (Northamptonshire)[4] gave a mean weight of 310gms and a mean major diameter of 80mm.

3 Cinder - a less dense slag, due to its high silica content. [illegible] med by a reaction between silicate slag and hearth lining [illegible] refore occurs at the interface between silicate slag and t[illegible] It is normally considered a diagnostic slag, i.e. de[illegible] working process, but in some instances be gene[illegible] be[illegible] s and siliceous materials. A[illegible] ly in association with smithing slag [illegible] d can therefore be considered to have derived from the iron smithing process. The total amount recovered was 0.434 kg..

4 Hearth Lining - vitrified clay lining. It is a non-diagnostic residue since kiln, hearth or furnace linings may become vitrified, due to high temperatures. This normally occurs in the tuyere zone, the region of highest hot-face temperatures. There were no tuyere mouths identified (tuyere mouth - a hole in

the clay hearth wall through which the air was blown). A total of 0.710 kg of hearth lining was recovered, most of which occurred in the same contexts as smithing slag deposits. It can therefore be considered to have derived from the smithing process.

3 The Temporal and Spatial Distribution of the Residues

The excavation was recorded by Square Numbers (Al etc) and by Feature Numbers (221 etc). Baulks between areas were recorded as, for example, Al/Cl, some Features were related to others the details being given under the heading of Feature2, eg. /194. A full listing of the weights of each residue type by Square Number,

Date, and Feature are given in Appendix 1.

3.1 Temporal Distribution

The phase distribution of the slag shows (Table 1) that there were major deposits of slag in the Medieval Period and in the Saxo-Norman Period. The residues dated to the 17th Century and later are only background levels, and probably derive from disturbance of earlier levels. Only two of the 16th Century features contained more than 0.5kg of smithing slag (and/or hearth bottoms). Feature 21 (Square Cl) was a soil level dated 15/16th C., and contained 0.655 kg. Feature 78 (Square Al) was a linear feature (gully?) and contained 1.090 kg of slag. Both these features probably represent disturbance of earlier material. In the 15th Century dated layers only Feature 62 (Square Cl), a mortar layer, contained a significant amount of slag (0.880 kg). This might have derived from iron smithing activity during a construction phase, but is probably only residual.

In the Medieval Period there was an overall larger quantity of slag, with six features containing more than 0.5 kg of smithing debris. Three of these contained more than 1 kg, Feature 139 (Square A3), a brown earth contained 3.040 kg. Feature 170 (Square A3), a layer in a well contained 1.625 kg of smithing debris, and Feature 183 (Square A1), described as a charcoal and slag layer, contained 4.885 kg. This layer overlay the main deposition of Saxo-Norman slag which were Features 196 (6.670 kg), 199 (10.830 kg) and 221 (18.730 kg). The last two features contained 0.505 kg of hearth lining which was over 70% of all the lining recovered from the site. These three layers formed the fill of a natural gully or depression. Therefore, they may represent deliberate levelling of the site. Five other features contained more than 0.5 kg of smithing debris of which Feature 154 (Square A1/C1, 4.780 kg) was an interface layer between Medieval and Saxo-Norman levels. Feature 250 (Square A1/C1, 5.000 kg and 0.105 kg of hearth lining) was also the infill of a depression. These deposits are evidence of a significant period of black smithing during the Saxo-Norman Period. At present it is not possible to determine whether the smithing took place on the area excavated or whether the area was levelled using the waste products of a smithy.

The overall temporal distribution is interpreted as the deposition of smithing debris during the Saxo-Norman Period which was disturbed and redeposited during the Medieval Period.

TABLE 1 WALTHAM ABBEY, ABBEY MEAD,
SLAG LISTING BY PERIOD (WEIGHT IN GRAMMES)

DATE	SMITHING SLAG	HEARTH BOTTOM	CINDER	HEARTH LINING
Unstratified	515	490	14	5
Modern	20	0	0	0
19th C	0	0	10	0
17th C	717	0	35	20
16th C	2395	305	35	10
15th C	1670	0	90	0
Medieval	11500	1420	40	55
Saxo-Norman	36860	11985	210	620

3.2 Spatial Distribution

The overall distribution of the smithing debris (ie. smithing slag plus hearth bottoms) by Square is given in Table 2 and the distribution of all the residues in Table 3. This shows that the smithing activity was concentrated in the area of Square A1, with a declining concentration towards C1. The other Squares can be considered to have only background levels of slag present. Within Square A1 the slag was heavily concentrated in the area of Features 183 (Medieval), and 221, 199, and 196 (Saxo-Norman).

TABLE 2 WALTHAM ABBEY SMITHING SLAG DISTRIBUTION BY SQUARE
AND PERIOD (WEIGHT IN GRAMMES)

	SQUARE						
PERIOD	A1	A1/C1	C1	A3	A3/C3	C3	C1/C3
Modern-15th C	2035		3137	170		770	
Medieval	5195	3530	2060	1830	135		170
Saxo-Norman	37620	5000	6110	115			

3.3 Interpretation of Distributions

The spatial and temporal distributions clearly show that a large quantity of smithing debris was deposited in Features 221, 199 and 196 (Square A1) during the Saxo-Norman Period; the quantities of slag decline (spatially and temporally) away from these layers (Table 2). This material was disturbed and redeposited in Medieval and later times. It is not possible to determine whether or not smithing was practiced on the site or whether the slag was used as suitable material for levelling the site. If the latter was the case it is probable that the slag derived from a nearby smithy.

TABLE 3 WALTHAM ABBEY, ABBEY MEAD SUMMARY BY SQUARE (WEIGHT IN GRAMMES)

SQUARE	SMITH	HB	CINDER	HL
0	0	0	14	5
A1	13060	2505	20	50
A1/C1	20155	6910	170	560
C1	17435	4505	120	35
A3	1920	280	40	15
A3/C3	135	0	0	45
C1/C3	202	0	35	0
C3	770	0	35	0
TOTAL	53677	14200	434	710

4 Analysis of a Sample of Smithing Slag

A sample of smithing slag from the earliest deposit (Feature 221) was selected for analysis. Smithing slags are generally heterogeneous, and it was not selected on the basis of being a 'representative sample', it can only be considered as an example of Saxo-Norman smithing debris. The methods of analyses were those described in other reports (e.g The Ironworking Residues from Raunds, Northamptonshire[4])

4.1 Morphology

Sample WA221 was a small part formed hearth bottom with dimensions of:

Weight	-	250 gms
Major Diameter	-	90 mm
Minor "	-	60 mm
Depth	-	30 mm

It had an agglomerated appearance with non-slag inclusions present. In section the slag was vesicular, the density and size of the vesicles varied across the section. The basal surface of the slag had a slight green tinge to the more usual grey colour of the slag.

4.2 Mineral Texture (Table 4)

A thick section was cut through the minor diameter of the sample. A segment was selected that included both the typical grey coloured slag and that with the green tinge. In the 'green area' (Table 4 Areas 1 and 2) the silicate was in the form of dendritic laths which became feathery in some areas. The silicate was in a glassy matrix in which (silicate?) crystallites had formed. Free iron oxide dendrites were absent except for one small area
(Table 4 Area 5). In the more typical grey region of the slag the silicate was in the form of euhedral crystals degrading to massive form in a glassy matrix (Table 4 Areas 3 and 4). Free iron oxide was absent in this region. In both regions there were inclusions of metallic iron.

The two regions appear to have approximately the same overall composition, but differ significantly in their cooling rates. The outer region, which was green, indicated very rapid cooling due to the fine structure of the silicate laths (feathery laths being the finest form), and the large percentage of glassy matrix present, ie there was insufficient time for the silicate to segregate out from the matrix. In the grey area the cooling rate was much slower giving rise to a lower percentage of glass phase present and euhedral or massive silicate. Overall the composition was silica rich due to the absence, except for one area, of free iron oxide. The presence of this pool of free iron oxide indicates the extreme heterogeneity of the slag which is typical to some degree of all ironworking slags but in particular of smithing slags.

TABLE 4 WALTHAM ABBEY, ABBEY MEAD,

VOLUMETRIC PHASE PERCENTAGES.

	SIL	GLASS	FEOX
Area 1 (green)	60	40	-
Area 2 "	40	60	-
Area 3 (grey)	70	30	-
Area 4 "	60	40	-
Area 5 (green)	20	-	80

SIL - Silicate Phase
GLASS - Glassy Phase
FEOX - Free Iron Oxide Phase

4.3 Chemical and Mineral Composition

Analyses were obtained using a Scanning Electron Microscope with an attached Energy Dispersive Analytical System, in the raster mode for Bulk Analyses and in the spot mode for Phase Analyses. The results (Table 5) show that the slag had an overall fayalitic composition typical of ironworking slags. The bulk analyses show considerable variation in composition, which is in agreement with the optical study and is generally characteristic of iron smithing slags. For example the silica/iron oxide ratio varies from 1/12.3 (B5) to 1/0.7 (B2). Analyses B1, B2, and B4 derived from the 'green' region and B5 an analysis of the iron oxide rich zone in that region. B3 was of the typical 'grey' slag, and was distinguished from the other area by firstly, having lower alkali oxide contents, reflecting the lower percentage of glassy phase present. Secondly, it was richer in iron oxide, and correspondingly lower in silica, and was closer to a 'fayalitic' composition (ie approxiamtely 70% FeO, 30% SiO_2). This reflects the greater amount of fayalite which was present in that area, but overall the composition was still silica rich. Overall the alkali oxide content was low which did not accord

with the optical study of the 'green' area but was in general agreement with the grey area. This discrepancy was due to the rapid cooling rate of the 'green' region prohibiting the formation of minerals. The

phase analyses confirm the silicate phase as fayalite ($2FeO.SiO_2$), but it was also silica rich. The glass phase had a high silica content, but was low in alkali oxide compared to other glass phase analyses. The iron oxide phase analysis indicated a wustite (FeO) rather than a magnetite (Fe_3O_4) composition.

4.4 Interpretation of Analyses

The morphology, mineral texture bulk and phase compositions are in accordance with the slag being a smithing slag. The slag was silica rich, chemically and minerally heterogeneous and different regions had cooled at different rates.

5 SUMMARY

Examination of the slags recovered from the Waltham Abbey, Abbey Mead excavations show that iron smithing was carried out on or close to the area excavated during the Saxo-Norman Period. Analysis of a slag sample showed it to have a typical smithing slag mineral texture and chemical and phase composition.

TABLE 5 WALTHAM ABBEY, ABBEY MEAD, BULK AND PHASE ANALYSES

BULK ANALYSES = B1-5

PHASE ANALYSES SIL = SILICATE PHASE

GLASS = GLASS PHASE

FEOX = IRON OXIDE PHASE

	B1	B2	B3	B4	B5	SIL	GLAS	FEOX
Na_2O	0.7	0.6	0.3	0.5	N.D	0.3	0.7	N.D
MgO	0.1	0.1	0.4	0.2	0.2	0.5	N.D	0.3
Al_2O_3	3.3	3.7	2.1	2.8	0.7	N.D	4.7	0.5
SiO_2	45.6	47.2	33.5	42.6	7.2	29.7	55.8	0.9
P_2O_5	0.9	1.1	0.7	0.5	0.1	0.1	1.9	N.D
S	0.1	0.1	0.1	N.D	N.D	N.D	0.1	N.D
K_2O	3.0	3.5	1.2	2.2	0.2	0.1	5.1	0.1
CaO	5.2	6.7	1.8	3.7	0.5	0.8	13.7	N.D
TiO_2	0.4	0.4	0.1	0.2	0.2	N.D	0.9	0.2
V_2O_5	N.D	0.2	0.1	N.D	N.D	0.1	N.D	0.1
Cr_2O_6	N.D	0.1	N.D	N.D	0.1	N.D	0.1	N.D
MnO	N.D	N.D	N.D	N.D	0.1	0.1	N.D	N.D
FeO	43.2	35.2	61.4	50.2	88.9	67.1	16.5	95.6
CoO	0.3	0.2	0.2	0.3	0.7	0.4	0.1	0.4
NiO	0.1	0.1	N.D	N.D	0.4	0.2	0.1	0.5
CuO	N.D	0.3	0.1	0.1	0.1	0.1	N.D	N.D
Total	102.9	99.5	102.0	103.3	99.4	99.5	99.7	98.6

REFERENCES

1 Huggins P.J and R.M. "Excavations of the Monastic Forge and Saxo-Norman Enclosure at Waltham Abbey 1972-3" Essex Archaeology and History Volume 5 1973"

2 McDonnell J.G "The Classification of Early Ironworking Slags" PhD Thesis Aston University 1986 (Copy in A.M.L. Library)

3 McDonnell J.G. "The ironworking slags from Amersham Mantles Green, Bucks" A.M.L. Report 4805.

4 McDonnell J.G. "The Ironworking Residues from Raunds, Furnells, Northamptonshire" A.M.L. Report 168/87

APPENDIX 1

WALTHAM ABBEY, ABBEY MEAD ESSEX SLAG LISTING BY SQUARE, PERIOD AND FEATURE NUMBER (Weight in Grammes)

FEATURE		- Feature Number
DATE		- Dates
	MOD	- Modern
	19	- 19th C.
	17	- 17th C.
	16	- 16th C.
	15	- 15th C.
	MED	- Medieval Period
	SN	- Saxo-Norman Period
SMITH		- Weight of Smithing Slag
HB		- " " Hearth Bottoms
CIN		- " " Cinder
HL		- " " Hearth Lining

* TOTAL IN SQUARE 0

FEATURE	DATE	SMITH	HB	CINDER	HL
0	UNSTRAT	0	0	14	5
** Subtotal **					
		0	0	14	5

* TOTAL IN SQUARE A1

FEATURE	DATE	SMITH	HB	CINDER	HL
1	MOD	20	0	0	0
49	15	240	0	10	0
79	15	75	0	0	0
80	15	325	0	0	0
26	16	285	0	0	0
78	16	1090	0	0	0
3	19	0	0	10	0
50	MED	310	0	0	0
183	MED	3745	1140	0	0
184	SN	40	0	0	0
190	SN	250	0	0	0
196	SN	4810	1860	0	0
199	SN	9610	1220	50	265
216	SN	720	0	0	0
220	SN	380	0	0	0
221	SN	13860	4870	120	240
** Subtotal **					
		35760	9090	190	505

* TOTAL IN SQUARE A1/C1

FEATURE	DATE	SMITH	HB	CINDER	HL
139	MED	3040	0	40	45
210	MED	35	0	0	0
250	SN	2220	2780	0	105
** Subtotal **					
		5295	2780	40	150

APPENDIX 1 (Continued)

* TOTAL IN SQUARE A3

FEATURE	DATE	SMITH	HB	CINDER	HL
177	16	170	0	0	0
20	17	0	0	0	10
93	MED	205	0	0	0
170	MED	1345	280	0	0
194	SN	0	0	0	5
200	SN	115	0	0	0
** Subtotal **					
		1835	280	0	15

* TOTAL IN SQUARE A3/C3

FEATURE	DATE	SMITH	HB	CINDER	HL
130	MED	135	0	0	0
** Subtotal **					
		135	0	0	0

* TOTAL IN SQUARE C1

FEATURE	DATE	SMITH	HB	CINDER	HL
148		515	490	0	0
62	15	880	0	80	0
103	15	150	0	0	0
21	16	655	0	0	10
66	16	15	0	0	0
68	16	95	0	0	0
86	16	0	305	0	0
4	17	32	0	0	10
43	MED	700	0	0	0
46	MED	600	0	0	0
149	MED	0	0	0	10
150	MED	760	0	0	0
154	SN	3525	1255	10	0
212	SN	535	0	0	0
214	SN	45	0	0	0
222	SN	500	0	0	0
225	SN	0	0	30	0
226	SN	210	0	0	0
229	SN	40	0	0	0
230	SN	0	0	0	5
** Subtotal **					
		9257	2050	120	35

* TOTAL IN SQUARE C1/A1

FEATURE	DATE	SMITH	HB	CINDER	HL
123	MED	455	0	0	0
** Subtotal **					
		455	0	0	0

APPENDIX 1 (Continued)

* TOTAL IN SQUARE C1/C3

FEATURE	DATE	SMITH	HB	CINDER	HL
28	17	0	0	35	0
11	MED	170	0	0	0
** Subtotal **					
		170	0	35	0

* TOTAL IN SQUARE C3

FEATURE	DATE	SMITH	HB	CINDER	HL
88	16	85	0	0	0
89	16	0	0	35	0
34	17	685	0	0	0
** Subtotal **					
		770	0	35	0
** Total **					
		53677	14200	434	710