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Ancient Monuments Laboratory
Report 90/93

ASSESSMENT OF SLAG AND OTHER METALWORKING FROM SANDY CEMETERY, BEDFORDSHIRE, 1989-91

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Summary

Selective examination of metalworking debris totalling 105kg from the excavation of Roman contexts at Sandy Cemetery produced evidence of both iron smithing and copper alloy melting and casting.

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ASSESSMENT OF SLAG AND OTHER METALWORKING DEBRIS FROM SANDY CEMETERY, BEDFORDSHIRE, 1989-91

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Introduction

The existence of a Roman settlement in the vicinity of Sandy, Bedfordshire had been known as far back as the seventeenth century. More recently, the discovery of ancient human remains, in the new extension to Sandy Municipal Cemetery led to a field assessment being carried out in 1987-88. Trial excavations confirmed the site to be the location of a Roman cemetery. This assessment examines material from three subsequent seasons of excavations carried out by Bedfordshire County Council Archaeology Service on the site between 1989 and 1991 when a total area of approximately 1600m^2 was investigated.

At the time of this assessment only summary reports for the first two seasons of excavation on the site were available. These had revealed a sequence of occupation on the site from the first century through to the fourth. The earliest evidence, including post hole structures, was dated to the late Iron Age or immediately post conquest, however, much of the early evidence had been disturbed by later Roman activity. A trackway bisecting the site on an east-west axis remained in use throughout the remaining Roman occupation of the site. In the first century the main area of settlement lay to the north of this track whilst the southern side included an ashy dump. The third and fourth century saw greater development in the area with stone footed buildings alongside the road, another area of ashy tips and hearths interpreted as a craft quarter, and a series of burials including an earlier cemetery to the north of the site and inhumations immediately adjacent to the track.

Evidence for metalworking, reported from the 1990 excavations, included the following [1];

Crucible fragments and small bronze offcut strips were found in the north eastern part of the site in the 4th century levels which suggest cold bronzeworking.

Hearth foundations were found and soil samples from them produced hammerscale suggesting blacksmithing. The hearths were concentrated on the west side of the site.

Tentative evidence of silversmithing may be inferred from the discovery of a damaged and deformed cluster of silver rings.

A total of 105kg of slag and other metalworking debris had been recovered during the three seasons of excavation and had been weighed and provisionally identified by staff at Bedfordshire County Council Archaeology Service. The Ancient Monuments Laboratory was asked to confirm these identifications and advise on the potential for further analysis.

Examination of ferrous metalworking debris

For the purpose of assessment approximately 50% (by weight) of the assemblage was visually examined and categorised[2] as follows:

Ferrous Metalworking Debris from Sandy Cemetery, Beds

Context No.	Preliminary interpretation	Weight (g)	AM Lab interpretation	Comments
202	Fe metalworking debris	2741	undiagnostic ironworking debris, cinder	
202	furnace lining ? + tuyere	497	vitrified hearth/furnace lining	
228	Fe metalworking debris	743	undiagnostic ironworking debris, vitrified hearth/furnace lining	
354	Fe metalworking debris	155	vitrified hearth/furnace lining	
391	not listed	1250	undiagnostic ironworking debris, iron-rich cinder, spheroidal and flake hammerscale	
503	Fe metalworking debris	141	cinder, fuel ash slag	
503	hammerscale	1 large jar	flake and spheroidal hammerscale	
520	Fe metalworking debris? slag	55	iron-rich cinder	
523	hammerscale	1 large jar	flake and spheroidal hammerscale	
523	furnace lining?	284	vitrified hearth/furnace lining	
763	Fe metalworking debris	40	dense ironworking slag	very dense
764	Fe metalworking debris	7	iron object	

Ferrous Metalworking Debris from Sandy Cemetery, Beds

Context No.	Preliminary interpretation	Weight (g)	AM Lab interpretation	Comments
790	furnace lining?	12	vitrified hearth/furnace lining	
792	?	13	fuel ash slag	
799	Fe metalworking debris	122	undiagnostic ironworking debris	high vesicularity
801	furnace lining?	50	vitrified hearth/furnace lining	
807	Fe metalworking debris	159	cinder, undiagnostic ironworking debris	
811	furnace lining?	28	vitrified hearth/furnace lining, vitrified hearth/furnace lining/iron-rich cinder	black glaze on lining, from ashy layer
815	hammerscale	medium jar	flake and spheroidal hammerscale	
816	hammerscale	0.5 med. jar	flake hammerscale	
824	furnace lining? (+tuyere)	419	vitrified hearth/furnace lining, tuyere frag.	
836	furnace lining?	33	vitrified hearth/furnace lining	lustrous crystalline appearance with quartz chips
848	furnace lining?	425	vitrified hearth/furnace lining, tuyere frag.	lightly slagged, some black glaze
848	Fe metalworking debris	2497	vitrified hearth/furnace lining/cinder	from 1989 ashy deposit
859	Fe metalworking debris	61	undiagnostic ironworking debris	
925	Fe metalworking debris	1340	undiagnostic ironworking debris, vitrified hearth/furnace lining	from ashy layer
950	furnace lining?	158	vitrified hearth/furnace lining	
954	Fe metalworking debris	137	iron-rich cinder, cinder, undiagnostic ironworking debris	from hearth
977	Fe metalworking debris	163	smithing hearth bottom frag.	
1039	droplets (fe)	<1	spheroidal hammerscale	
1042	Fe metalworking debris	762	dense ironworking slag	
1048	Fe metalworking debris	1096	smithing hearth bottom	150x120x50mm
2000	Fe metalworking debris	477	undiagnostic ironworking debris, cinder	
2001	Fe metalworking debris	375	smithing hearth bottom	110x100x25mm
2001	Fe metalworking debris	1093	vitrified hearth/furnace lining, undiagnostic ironworking debris, cinder	
2002	Fe metalworking debris	908	undiagnostic ironworking debris	
2038	(?tuyere) furnace lining	377	vitrified hearth/furnace lining	
2091	Fe metalworking debris	681	vitrified hearth/furnace lining	
2118	Fe metalworking debris	2074	vitrified hearth/furnace lining	
2159	Fe metalworking debris	713	undiagnostic ironworking debris	

Ferrous Metalworking Debris from Sandy Cemetery, Beds

Context No.	Preliminary interpretation	Weight (g)	AM Lab interpretation	Comments
2159	Fe metalworking debris	325	smithing hearth bottom	100x75x25mm
2258	Fe metalworking debris	1430	undiagnostic ironworking debris, cinder	
2258	Fe metalworking debris	350	smithing hearth bottom frag.	85x85x35mm
2356	Fe metalworking debris	3067	iron-rich cinder/undiagnostic ironworking debris	
2356	furnace lining?	1810	iron-rich cinder/undiagnostic ironworking debris/cinder	
2362	?	16	fuel ash slag	
2376	furnace lining?	21	vitrified hearth/furnace lining	
2387	Fe metalworking debris	454	undiagnostic ironworking debris, vitrified hearth/furnace lining	
2396	hammerscale	c 0.5 medium jar	flake and spheroidal hammerscale	
2396	Fe metalworking debris	351	undiagnostic ironworking debris	
2397	Fe metalworking debris	2881	dense ironworking slag, undiagnostic ironworking debris, cinder	
2397	hammerscale	c 0.5 medium jar	flake and spheroidal hammerscale	
2397	furnace lining?	875	vitrified hearth/furnace lining	
2442	hammerscale	c 0.5 medium jar	flake and spheroidal hammerscale	
2526	furnace lining	272	vitrified hearth/furnace lining, undiagnostic ironworking debris	
2560	hammerscale	1 large jar	flake and spheroidal hammerscale	
2560	Fe metalworking debris	1287	undiagnostic ironworking debris, iron-rich cinder	
2560	?Fe + "Ca" (=Cu?)metalworking debris	168	iron-rich cinder with copper corrosion stain	
2656	Fe metalworking debris	575	smithing hearth bottom	100x90x40mm
2656	Fe metalworking debris	2013	vitrified hearth/furnace lining	
2662	Fe metalworking debris	69	undiagnostic ironworking debris	
2662	hammerscale	c 1 large jar	flake and spheroidal hammerscale	from ashy layer
2662	furnace lining	6	vitrified hearth/furnace lining	
2796	hammerscale	c 2 large jars	flake and spheroidal hammerscale	
3507	Pb/Ag	<1	unknown poss. slag	
3511	Fe metalworking debris	293	cinder/fuel ash slag	
3620	Fe metalworking debris	500	smithing hearth bottom	100x90x45mm

Ferrous Metalworking Debris from Sandy Cemetery, Beds

Context No.	Preliminary interpretation	Weight (g)	AM Lab interpretation	Comments
3620	Fe metalworking debris	6195	vitrified hearth/furnace lining, undiagnostic ironworking debris, cinder, iron-rich cinder	
3679	Fe metalworking debris	1201	vitrified hearth/furnace lining	green /purple red glazes poss. non-ferrous working
3764	Fe + "Ca" (=Cu?)metalworking debris	59	vitrified hearth/furnace lining	green corrosion specks poss. non-ferrous working
3801	Fe metalworking debris	852	undiagnostic ironworking debris	crystalline surface
3801	Fe metalworking debris	350	smithing hearth bottom	80x70x40mm
3898	Fe metalworking debris	413	dense ironworking slag	
3974	Fe metalworking debris	555	undiagnostic ironworking debris	
3980	?	5	fuel ash slag	
3988	Fe metalworking debris	157	undiagnostic ironworking debris, cinder	
4008	Fe metalworking debris	539	vitrified hearth/furnace lining	
4012	Fe metalworking debris	362	cinder	
4012	furnace lining	80	vitrified hearth/furnace lining	
4030	Fe metalworking debris	2661	vitrified hearth/furnace lining/undiagnostic ironworking debris + ironstone (disposed of)	
4036	Fe metalworking debris	359	cinder	
4036	hammerscale	1 small bag	flake and spheroidal hammerscale	
4038	Fe metalworking debris	122	undiagnostic ironworking debris	
4051	hammerscale	1 small bag	flake and spheroidal hammerscale	from fill of hearth
4051	Fe metalworking debris	118	vitrified hearth/furnace lining, cinder	from fill of hearth
4054	hammerscale	1 small bag	flake and spheroidal hammerscale	
4058	Fe metalworking debris	121	dense ironworking slag	
4102	Fe metalworking debris	1 tube	hammerscale, mainly spheroidal, some flake	

Better evidence for the smithing of iron was provided by hammerscale. These micro-slags may conform to two types. The first, **flake hammerscale**, consists of "fish-scale" like fragments of the oxide/silicate skin of the iron which become dislodged due to mechanical and thermal shock during hot working. **Spheroidal hammerscale** results from the solidification of small droplets of liquid slag expelled during higher temperature hammering of the iron, particularly when two components are fire-welded together but also during the primary smithing of the iron bloom into a billet. Hammer-scale was identified in 16 of the contexts from Sandy Cemetery examined. Most of these contained both morphological types, thereby indicating more complex ironsmithing activities than the simple shaping of metals (as might predominate in trades such as nail smithing). Hammerscale distributions are regarded as important indicators of the location of ironsmithing activities because quantities are more likely to remain in the vicinity of the smithy than the bulk slags which may be removed elsewhere, for dumping or for use as hardcore.

Undiagnostic ironworking slag is also largely of fayalitic composition but has an amorphous, blocky, form. However, as similar material can originate from either iron smithing or iron smelting (extraction of metal from ore) it cannot help to distinguish the nature of the ironworking activity on site. Five contexts contained slag of sufficiently low vesicularity to be classified as **dense ironworking slag.** These resemble certain products of iron smelting, but, given the small quantities present and lack of supporting evidence in the form of more diagnostic smelting slags, ores or identifiable furnace structures, these cannot be regarded as evidence for on-site iron smelting.

Fuel ash slag is a very lightweight and normally light-coloured (grey-brown), highly porous material that results from the reaction between alkaline fuel ash and silicates from soil, sand or clay at elevated temperatures. The reaction is shared by many pyrotechnological processes and the slag is not diagnostic. Finally context 2560 produced some **iron-rich cinder with copper corrosion stain**. The origins of this cannot be stated with any certainty, although it is quite probable that a blacksmith would occasionally work with non-ferrous metals, for example in brazing, inlaying or copper riveting of iron objects.

Examination of non-ferrous metalworking debris

The Sandy Cemetery site produced a limited number of crucible fragments and other non-ferrous metal working debris and a selection of these were examined as part of this assessment. Some of the crucible fragments were analyzed qualitatively by X-ray fluorescence (XRF) analysis and gave the following results:

Selective examination & analyses of non-ferrous debris from Sandy

Find No.	Context	Elements	Comments
785	202	(Ca) **Fe**	over-fired ceramic?
1165	425		wheel thrown crucible base
1880	2009		probable clay mould frag.
1881	2664		oxidised fired frag. uncertain use
1882	2526	**Sn Pb**	straight sided, vitrified crucible rim frag. prob. I.A./early Roman type
2577	2560		poss. clay mould frag.
3090	2373		vitrified crucible rim
3091	3078	(P) (Ca) Fe Cu (Sn) **Pb**	?crucible with poss. litharge cake attached
3092	3273		straight sided vitrified crucible rim frag. prob. I.A./early Roman type
3093	3288	**Fe Cu Zn** Sn **Pb**	thick walled hand made crucible
3095	2437	**Fe Cu Zn Sn Pb**	rim of small crucible
3096	2441		crucible frag.
3612	u/s		crucible base
3768	3891	Fe **Cu Sn** Pb	failed investment mould casting
3850	3890		clay mould frag. prob. piece mould
	836		vitrified hearth/furnace lining

Codes: **XXX** elements strongly detected*
XXX elements moderately detected*
(XXX) elements weakly detected*

* Based on peak height of fluorescence spectrum. This is not necessarily proportional to the elemental concentration in the original alloy, or to the composition of the surviving compounds, for reasons explained below;

P = phosphorus, probably deriving from crushed bone ash in litharge cakes.
Ca = calcium, from ceramic fabric or crushed bone ash in litharge cakes.
Fe = iron, present within soil or ceramic fabric.
Cu = copper, from alloy being melted.
Zn = zinc, from alloy being melted (tends to volatilise and pass into the ceramic easily and is therefore retained in detectable quantities, even when present only as traces in metal being melted).
Sn = tin, from alloy being melted (analysis of crucible fragments may not give a signal above detection limits, even when tin is present as a major constituent in the alloy melted).
Pb = lead, from alloy being melted or as oxide in litharge cake, presence tends to be exaggerated due to the metal's strong tendency to fluoresce.

Examination showed the **crucibles** to included Iron Age/early Roman straight sided, triangular forms with vitrified rims due to heating from above (sf1882 & 3092) and wheel thrown Roman forms. XRF analysis of crucibles cannot determine the exact composition of the alloys which had been melted in them, due to differences in the behaviour, survivability and "detectability" of the various elements. However, a range of bronzes, leaded bronzes and brasses was indicated for the examples analyzed. Such alloys would have been suitable for the casting of small objects. Evidence for such casting is supported by **mould fragments** (sf1880, 2577, 3768 & 3850), which probably include the remains of both piece moulds and an investment mould, together with a number of copper alloy **spillages**.

A further technological process, the refining of silver, may be deduced from a single find (sf3091). The thick crust on this sherd contains a very high content of lead with respect to copper, together with some calcium and phosphorus. This analysis suggests the material is **litharge cake**, produced when the lead used to remove base metals from silver is oxidised and absorbed into the bone ash lining of a ceramic vessel[3].

The vitrified sherd (sf785) appears to be **over-fired ceramic** rather than a metallurgical crucible fragment. This interpretation was supported by XRF analysis which found no metallic traces on the inside of the sherd.

Conclusions

The slag assemblage from Sandy Cemetery contained a variety of metalworking waste products. Although much of the ferrous debris assemblage was not diagnostic, the presence of smithing hearth bottoms and hammerscale indicates that iron smithing had occurred, and it would seen likely that most, if not all, of the non-diagnostic slag also derived from this activity. Evidence for the melting and casting of copper alloys was provided by a limited number of crucible and mould fragments and spillages of metal. The possibility of silver refining at Sandy should be considered, although evidence for this is tenuous at present.

Potential for further work

Particularly in urban situations there is a likelihood that metalworking debris was dumped at some distance from the site of the process which produced it and this may lessen the potential for more detailed examination of the debris, which would ideally also examine the associated structures, raw materials and possible products. Although it is believed that hearths were found on the site, detailed matching of metalworking debris with contexts and associated structural features was beyond the scope of this assessment. If, when phasing has been carried out, there appear to be clear associations between the metalworking debris and the hearths, then I would strongly recommend an integrated study of the evidence for metalworking.

Storage of slag

Ironworking slag, being predominantly fayalitic, is not prone to deterioration and requires no special storage treatment. Crucibles and moulds can be treated in a similar way but the copper alloy spillages should be stored in a low humidity environment to reduce the likelihood of further corrosion. It is recommended that all the slag should be saved.

References

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3. Bayley, J. and Barclay, K. (1990) The Crucibles, Heating Trays, Parting Sherds, and Related Material in Biddle, M. *Object and Economy in Medieval Winchester* **i**, Oxford, 175-197.