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THE ASSESSMENT OF ROMAN AND LATER SLAG AND OTHER METALWORKING DEBRIS FROM WINCHESTER, BROOKS 1987-8

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Summary

54kg of ferrous metalworking debris from Roman contexts was examined and found to derive from both smithing and iron smelting. However, there is no evidence that either of these activities was carried out on the site. Selective examination was also carried out on post-Roman ironworking slag and non-ferrous metalworking debris of all periods. Evidence for non-ferrous processes included the waste products of copper alloy and gold melting and silver refining.

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Roman Ironworking debris from Winchester, Brooks

Context	Period	Phase	Weight (g)	Interpretation	Comments
16277	III	38	10	vitrified hearth/furnace lining	
16277	III	38	16	iron object/lump	
16280	III	38	196	flake and spheroidal hammerscale	
16297	III	38	8	cinder	
16300	III	38	19	cinder	
15557	III	40	7	iron-rich cinder	
15563	III	40	18	iron object/lump	
15563*	III	40	30	undiagnostic ironworking debris	
15563	III	40	32	iron object/lump	
15570	III	40	5	tap slag	
15570	III	40	72	iron-rich cinder	
16658	III	40	254	undiagnostic ironworking debris	
17510	III	40	58	iron object/lump	
20009	III	40	1895	flake and spheroidal hammerscale	large quantities hammerscale and some iron frags. concreted into a lump.
20020	III	40	6	copper alloy dribble	
20081	III	40	788	ferruginous concretion + iron-rich cinder	
15567	III	43	38	iron-rich cinder	
15568	III	43	14	cinder	
13356	IV	44	6	cinder	
13357	IV	44	12	ferruginous concretion	
13358	IV	44	14	cinder	
14236	IV	44	4	ferruginous concretion	
14236	IV	44	6	undiagnostic ironworking debris	
14236	IV	44	18	cinder	
16513	IV	47	724	iron-rich cinder	
13817	IV	48	2	roasted ore	
14162	IV	48	5	vitrified hearth/furnace lining	
14162	IV	48	78	iron-rich cinder	
14163	IV	48	12	dense ironworking slag	
11929	IV	49	60	tap slag	
11929	IV	49	100	undiagnostic ironworking debris	
11975	IV	49	135	unidentified	
11975	IV	49	146	probable ore	
13661	IV	49	5	undiagnostic ironworking debris	
13661	IV	49	5	vitrified hearth/furnace lining	
13661	IV	49	<1	flake hammerscale and roasted ore	
13666	IV	49	8	roasted ore	
13667	IV	49	1	vitrified hearth/furnace lining	
13137	IV	50	10	undiagnostic ironworking debris	
13137	IV	50	13	vitrified hearth/furnace lining	bright blue specks
13137	IV	50	19	tap slag	
13137	IV	50	31	roasted ore	
13139	IV	50	7	roasted ore	

Roman Ironworking debris from Winchester, Brooks					
Context	Period	Phase	Weight (g)	Interpretation	Comments
13140	IV	50	27	roasted ore	
13141	IV	50	3	spheroidal hammerscale + roasted ore	
13142	IV	50	11	spheroidal hammerscale + roasted ore	
13146	IV	50	54	stone?	
13147	IV	50	2	spheroidal hammerscale	
13151	IV	50	16	undiagnostic ironworking debris	
13638	IV	51	26	roasted ore	
13638	IV	51	166	tap slag	
13189	IV	52	20	tap slag	
13422	IV	52	1	cinder	
13422	IV	52	20	tap slag	
13559	IV	52	25	tap slag	
13117*	IV	53	6	undiagnostic ironworking debris	
30060*	IV	56	5	cinder	
30060	IV	56	20	iron-rich cinder	
16020	IV	59	6	vitrified hearth/furnace lining	
11699	IV	60	7	flake and spheroidal hammerscale	
11699*	IV	60	12	vitrified hearth/furnace lining	glazed
11699	IV	60	40	vitrified hearth/furnace lining	
11699	IV	60	45	cinder	
11699	IV	60	48	iron object/lump	
11699	IV	60	300	ferruginous concretion	
11699	IV	60	460	smithing hearth bottom	100x90x50mm
11699	IV	60	840	undiagnostic ironworking debris	
11699	IV	60	2670	tap slag	
11798	IV	60	16	cinder	
13134	IV	60	1	cinder	
13134	IV	60	23	roasted ore	
13195*	IV	60	1	vitrified hearth/furnace lining	
13195	IV	60	50	tile	
13195	IV	60	140	tap slag	
15995	IV	60	20	vitrified hearth/furnace lining	
15995	IV	60	40	undiagnostic ironworking debris	
15995	IV	60	228	roasted ore	
15998	IV	60	20	vitrified hearth/furnace lining	
15998	IV	60	48	iron object/lump	
16536	IV	60	15	lead/tin waste	
16536*	IV	60	20	undiagnostic ironworking debris	
16788	IV	60	4	vitrified hearth/furnace lining	
16788	IV	60	6	vitrified hearth/furnace lining	
16788	IV	60	6	vitrified hearth/furnace lining	
16788	IV	60	51	iron-rich cinder	
13500	IV	61	18	litharge cake	copper corrosion specks
13500	IV	61	388	tap slag	

Roman Ironworking debris from Winchester, Brooks					
Context	Period	Phase	Weight (g)	Interpretation	Comments
13103	IV	62	44	fired clay	
13103	IV	62	45	roasted ore	
13103	IV	62	45	tap slag	
13103	IV	62	60	dense ironworking slag	
13106	IV	62	92	iron object/lump	
13106	IV	62	3894	tap slag	
13122	IV	62	464	tap slag	
13186	IV	62	125	dense ironworking slag	
13186	IV	62	350	tap slag	
11866	IV	63	68	iron object/lump	
13095	IV	63	51	fired clay	
13102	IV	63	1872	tap slag	
13120	IV	63	24	iron-rich cinder	
13120	IV	63	1098	tap slag	
15215			32	fired clay	
16288			20	vitrified hearth/furnace lining	

* denotes crucible or mould fragments also found in this context

Roman slag weight totals from Winchester, Brooks	
slag type	total weight (kg)
tap slag	12.42
dense ironworking slags	0.22
prob. ores & roasted ores	0.54
smithing hearth bottoms	0.77
hammerscale	0.25
ferruginous concretion +	3.49
ferruginous concretions	23.58
undiagnostic ironworking slag	1.49
vitrified hearth/hearth/furnace lining	2.27
cinder	1.18
iron-rich cinder	5.13
iron objects	1.53
fuel ash slag	0.05
fired clay	0.13
total	53.05

The largest category of material in the assemblage was that identified as **undiagnostic ferruginous concretion**. This forms as a result of the redeposition of iron hydroxides, (similar to the natural phenomenon of iron panning), although in this instance the process is likely to be enhanced by the nature of the surrounding archaeological deposits (This is certainly the case for the ferruginous concretion with hammerscale mentioned below). Although "bog ores" of similar appearance are known to have been used as a source of iron for smelting in antiquity, the material examined from Winchester, Brooks would appear to be contaminated with soil and rock fragments and therefore insufficiently rich in iron for the metal to be extracted by the bloomery smelting furnaces of the Roman period.

The fragments of dense, fayalitic (iron silicate) **tap slag** show a characteristic "ropy" flowed morphology on their upper surface and very low vesicularity at their fracture surfaces. These provide excellent evidence of the smelting (*i.e.* primary extraction from the ore) of iron and are typical waste products of the tapped bloomery furnace, in use during the Roman period, from which the molten slag was run out rather than collecting within its interior. Much smaller quantities of **dense ironworking slags** probably also derive from iron smelting although they do not show the flowed structure of the tap slag. Further evidence of smelting was provided by the limited quantities of **probable ores** and **roasted ores**. Although no analyses of these were carried out they appeared to be largely hematite/magnetite of sufficiently high grade to be a viable source of iron, given the furnace technology of the period.

These four categories of material have been combined in Figure 1 to allow comparison of the evidence of smelting over the four periods into which the Roman occupation of the site has been divided. In the first three phases quantities are minimal and it is only in the mid 4th-5th century that a sharp rise in quantity is observed. However, even then the total figure of 12kg is small in comparison with what might be expected in the immediate locality of a smelting furnace. Whilst it is common for slag to be reused as road metalling or even incorporated into masonry this would not appear to be the case here; over 10kg of tap slag was recovered from the two "dark earth" layers and from a phase of late activity sandwiched between them. The existence, and location, of this tap slag may therefore be best explained as material dispersed from a furnace operating in the vicinity.

Evidence for the smithing (*i.e.* hot working) of iron comes in two main forms; bulk slags and micro slags. Of the bulk slags produced during smithing only the **smithing hearth bottoms** are unlikely to be confused with the waste products of smelting and are therefore considered to be diagnostic of smithing. These hearth bottoms are recognisable by their characteristic plano-convex form, having a rough convex base and a smoother, vitrified upper surface which is flat, or even slightly hollowed as a result of the downwards pressure of the air blast from the tuyère. Compositionally, smithing hearth bottoms are also predominantly fayalitic and form as a result of high temperature reactions between the iron, iron-scale and silica from either the clay furnace lining or sand used as a flux by the smith. In addition to bulk slags, iron smithing also produces micro slags of two types. **Flake hammerscale** consists of fish-scale like fragments of the oxide/silicate skin of the iron dislodged during working. **Spheroidal hammerscale** results from the solidification of small droplets of liquid slag expelled during working, particularly when two components are being fire welded together or when a slag-rich bloom of iron is first worked into a billet or bar. Hammerscale is considered important in interpreting a site not only because it is highly diagnostic of smithing but, because it is often allowed to build up in the immediate vicinity of the smithing hearth and anvil, it may give a more precise location of the activity than the bulk slags which may be transported elsewhere for disposal[2].

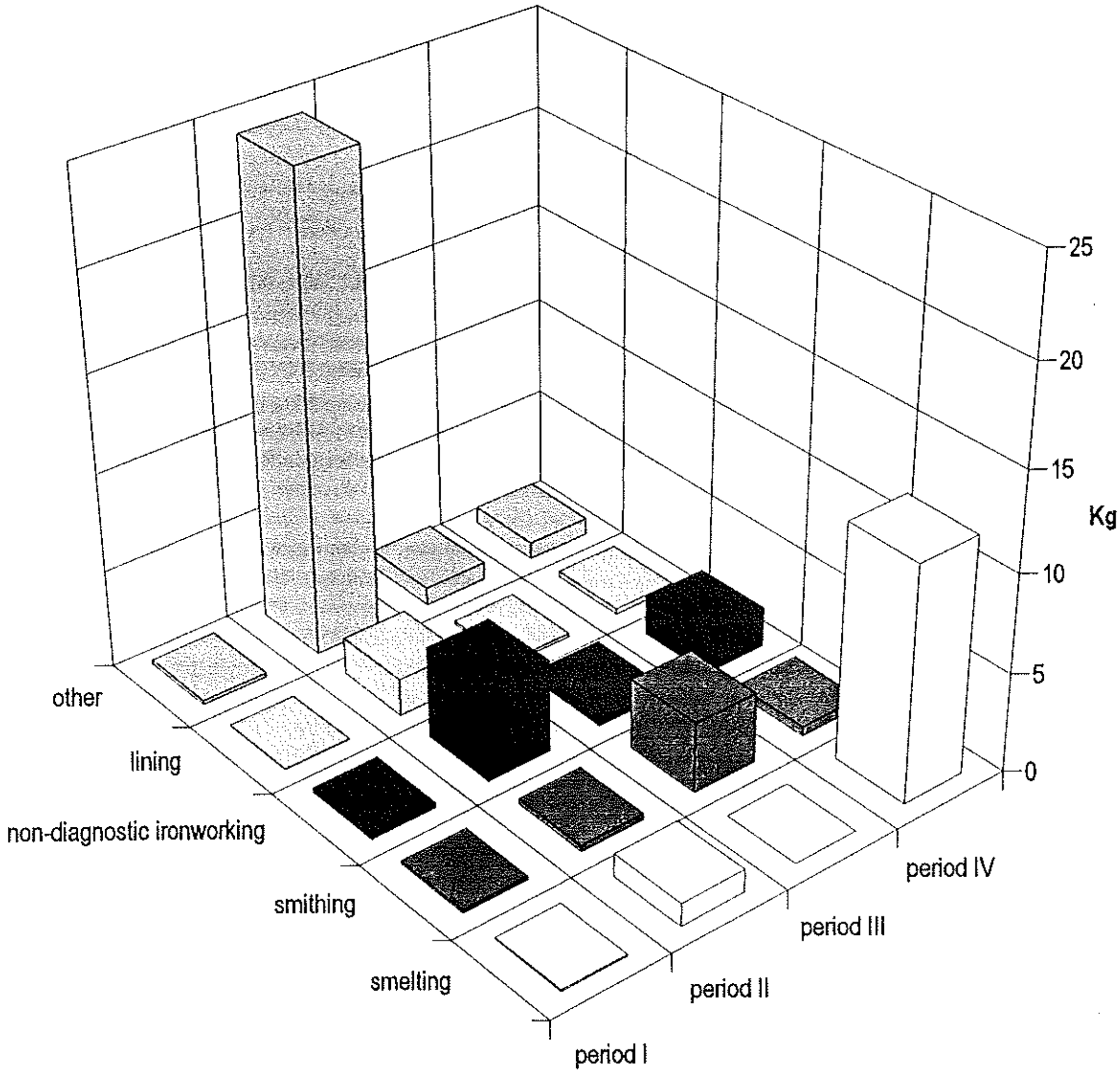
Only three examples of smithing hearth bottoms were identified from the Roman slags, none of which shared the same context or phase. By themselves such small quantities were insufficient to provide good evidence of smithing activity in the immediate locality, however, hammerscale had been recognised and extracted from soil samples over a wide range of contexts within the site. Some of the ferruginous concretions contained large quantities of hammerscale and clearly derived from more than short-term smithing activities, however most of these concretions were recovered from road surfaces and built up areas and may therefore have been transported into the area as hardcore rather than being representative of local smithing activity. Hammerscale recovered from contexts other than road surfaces was generally present only in very small quantities. Without knowing the sampling strategy it was not possible to judge its significance, particularly in the absence of any structural evidence of hearths.

The apparent increase in smithing activity in Phase III, as shown in Fig.1, is heavily biased in favour of a small number of the ferruginous concretion + hammerscale blocks from the roads of that period. Considering that most evidence for smithing was in the form of samples rather than total weights, comparison of the quantities of this debris would not be meaningful.

Material listed as **vitrified hearth/furnace lining** may derive from either iron smelting, iron smithing or, particularly with fragments showing coloured glazes, of non-ferrous metal working. The material forms as a result of a high temperature reaction between the clay lining of the hearth/furnace and the alkali fuel ashes or fayalitic slag. The material may show a compositional gradient from unmodified clay on one surface to an irregular cindery material on the other. An associated material, classed as **cinder,** comprises only the lighter portion of this, a porous, hard and brittle slag formed as a result of high temperature reactions between the alkali fuel ashes and either fragments of clay which had spalled away from the hearth/furnace lining or another source of silica, such as the sand used as a flux during smithing. **Iron-rich cinder** is a similar material but contains a significant iron content, making it denser. More dense still are those slags classed as **undiagnostic ironworking slags**. The compositions of these fragments are predominantly fayalitic, but their morphology is irregular and it is not possible to distinguish between the similar materials produced by smelting and smithing operations.

Finally a very small amount of material was classified as **fuel ash slag**, a very lightweight, light coloured (grey-brown), highly porous material which 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.

Figure1. Quantification of Roman metalworking debris by period



The preliminary examination of Post-Roman ferrous metalworking debris.

A brief examination of a selection of the post Roman metalworking slags and other debris was made, concentrating on the more diagnostic slags and the hearth linings. As mentioned above no attempt was made to relate these materials to their archaeological contexts.

Post-Roman Ironworking debris from Winchester, Brooks

Context	Weight (g)	Interpretation	Comments
10004	20	blue glass waste?	
10007	20	vitrified hearth/furnace lining	
10048	350	undiagnostic ironworking slag	
10048	550	smithing hearth bottom	100x100x35mm
10072*	40	vitrified hearth/furnace lining	pink/white/green glaze
10077	60	tap slag	
10139	50	vitrified hearth/furnace lining	black/green glaze
10171	70	vitrified hearth/furnace lining	green/blue glaze
10192*	40	vitrified hearth/furnace lining	black glaze
10217	25	vitrified hearth/furnace lining	
10275	15	vitrified hearth/furnace lining	
10318	550	vitrified hearth/furnace lining	
10337	750	vitrified hearth/furnace lining	
10343	25	vitrified hearth/furnace lining	black glaze
10424	30	vitrified hearth/furnace lining	black glaze
10438	80	vitrified hearth/furnace lining	
10486	10	vitrified hearth/furnace lining	black glaze
10673	140	smithing hearth/furnace bottom	100x8x40mm
10701	30	vitrified hearth/furnace lining	
10719	40	dense ironworking slag	
10853	30	vitrified hearth/furnace lining	
11017	15	vitrified hearth/furnace lining	black glaze
11070	600	smithing hearth bottom	110x90x50mm
11084	10	vitrified hearth/furnace lining	black glaze
11213	25	tap slag	
11217	30	tap slag	
11505	30	dense ironworking slag	
11505	30	tap slag	
11533	40	vitrified hearth/furnace lining	
11550	70	vitrified hearth/furnace lining	black glaze
11559	80	dense ironworking slag	
11566	40	vitrified hearth/furnace lining	
11573	15	tap slag	
11574	15	vitrified hearth/furnace lining	
11595	300	tap slag	
11601	40	vitrified hearth/furnace lining	
11610	30	vitrified hearth/furnace lining	black glaze

Context	Weight (g)	Interpretation	Comments
		Post-Roman Ironworking debris from Winchester, Brooks	
11610	100	vitrified hearth/furnace lining	
11619	100	dense ironworking slag	
11624	450	smithing hearth bottom	110x90x40mm
11624	250	smithing hearth bottom	90x70x35mm
11624	100	vitrified hearth/furnace lining	
11634	150	vitrified hearth/furnace lining	red/green/black glaze
11645	30	vitrified hearth/furnace lining	black glaze
11645	30	vitrified hearth/furnace lining	
11661	50	tap slag	
11705	15	vitrified hearth/furnace lining	black glaze
11722	10	vitrified hearth/furnace lining	black glaze
11775	15	vitrified hearth/furnace lining	red glaze
11857	100	tap slag	
11970	1100	possible ore	
12043	1	spheroidal hammerscale	
12239	1	flake + spheroidal hammerscale	
12641*	100	frag. smithing hearth bottom	90x90x30mm
12843	10	vitrified hearth/furnace lining	translucent olive green glaze
12909	20	vitrified hearth/furnace lining	
13179	40	cinder	
13647	20	vitrified hearth/furnace lining	black glaze
13953	15	vitrified hearth/furnace lining	black glaze
13957	30	vitrified hearth/furnace lining	
14538	5	vitrified hearth/furnace lining	red/black glaze
14696	15	dense ironworking slag	
14696	200	tap slag	
14801	100	tap slag	
14809	400	vitrified hearth/furnace lining	black glaze
15831	30	dense ironworking slag	
15837	30	vitrified hearth/furnace lining	
15838*	500	fired clay	
15840*	20	dense ironworking slag	
15918	100	probable roasted ore	
15918	20	vitrified hearth/furnace lining	
15990*	30	tap slag	
16062	40	iron object	
16534	50	iron object	
16542	15	vitrified hearth/furnace lining	
16546	200	dense ironworking slag	
16565	100	galena?	
16757	20	vitrified hearth/furnace lining	
16761*	100	vitrified hearth/furnace lining	

* denotes crucible or mould fragments also found in this context

Post-Roman slag totals from Winchester, Brooks	
slag type	**total weight (kg)**
tap slag	940
dense ironworking slag	515
prob. ores & roasted ores	1200
smithing hearth bottoms	2090
hammerscale	1
undiagnostic ironworking slag	400
vitrified hearth/furnace lining	3160
cinder	40
iron object	40
fired clay	500
galena?	100
blue glass waste?	20

As with material from Roman contexts, later debris was identified as deriving from a range of metalworking activities, including **tap slags**, which are diagnostic of iron smelting, and **hearth bottoms** from iron smithing. However, the total quantities of diagnostic iron smelting and smithing debris present were very low, being of the order of a couple of kilograms only. With the exception of possible concentrations in contexts 11624 and 10048 the material appears to be very widely dispersed across the site. Thus it would seem likely that much of the material was residual or brought in from metalworking areas beyond the site. Reference to the context information sheets may clarify this.

The largest category of debris present was the **vitrified hearth/furnace lining**. Not only did this appear to comprise a much higher proportion of the post-Roman material than it had done for the Roman assemblage, but differences in the nature of the material were evident. Most of the Roman material had been heavily attacked by the slag to give a bloated cindery outer surface. Post-Roman contexts more commonly produced linings with only a thin glaze on their outer surfaces, often showing various distinctive colours from red, green and blue to black. This suggests that much more of the post-Roman material derived from the working of non-ferrous alloys than had been the case for the Roman assemblage. Certainly many of the contexts which produced vitrified linings also contained crucible and mould fragments and these provide evidence of the nature of the non-ferrous metalworking being carried out.

The Preliminary examination of crucible and mould fragments

The Winchester, Brooks site produced a significant number of crucible fragments and other non-ferrous metalworking/metal processing debris, covering a range of processes but only 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:

XRF analyses of crucible fragments from Winchester, Brooks

context	find No.	object	Elements present	comments
10422	483	crucible frag.	(Si) **Ca Ti Fe**	poss. unused
12165	6833	crucible? frag.	Ca Cu Fe **Pb**	poss. cupel
14231	6537	lump	Si (P) **Ca** Fe **Pb**	litharge cake
14678	8140	crucible frag.	(Ca) **Cu Fe Pb**	leaded bronze melting
15012	7035	crucible frag.	**Ca** (Mn) **Fe** (Ti) **Pb**	uncertain use
15654		lump	**Ca Cu** (Fe) **Pb**	litharge cake
16536		lump	(Fe) **Sn Pb**	corroded pewter?
16565		mineral	(Ca) (Fe) **Pb**	galena?
16761	6509	crucible	**Si Ca** (Fe)	large bag shaped crucible
30060	8319	crucible frag.	(Ca) **Fe** (Cu) (Zn) (Au)	gold melting

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;

Si = silicon, from sample fabric/soil contamination.
Ca = calcium, from ceramic fabric or crushed bone ash in litharge cakes.
Ti = titanium, as background contaminant - as Si.
Mn = manganese, present within soil or ceramic fabric.
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, detected strongly in the "lump" from 15654, but 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.
Au = gold, also visible as untarnished metallic droplets.
Pb = lead, present as the major constituent in galena, and the corroded pewter "lump". (presence on crucible fragments tends to be exaggerated due to the metal's strong tendency to fluoresce).

Examination and analysis of a selection of the crucibles and associated material showed a wider range of technological processes than had been expected. Several lumps of litharge cake were identified (14231 & 15654), providing evidence of the refining of silver. At least one ceramic fragment (12165 sf483) appeared to be a pot sherd reused as a cupel in testing the purity of a precious metal[3] The crucibles[4] themselves ranged from a small wheel thrown Roman type (16565 sf8319) containing traces of gold to a complete late Saxon/early Medieval "bag shaped" form. Although the latter had clearly been used for some high temperature process the exterior surfaces gave no clue to the nature of the material. The smaller fragments allowed XRF analysis to be undertaken on the interior surfaces and suggested the melting of a range of copper alloys. The exact composition of these alloys could not be deduced due to differences in the behaviour, survivability and "detectability" of the various components, though a range of bronzes and leaded bronzes rather than brasses would seem likely for the few examples analyzed. Such alloys would have been suitable for the casting of small objects and the more unusual survival of a mould fragment (13493 sf9637) also derives from this activity, as may the copper alloy "spillage" from (20020) identified during the assessment of the Roman slags.

The presence of what appears to be a piece of the lead ore, galena (16565) is not easily explained. Two bags of ceramic (11565 sf3317 & sf3318) do not correspond to any known technological process and are thought most likely to be over-fired pottery. The dense lump from context 16536 contains lead and tin and appears to be heavily corroded pewter or solder; it is not thought that this find provides any evidence of local production of this alloy. Finally (15838 & 15926) are examples of decayed "forest" glass objects rather than waste materials (although a possible fragment of glass waste was identified within the post Roman slag assemblage). 15838 appeared to be a fragment of a glass vessel whereas 15926 is part of a linen smoother.

Conclusions

The metalworking and metal processing debris assemblage from Winchester, Brooks was noteworthy for its range of processes and materials rather than the quantities of material recovered. The waste products derived from both iron smelting, *i.e.* the primary extraction of iron from its ore, and iron smithing, *i.e.* the hot working of iron. It is difficult to be precise on the nature of the iron smithing; the existence of a large proportion of spheroidal hammerscale points to more than the hot shaping of metals (as would be the case for a specialist farrier or nailsmith) and either primary bloomsmithing or fire welding is indicated. Whilst both smelting and smithing processes were carried out in during the Roman occupation of the site, the extent to which the small quantities of similar material from later contexts represent residual material rather than evidence of contemporary activity could not be determined without access to the contextual records.

In addition to ironworking, evidence was found for copper alloy melting/casting in both the Roman and post Roman periods. Additionally, the Roman assemblage produced limited evidence for silver refining, cupellation (assaying of precious metals), gold melting/casting and possibly glass working. Considering the limited quantities of metalworking debris and the corresponding lack of structural evidence of furnaces and hearths for technological processes, it would seem likely that the excavated area was peripheral to any foci of industrial/craft activity, but that these may have existed in the vicinity of the site.

Potential for further work

The limited relationship between the slag assemblage and the structures excavated at Winchester, Brooks suggests that further examination and analysis of the metalworking debris would not contribute significantly to the interpretation of the site and therefore no further work on the Roman period is recommended. The extent of the continuation of slag tapping furnace technology beyond the Roman period is not well understood and deserves attention nationally. The strong possibility that some of the apparently post-Roman material on this site is residual makes the Brooks material inappropriate for such a study, however, an examination of the integrity of post-Roman contexts containing tap slag concentrations would be of interest in this respect. Concentrations of furnace lining, slags and crucible fragments among the later contexts of the site should be sought. If these appear to coincide with *in situ* structural evidence, such as hearths or furnaces, then a more detailed follow up examination and analysis program could be carried out to clarify the nature of the activities.

Storage of slag

Ironworking slag, being predominantly fayalitic, is not prone to deterioration and requires no special storage treatment. It is recommended that all the slag and other technological debris should be saved.

Bibliography

The following references include additional detail on some of the technological processes and their expected products and waste products:

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4. Bayley, J. (1992) *Anglo-Scandinavian Non-Ferrous Metalworking from 16-22 Coppergate.* The Archaeology of York **17/7**, London, Council for British Archaeology.