Evaluation of metallurgical residues from Hartshill Copse (HCB01)

Dr T.P. Young

Abstract

The assemblage is dominated by residues from iron smelting recovered from two smelting furnaces, interpreted to be of Iron Age date. The furnaces are within a tradition of non slag-tapping furnaces, in which the slag accumulates in a basal pit. The pit was packed with large pieces of charcoal or wood before the smelt, giving rise to slags with characteristically large fuel moulds. The slag blocks were normally removed and the furnace reused, but in one instance the slag block (furnace bottom) from the final smelt remained in-situ in the pit.

Micro-residues suggest that smithing, presumably including the bloomsmithing, was undertaken in an area immediately to the east of the smelting furnaces. Micro- and macro- smithing residues also occur in up to five or six clusters across the site, suggesting that smithing was also undertaken elsewhere. However, a similarly wide distribution of smithing residues across the HCB03 site to the south might suggest that at least some of the spread was produced by transported material. Smithing slags are well represented from a pit 150m east of the smelting area, with an assemblage including at least eleven smithing hearth cakes, together with lining fragments including a bulbous blowhole.

The material from the site has great potential for increasing understanding not only of iron production on this site, but also for the greater understanding of Iron Age furnace technology.

Contents

Background

The material investigated for this evaluation comprised 47.4kg macroscopic material from 35 contexts, plus a single 33.9kg furnace bottom and 67 micro-residue samples. Inspection of the material by hand-lens and by low-powered binocular microscope has been undertaken for all material, except for the large “furnace bottom” (context 3549) which remains with CAT.

Description

The material falls into three groups:

1. Residues from iron smelting.

The majority of this material (total 56.2kg) derives from two features ([3525] and [3579]) identified by the excavators as smelting furnaces.

In one [3525] a substantial (33.9kg) “furnace bottom” (3549 find 228) remained in-situ. This slag cake was a truncated ellipse in plan, approximately 0.50m long (E-W) by 0.42m wide (N-S) and up to 0.20m thick. Material removed from the same feature as “lining” (3634) contained a substantial amount of slag from the “burr” region of a slag cake, and these may be associated with the main slag cake in (3549). The cleared pit measured 1.00m (E-W) by 0.78m (N-S), with a “bowl” shape 0.35m deep. The fired clay lining (3634) is recorded as a layer up to 0.08m thick distributed fairly uniformly across the cut. Associated micro-residues include slag fragments and spheroidal slag blebs, some significantly larger than spheroidal hammerscale.

The second such feature [3579] was again a bowl-shaped cut, 0.95m approximately in length (E-W) and 0.75m in width (N-S), with a preserved depth of approximately 0.2m. The deepest part of the bowl was offset towards the western end of the cut. The lining (3635) is recorded as 0.05m thick on the floor of the bowl, but 0.15-0.20m thick at the edges. It contained a substantial (1.7kg) piece of furnace bottom. The inner edge of the lining appears to be inclined steeply inwards. The fill of the pit (3629) was a soft deposit with a relatively small proportion of slag. It had a truncated elliptical shape in plan, suggesting removal of a slag block similar to that recorded in furnace [3525]. The fills yielded a large amount of micro-residues, including large spheroids.

Smelting slags from these features comprised material which had formed around large charcoal/wood fragments, in a massive form, or made up of coalesced prills.

Similar slags which can confidently be assigned to iron smelting were found close to the furnaces in postholes [3045], [3117] and [3163] as well as pit [3267]. Away from the immediate area of the two furnaces, smelting slags also occurred in pits [2477] and [3106].

2. Macro-residues from iron-working

The macroscopic slags assignable to iron-working (smithing) essentially comprise plano-convex smithing hearth cakes.

The most significant assemblage derives from context 2631 (fill of pit 2630), which yielded 11 smithing hearth cakes or part cakes. The smithing hearth cakes from this context have a range in weight from 115 to 1305g. Where visible, all evidence for fuel is indicative of charcoal. In addition to the slag cakes, the assemblage from context 2631 also contains some heavily slagged hearth lining including a piece from a blowhole with an overhanging, convex form.

Three contexts (2958, 3416, 3845) yielded individual plano-convex smithing hearth cakes and a burr fragment (2358) is probably from a smithing hearth slag, although its production on a smelting furnace cannot be ruled-out. One of the isolated smithing hearth cakes was recovered from a Medieval context (3845) and one from a Romano-British context (3416).

3. Micro-residues from iron-working

Flake and spheroidal hammerscale was recovered from a significant number of soil samples from late prehistoric features over a wide area of the site. Hammerscale was recovered from only one context currently dated to later: the medieval context 3847.

Interpretation

Date of metallurgical activity

The slag assemblage indicates that both iron-smelting and iron-working were undertaken on the site during the period broadly designated Phase 1 (Late Prehistoric). Only a very small amount of material occurred in Romano-British or Medieval contexts, and it is possible, although not certain, that such material may be residual.

The iron smelting slags are similar to those from 5th/6th century BC contexts on the HCB03 site to the south, and certainly share the same technology. However, such a technology must be presumed to have been general in the 1st millennium BC.

Scale of activity and geographical distribution

The wide distribution of iron-working micro-residues, and to a lesser extent the smithing slags and unidentified slag fragments, across the prehistoric site (Figure 1, D) is rather similar to the broad spread of such residues in the ALSF-funded excavation to the south. Indeed, the only focussed deposits of metallurgical remains occur in the area close to the two iron smelting furnaces.

This metal-working area (Figure 2) comprises the truncated bases of two iron-smelting furnaces in the west, and an area to the east in which various pits and postholes yield an assemblage of micro-residues from smithing. This suggests that iron-working processes, perhaps the bloomsmithing of the products of the smelting furnaces, occurred in the area immediately east of the furnaces. This area yielded 68.3kg out of the 81.3kg total slag assemblage.

Although the total amount of metallurgical residues is significant (81.3kg), it is to be noted that 56.2kg of the assemblage derives from the smelting furnaces, with a further 11.1kg from an adjacent posthole and 8.7kg from a single deposit of smithing debris. Thus only 5.2kg of residues were retrieved from the remainder of the site outside these four features.

This distribution raises questions not only about the scale, duration and frequency of the metallurgical activity, but also about the fate of the other residues which may be assumed to have been produced.

The pattern of distribution shows some similarities with that on the ALSF-funded site to the south; there a widespread, but low density, spread of metallurgical debris occurred, with the focus of activity only recognisable because of micro-residue concentrations in postholes, rather than by the occurrence of macroscopic slags.

On sites in the Humber wetlands (Clogg 1999, Halkon 1997) “furnace bottom” slag masses were found on mounded dumps (and therefore indicate a technology in which the pits were cleared) and had weights of 12-60kg. The disposal of the “furnace bottoms” onto upstanding dumps might explain the paucity of such slags in the Hartshill site’s negative features.

The distribution of iron-working (smithing) residues appears to follow the distribution of prehistoric features, except for the NW corner of the site where there is an absence of residues. Although widely distributed the residues appear to be clustered into several distinct areas:

1. around 040 830. A strongly marked cluster of microscopic evidence just to the east of the smelting furnaces

2. around 100 830. A weak cluster of microscopic and macroscopic residues

3. around 100 900. A weak cluster of mainly microscopic residues

4. around 180 810. A cluster of microscopic and macroscopic residues in the area around the pit containing multiple smithing hearth cakes.

5. a small cluster of microscopic residues around 070 710.

In addition to these clusters, material (smithing slag and other unidentified macroscopic slags) also occurred around the area of the Medieval structure (130 760) and to the south side of the ditched R-B enclosure (260 700).

Technology

The surviving in-situ “furnace bottom” indicates a smelting technology in which the slag accumulates in a pit below ground level, rather than being tapped from the furnace. Such “furnace bottoms” are often characterised by the inclusion of larger pieces of charcoal than is common in other varieties of bloomery furnace. Material currently under investigation by the author from Early Christian sites in Ireland, apparently produced using a very similar technology, suggests that the large pieces of charcoal may have formed a careful and ordered packing of the pit. To some extent this resembles the operation of the “slag-pit furnaces” known in Eastern Europe (Pleiner 2000), but these employed a packing of grass or straw and appear to have been single-use structures, rather than having the slag block removed after each smelt as is clear from British examples (e.g. Clogg 1999, Halkon 1997).

The Irish examples of this technology have been described as “bowl furnaces” (Scott 1990), but it seems clear that they would not have functioned without a shaft to contain a significant bed depth for reduction above the level of the blowhole, which appears to have been at, or lightly above, ground level (Young 2003).

Although micro-residue evidence suggests that smithing, presumably including bloomsmithing, took place close to the smelting furnaces, there is no evidence so far for a smithing hearth in this area (or anywhere else on site), nor is there any evidence for the large smithing hearth cakes usually associated with bloomsmithing on later sites. One possibility is that initial reheating of the raw bloom may have taken place in the smelting furnace, rather than in a separate bloomsmithing hearth.

The presence of the convex blowhole associated with smithing slags (2631) is interesting. Such blowholes have been found on other sites and it remains unclear whether they represent the eroded stumps of tuyères, or simply a bulbous, shaped hearth wall at the point of entry of the blowhole. It is equally unclear whether these finds are associated with smelting furnaces or smithing hearths, because they have not been recovered in-situ.

The final stages of iron production and artefact creation (blacksmithing) are probably represented by the broader spread of residues, but it remains unclear whether the residues have been transported, or whether the smithing was broadly distributed. The clustered spread of residues hints at perhaps four or five locations for the smithing activity.

Assessment of potential

The HCB01 metallurgical assemblage is very significant assemblage with the potential to enhance understanding both on a site basis and on broader issues of early technology.

The key component of the assemblage is the in-situ “furnace bottom”. These slag accumulations from the base of early non-tapping smelting furnaces are rather poorly known and there are only rather superficial published descriptions. The opportunity to examine one found in-situ is extremely rare (although the author is working at present on a similar specimen from Ireland).

The detailed analysis of the furnace bottom has the potential to address several particular issues:

1. what was the nature of the ore being utilised? Although assumptions have been made about the ore being used in this area, there is little detailed evidence.

2. does any heterogeneity within the “furnace bottom” provide evidence for the nature of the blowing arrangements?

3. can the chemical investigation of the “furnace bottom” provide evidence for the construction of a mass-balance description of the smelting reaction? This approach (following the techniques of Thomas and Young 1999a and 1999b) can reconstruct the efficiency of the furnace in terms of iron reduction, provide evidence on the involvement of the furnace lining in the reaction and provide an indication of the size of bloom being produced.

4. is the furnace bottom the product solely of iron smelting, or was reheating during bloomsmithing also undertaken in the furnace?

5. does the pit fill provide evidence for the nature of the pit fill (if any) at the start of the smelt? This question may need to be address using the macro- and micro-botanical evidence as well as the study of the metallurgical residues.

The other smelting slag remains from the smelting area (and indeed from HCB03) may have the potential for enhanced interpretation once the structure and chemistry of the in-situ complete furnace bottom is understood.

The smithing slags from the remainder of the site have a fairly low potential for the furtherance of technological issues, with the exception of investigation of the blowhole. They do, however, have the potential to shed further light on issues of site structure.

Future investigations

Following the comments above on the great potential of the smelting residues from this site, it is recommended that additional investigations are focused on the analysis of those materials. In particular the in-situ “furnace bottom” will repay detailed investigation and mapping of its textural and chemical variations. The piece should first be mapped as a whole, and related back as closely as possible to the detailed observations of the pit containing it. The piece then needs to be cut and specimens removed to enable mapping of the variations of microstructure and chemistry. This would entail investigation, description and analysis of between twenty and thirty polished block and bulk analyses, with the sampling density to be determined by the complexity indicated by the initial examination.

The loose fragments of slag from the furnaces and other features should then be redescribed and investigated in light of the new information gleaned from the main block.

A limited campaign of analysis of micro-residues should be undertaken to complement the work already undertaken on the HCB03 site, specifically to take advantage of the apparent spatial separation of smithing and smelting with the HCB01 assemblage.

References

Clogg, P. 1999. The Welham Bridge Slag. pp 81-96 *In* P. Halkon and M. Millett, *Rural settlement and Industry: Studies in the Iron Age and Roman Archaeology of Lowland East Yorkshire*. Yorkshire Archaeological Society.

Crew, P. 1991. The Experimental Production of Prehistoric Bar Iron, *Historical Metallurgy*, **25**, 21-36

Halkon, P. 1997. Fieldwork on early iron working sites in East Yorkshire. *Historical Metallurgy*, **31**, 12-16

Pleiner, R. 2000. *Iron in Archaeology: The European bloomery smelters*, Prague.

Scott, B.G. 1990. *Early Irish Ironworking*. Ulster Museum Publication 266. Belfast.

Thomas, G.R. & Young, T.P. 1999a. A graphical method to determine furnace efficiency and lining contribution to Romano-British bloomery iron-making slags (Bristol Channel Orefield, UK). *In:* Young, S.M.M., Budd, P.D., Ixer, R.A. and Pollard, A.M. (eds). *Metals in Antiquity*, British Archaeological Reports International Series, 792, 223-226. Archaeopress, Oxford. [ISBN 84171 008 3]

Thomas G.R. & Young, T.P. 1999b. Bloomery furnace mass balance and efficiency. *In:* Pollard, A.M. (ed) *Geoarchaeology: exploration, environments, resources,* Geological Society of London, Special Publication, 165, 155-164.

Young, T.P. 2003. Is the Irish iron-smelting bowl furnace a myth? A discussion of new evidence for Irish bloomery iron making. *Geoarch Report 2003/09*. 4pp.

Figure Captions

Figure 1. Distribution of metallurgical residues
A. Macroscopic iron-smelting slags
B. Microscopic iron-smelting slags
C. Macroscopic iron smithing slags
D. Microscopic iron smithing slags
E. Macroscopic slags unassigned to process

Figure 2. Distribution of metallurgical residues with the Iron Age iron-working complex.

Contexts in red have yielded smelting residues (blue cross indicated smithing residues also occur)

Contexts in blue have yielded smithing residues

Contexts in black have yielded undiagnostic slags.

context	weight	sample	notes	provisional date
macroresidues				
15	225		slag - smelting	
2124	75		3 slag fragments	R-B
2149	40		slag piece	LPRE
2193	15		slag piece	LPRE
2289	375		broken nub of slag with large charcoal	LPRE
2307	25		slag piece	P-MED
2358	310		massive worn burr fragment	LPRE
2458	335	220	fired clay	LPRE
2481	120		smelting slag	LPRE
2631	8700		11 p-c smithing hearth cakes (115 to 1305g)	LPRE
2634	50		slag piece	LPRE
2673	5		cinder?	LPRE
2690	10		piece of dense slag	LPRE
2958	310		small p-c smithing hearth cake	LPRE
3022	370		broken slag pieces, 230 dense, 140 light	LPRE
3024	200		slag sheet	LPRE
3047	165		smelting slag	LPRE
3051	30		lining	LPRE
3069	25		slag nub	LPRE
3107	445		probable smelting slag	LPRE
3116	50		4 slag pieces	LPRE
3118	25		flowed slag fragment	LPRE
3164	11120		smelting slags and lining	LPRE
3218	20		2 slag pieces	LPRE
3258	155		9 balls of corrosion	LPRE
3268	170		smelting slag	LPRE
3278	5		2 slag pieces	LPRE
3416	365		small p-c smithing hearth cake	R-B
3549	34940		furnace base, plus collection of fragments and 810g of fired clay	LPRE
3629	1325		830g of slag debris and 495g of fired clay	LPRE
3634	10190		3350g slag fragments, mainly burr area, with 6840g of fired clay	LPRE
3635	9765		1760g large furnace bottom fragment, approximately 3500g other slag debris and 4500g of fired clay	LPRE
3806	185		4 irregular slag pieces	MED
3845	275		small p-c smithing hearth cake	MED
4055	865		slag/concretion	MED

microresidues

context	weight	sample	notes		flake	spheroidal	slag
2029		202	stone flake?	LPRE	y		
2029		202	rust?	LPRE			
2035		204	stone flake	LPRE	y		
2165		209	stone flake slag	LPRE	y		y
2169		210	stone slag flake sphere	LPRE	y	y	y
2179		211	stone slag spheres flake	LPRE	y	y	y
2185		212	stone rust flake	LPRE	y		
2193		214	stone flake slag	LPRE	y		y
2203		215	stone flake sphere	LPRE	y	y	
2236		216	stone sphere	LPRE		y	
2290		217	stone	LPRE			
2389		244	clay stone	LPRE			
2413		218	stone slag	LPRE			y
2418		245	stone	LPRE			
2418		245	clay stone	LPRE			
2423		219	stone	LPRE			
2458		200	stone clay rust	LPRE			
2480		227	stone sphere flake	LPRE	y	y	
2508		221	stone rust	LPRE			
2616		224	stone flake	LPRE	y		
2624		222	stone slag	LPRE			y
2631		223	stone flake	LPRE			
2644		225	stone flake sphere	LPRE	y	y	
2646		226	stone slag sphere?	LPRE		y	y
2724		228	stone slag spheres flake	LPRE	y	y	y
2747		230	stone	LPRE			
2843		229	stone slag sphere flake	LPRE	y	y	y
2884		258	flake sphere stone rust	LPRE	y	y	
2891		247	stone rust	LPRE			
2895		246	stone slag spheres flake	LPRE	y	y	y
2937		269	stone slag?	LPRE			y
2956		232	stone slag	LPRE			y
2958		233	rust slag flake sphere	LPRE	y	y	y
3022		270	stone slag?	LPRE			y
3024		262	stone flake sphere (large assemblage)	LPRE	y	y	
3038		271	stone slag spheres flake	LPRE	y	y	y
3059		234	stone slag spheres flake	LPRE	y	y	y
3069		263	stone slag spheres flake	LPRE	y	y	y

3071	235	stone flake sphere	LPRE	y	y	
3089	257	clay stone	LPRE			
3109	236	stone	LPRE			
3114	261	stone slag spheres flake	LPRE	y	y	y
3116	260	stone slag spheres flake	LPRE	y	y	y
3118	259	stone slag flake	LPRE	y		y
3164	268	stone slag sphere flake	LPRE	y	y	y
3182	266	flake clay stone sphere	LPRE	y	y	
3184	264	stone slag spheres flake	LPRE	y	y	y
3191	265	stone slag sphere flake	LPRE	y	y	y
3195	267	stone slag flake	LPRE	y		y
3274	237	stone slag spheres flake	LPRE	y	y	y
3451	254	stone flake	LPRE	y		
3549	249	clay stone spheres	LPRE		y	
3605	250	stone slag spheres flake	UNDATED	y	y	y
3628	253	stone clay slag flake	UNDATED	y		y
3629	256	clay slag spheres (big bag)	LPRE		y	y
3634	281	clay stone slag big spheres! (big bag)	LPRE		(big)	y
3634	282	stone clay slag?	LPRE			y
3634	283	stone slag sphere	LPRE		y	y
3634	284	stone big spheres	LPRE		(big)	
3635	279	stone clay slag (big bag)	LPRE			y
3635	280	clay slag (big bag)	LPRE			y
3639	255	stone flake	LPRE	y		
3667	273	stone slag spheres flake	UNDATED	y	y	y
3719	276	stone flake sphere rust	LPRE	y	y	
3847	277	flake stone sphere	MED	y	y	
3880	278	stone slag spheres flake	LPRE	y	y	y
3913	285	sphere flake stone rust	LPRE	y	y	

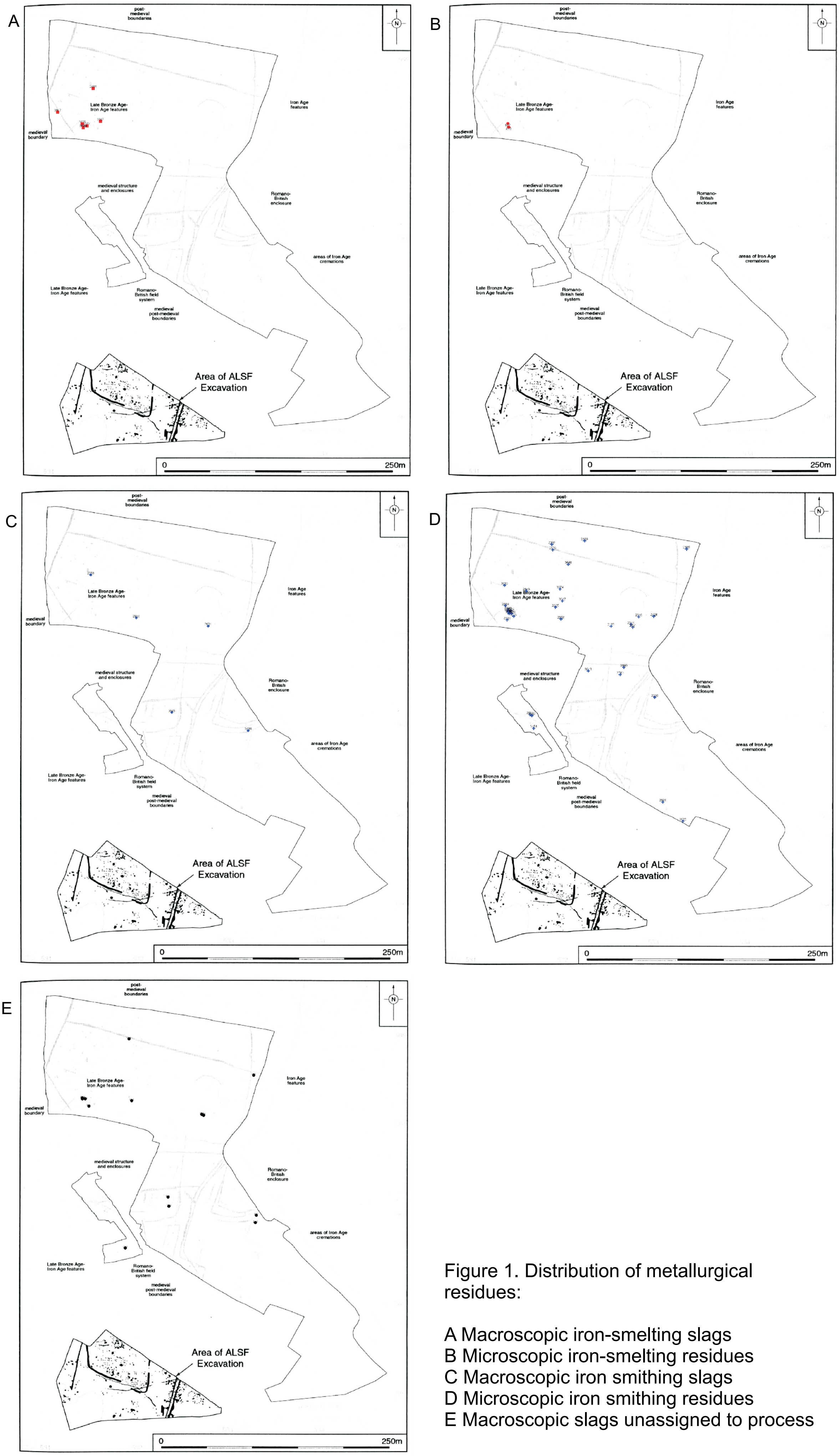

Figure 1. Distribution of metallurgical residues:

A Macroscopic iron-smelting slags
B Microscopic iron-smelting residues
C Macroscopic iron smithing slags
D Microscopic iron smithing residues
E Macroscopic slags unassigned to process

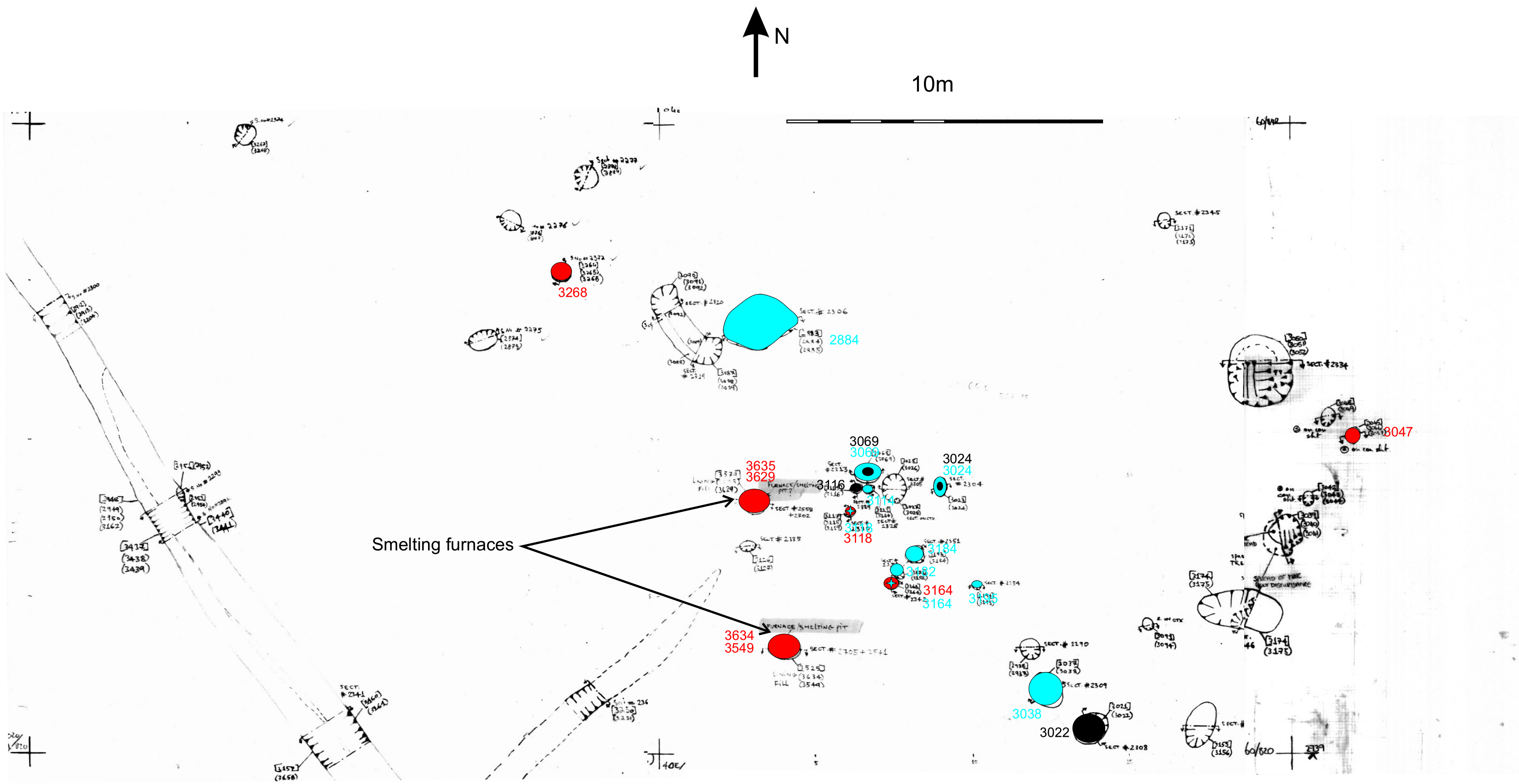

Figure 2. Distribution of metallurgical resides within the Iron Age iron-working complex

contexts in red have yielded smelting residues (blue cross indicates smithing residues also occur)
contexts in blue have yielded smithing residues
contexts in black have yielded undiagnostic slags