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Evaluation of archaeometallurgical residues from the N9/N10 Waterford-Kilcullen, Site 3-5, Milltown/ Ballynamorohan, Co. Kilkenny (E2499)

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Abstract

This site yielded two distinct suites of residues from iron-making and iron-working; one of Iron Age date, the other of early medieval age. Both suites present some problems with interpretation and both suites are relatively small (the total assemblage is 11.3kg, of which 8.6kg are macro-residues and 2.7kg are bulk samples including micro-residues. Almost all of the macro-residues are from iron smelting; evidence for smithing is largely from the microresidues.

In Area 3 a cluster of pits (some of which have given ^{14}C dates covering the 1st Century BC / 1st Century AD) were interpreted during the excavation phase as representing the basal pits of slagpit iron-smelting shaft furnaces, together with associated possible ore roasting pits. There was only a rather small quantity of macroscopic residue recover from these features and their interpretation leans heavily on micro-residue evidence. A few of these features are indeed likely to be the basal pits of slagpit furnaces, one appears to have possibly been a smithing hearth, but most are of uncertain origin, and probably not metallurgical. The majority of the smelting residues retrieved came from a single, rather complex, furnace cut [c126], the significance of which is discussed.

The backfill of an early medieval cereal-drying kiln in Area 3 also produced several pieces of residue, including the only smithing hearth cake from the site, but it is unclear whether these represent contemporary waste or residual Iron Age material.

In Area 4, a circular structure [c4] contained a large central "furnace" with abundant iron smelting waste. Both furnace and structure have given early medieval (7th-9th Century) ^{14}C dates. The central "furnace" is large and is associated with various more subtle features around it. Possible interpretations of this furnace are discussed. Well-dated early medieval iron smelting has proved elusive on many of the recent road schemes, so this is a useful addition to understanding. The undertaking of smelting within a building has also not generally been demonstrable on Irish sites, although smelting inside roundhouses is documented from elsewhere.

Contents

Abstract 1

Methods 1

Results
Iron smelting: Area 3 1
Iron smithing: Area 3 2
Iron smelting/smithing: Area 4 2
Other materials 2

Interpretation
Area 3 3
Area 4 4

Summary 4

Evaluation of potential 5

References 5

Catalogue 6
Table of pits, Area 3 11
Figure 1 12

Methods

All investigated materials were examined visually, using a low-powered binocular microscope where necessary. For microscopic residues a general statement of the nature of each assemblage was recorded (Table 1). As an evaluation, the materials were not subjected to any high-magnification optical inspection, nor to any other form of instrumental analysis. The identifications of materials in this report are therefore necessarily limited and must be regarded as provisional.

Results

Iron Smelting: Area 3

The iron smelting slags are represented mainly in terms of weight by dense flow slags; slags which show clear evidence of fluid flow within the furnace. These range from large blocks of amalgamated flow slags with moulds of large pieces of wood/charcoal (e.g. [c132]), down to individual prills and even to isolated

spheroidal slag droplets. The droplets may show "dimples" from contact with the fuel (the "coffee bean spheroids") and also may show the accumulation of strings of spheroids (multiples) where there was a persistent slag drip in the furnace. Almost all the slag derives from fills [c54] and [c116] of cut [c126].

Also present in the fills of [c126] were two large blocks of slag from close to the wall of the slagpit on the blowing side of the furnace, where the highest volumes of slag are produced and flow down the wall into the pit. One of these shows the pit margin, with dense amalgamated lobate flow slags adjacent to the wall and descending from the base of piece. The upper part of the block shows a dense slag layer with a smooth, probably blown top. The second shows a similar range of structures, but also shows the vitrified face of the furnace wall rising above the dense slag layer, towards the (unpreserved) blowhole. Although these pieces are marginal to the original "furnace bottom" (FB), they suggest that the FB may have been dense, with a smooth blown top, at least proximally.

More subtle evidence for smelting comes from a range of lower density slaggy materials mainly recovered from the bulk sieved samples. These include low density flowed materials, mainly individual blebs and many of which are of low density. There appears to be a continuum between drips of dense slags that have reacted with other materials on the floor of the furnace, through to materials that may have arisen through melting of the hearth floor materials (the possible fuel ash slags).

Many of the micro-residue samples show materials that are fine particles including magnetic iron oxides. In some cases these may be corrosion products of iron and other natural materials, but where abundant they are believed to represent small particles of bog iron ore, that have passed through the furnace either completely or partially without reacting. Since these materials are not readily identifiable under low powered light microscopy they have been largely listed here as IFM (indeterminate ferruginous material). Aggregates of such material, together with charcoal dust and sometimes sand grains, may form a material which resembles a sinter.

Fragments of furnace structure have been recovered from several contexts. These include both oxidised and reduced fired ceramic, sometimes deeply vitrified with a convoluted surface. Discrimination between fragments of smelting furnaces and smithing hearths may not be possible.

Iron smithing: Area 3

The smithing evidence in Area 3 is mainly in the form of microresidues. The residue types include flake hammerscale (the oxidised surficial layer of the workpiece which spalls off to give thin sheets of iron oxides), slag flats (similar to flake hammerscale, but involve a thicker layer of surficial oxide and slag), spheroidal hammerscale (droplets of slag expelled from the workpiece during hammering, particularly during forge welding) and larger slag spheroids (formed from slag droplets cooling as they fall through the fuel bed).

Also from Area 3, but of uncertain age, is the only macroscopic smithing slag identified from the site. This is a small dense smithing hearth cake (SHC) weighing 260g. Small SHCs such as this are normally indicative of blacksmithing (the working of finished iron to make or repair artefacts), but Iron Age SHCs are poorly known in Ireland, and SHCs of this size are known to be associated with bloomsmithing (the refining of the raw bloom down to finished iron) in assemblages from North Wales (Crew 1989).

Iron smelting/smithing: Area 4

The residues recovered from "furnace" [c123] in area 4 are probably associated with iron smelting, but are unusual in some respects.

The flow slags are generally in small fragments, suggesting flow in small prills between small charcoal fragments. No flow slags showed evidence for flow around large pieces of charcoal or wood.

The furnace floor materials include various fuel ash slags, ashy "sinters" and fine rounded particles (IFM) that may be ore dust. Some of these materials are in balls many 10s of mm across with slightly flowed surfaces. It is possible that this is an indication of the raking of hot material from the furnace.

Rather more problematic are fragments of an internally prilly slag cake that might be an open-textured "thin crust" SHC, rather than an FB. In addition there are two fragments from the tip of a ceramic tuyère from within the furnace and one probable piece from an adjacent charcoal spread. The tuyère was of about 150-160mm diameter, closely comparable with material from early medieval sites such as Clonfad and Clonmacnoise. However, all the current evidence suggests that tuyères on the early medieval sites are associated with smithing rather than smelting.

Other materials

The topsoil yielded several pieces of clinker. These are slaggy materials generated from the burning of coal. Although clinkers can be generated in wide variety of processes, including metallurgical ones (such as in a coal/coke-fuelled smithy), the most likely origin of such material is from the waste from the boilers of steam engines. Steam power was widely used in agriculture in the mid-20th century.

Two contexts ([c18] and [c198]) yielded lumps of a lobate material, closely resembling slag externally, but which appears to be a natural material, probably a manganese ore hosted in a limestone. The material from [c198] is probably that which gave rise to the initial description of smithing slag from the trench [c205]. There is now no remaining metallurgical evidence to link this structure with ironworking.

Microresidues from various samples contain materials which have been heated, but are not necessarily of metallurgical origin. Most significant of these is a dark material of slag-like appearance, but organic composition, that is derived from the burning of organic material. This is listed in the catalogue as BOM (Burnt Organic Material).

Interpretation

Area 3

The metallurgical activity in Area 3 clearly included both primary smelting and smithing (presumably bloomsmithing). The residues indicate the use of a non-slag taping slagpit shaft furnace for the smelting and the residues suggest the use of a bog iron ore (although a fragment of high grade goethite rock ore with a botryoidal texture recovered from the topsoil hints that other sources of ore might also have been available).

It is more problematic however to assign uses to individual features within the complex. Diagnostic macroscopic slags are relatively rare, and apparently none was recovered in-situ. The only evidence for use of most of the features therefore is morphology, degree of burning of subsoil and the rather sparse micro-residue assemblages.

Most slagpit smelting furnaces that are known from Ireland, notwithstanding the possibility of circular argument, were incompletely cleared of debris before being abandoned. In addition, many abandoned furnaces were used as places to dump waste from later activities. Even badly truncated furnaces usually yield some residues. The lack of smelting residues in most of these features would suggest (but certainly does not prove) that they are not smelting furnace bases.

Over reliance on micro-residues may also be problematic. Since the particles involved are small, they are capable of easy transmission to features with which they have no genetic association. They are also easily moved by post-depositional process, particularly both earthworms. Small quantities of micro-residues should not, therefore be taken as being a good indicator of pit use; they may merely reflect, for instance, an original distribution of residues in an overlying layer that has percolated downwards.

The occurrence of a few pieces of macro-residue is equivalently not a good indicator of use (compare the slag found on this site in the cereal drier [c81]).

Table 2 gives a list of the pits and their metallurgical contents (based on table supplied by M. Grant, *pers. comm.* 2008). A broad categorisation of the evidence of the associated archaeometallurgical assemblages is given on the table, dividing them into categories of "none", "sparse uncertain", "sparse smithing", sparse mixed", "moderate smithing", "sparse smelting", "moderate smelting" and "rich smelting".

The spatial distribution of these assemblages is shown on Figure 1, where they demonstrate a coherent pattern. Almost all the pits near the western and northern edges of the cluster show weak, or no evidence for a metallurgical use. The central part of the cluster shows some evidence for smithing, with the most abundant evidence from pit [c130].

Strong evidence for smelting occurs in features to the south and east of the smithing evidence, with rather weaker evidence in pits to the west and north of the smithing.

Actually tying down the smithing activity to any particular feature in the area is not easy. The richest assemblage (pit [c130]) is provided by less than 30g of micro-residues. It is by no means certain that this indicates that [c130] was a smithing hearth. It is possible that it is, but the dimensions are quite small compared to typical smithing hearths. The quantities of smithing micro-residues present in the adjacent features are very small. In at least one instance, the small quantities of flake hammerscale occur within an assemblage which otherwise appears to be from smelting [c119]. One possibility is that the smithing hearth was shallow and has been strongly truncated – perhaps represented only by one of the "charcoal spreads", or perhaps removed entirely.

The strongest smelting evidence comes from the complex structure [c126]. The elongate form of this structure hints at a form of furnace with a furnace arch, to permit clearance of the basal pit, connecting the furnace proper with an external working hollow. Indeed the strangely arcuate form of the structure (particularly on the site photographs) suggests that the feature may be two separate furnaces with abutting or intersecting working hollows and the furnaces themselves at either end of [c126]. The distribution of [c53] just in the western furnace may be indicative of the last phase of use of the structure. The 1.7kg of smelting fines in this furnace fill only accentuates the lack of residues in all the other features. The furnaces in this interpretation appear to be of moderate size (approximately 0.45x0.55m for the western and 0.4x0.5m for the eastern).

Such furnaces had not been widely recognised in the Irish Iron Age, but recent work on the M7-M8 suggests that they may be relatively common on sites of 1st Century BC/1st Century AD date (e.g. Derrrinsallagh 4; Young 2008d and discussion therein). The Derrinsallagh 4 furnace is somewhat smaller than the size suggested by the two terminations of [c126], but the possibility of a furnace arch in a slightly larger furnace (also Iron Age) was raised at Morrett Site D (Young 2005).

Amongst other features yielding small amounts of smelting residues, a stepped profile compatible with a furnace-arch-working hollow can also be interpreted in [c200], and if more deeply truncated, paired features such as [c202/c195] and [c194/c139]. Although the residue evidence is not strongly supportive of these features also being smelting furnaces, it is possible – and in this interpretation they would be the deeply truncated remnants of similar furnaces.

Pit [c100], separated from the other possible furnaces by about 15-20m, has a rich assemblage of smelting fines, and is almost certainly the deeply truncated base of a slagpit smelting furnace. This furnace is apparently quite small (0.38x0.34m); a size which is particularly seen in furnaces from the first millennium AD.

The division of the pits of Area 3 by residue content shows some degree of correlation with the previous morphological classification. Of the south-western group of pits all of those tentatively suggested to be the bases of furnaces on morphological criteria (though none showed burning) were barren of archaeometallurgical residues, as were two of the four broader, shallower pits. Two pits in this group ([c101], [c204]) did contain sparse assemblages of microresidues probably from smelting. It may be relevant that these two are amongst the closest pits of the group to the smelting furnace [c126], and hence perhaps the most likely to receive some "contamination".

To the north of the area with the evidence for smithing, the pits are particularly large and were suggest (M. Grant *pers. comm.* 2008) that many of them might be ore roasting pits ([c125], [c127], [c138], [c196], [c110]). Two other pits in this group are only slightly smaller ([c131], [c118]). As a whole this group shows average diameters of about 0.75m. One of them shows a burnt base [c127]. Several of them show quite high levels of charcoal inclusions, and an alternative interpretation for them is that they may include pits used for making charcoal.

The central group of pits which show some the presence of some smithing residues are rather variable in form.

Some of the most interesting residues shedding light on the use of the smelting furnaces are the two large blocks of slag from [c53] and [c116]. These pieces, which appear not to be from the same slag cake, show evidence for the nature of the smelting "furnace bottom" (FB) on the blowing (proximal) side of the furnace. In both cases there is a smooth-topped dense slag puddle on top of the FB close to the wall. Other Iron Age FBs also show some signs of smooth-surface, flown slag on the upper surface of the FB close to the blowhole (e.g. Adamstown, Young 2005 and Tullyallen, Young 2003). These pieces are however different from these previous examples in having a much denser slag, apparently in the form of a puddle which had a blown surface, rather like some SHCs. Since the form of the furnace and the FB in this instance is so poorly known, it is conceivable that the air blast played onto the surface of the FB, either by design or accident, but it is also possible that the furnace was reused for reheating the bloom for bloomsmithing after smelting and that the partially cleared slag became modified through growth of an SHC during that process. It is interesting that despite the number of recent discoveries of Iron Age smelting sites, there are very few well-described instances of smithing on these sites (very few of which have been sampled as intensively for micro-residues as in the exemplary recording of Site 3-5).

Area 4

Area 4 also has its interpretational complexities. The pit with the fired base described as a furnace was elongated NE-SW, with a length of about 0.8m and a width of 0.6m. These dimensions would be exceptionally large for a smelting furnace, but more consistent with a smithing hearth. There was also the curious feature of the oxidised fired clay extending 0.4m from the "furnace" towards the NW.

This distance is far too far for a simple extent of firing from within the known pit, but suggests one of two things: either the "furnace" is a structure that has been rebuilt within the same furnace setting, so the firing of the soil relates to an earlier furnace location within the furnace setting, or that the firing was due to heat from a source above, now truncated.

This second possibility is the more attractive, for there are hints on other medieval sites that furnaces with arches to allow clearance were sometimes built on the ground, rather than sunken into it as in the case of the Iron Age arched furnaces of the Derrinsallagh 4 type (see above; Young 2008d). The working hollow, into which the slag would be raked during clearance (and possibly bloom extraction) might, however, be sunken into the ground in front of the furnace arch. Movement of the hot material on the base of the furnace might explain the balls of furnace floor sinter-like material with flown and smoothed surfaces; they could have been generated by the raking-out of the hot residues.

Such a geometry has been proposed for Derrinsallagh 1 (14^{th}-15^{th} century; Young 2008b), which had a disturbed large furnace structure lying at a higher level than a pair of working pits containing smelting residues and Ballykilmore (14^{th}-15^{th} century; Young 2009a), where large pits within the enclosure ditch were initially interpreted as being furnaces but appear more likely to be working hollows from furnaces set higher up on the ditch margin.

A further link with the Ballykilmore medieval furnace is the occurrence of tuyère fragments amongst the residues. The significance of these tuyère occurrences is uncertain, but it is not inconceivable that the working hollow could have been employed for reheating the bloom for its initial compaction, with the simple addition of a tuyère.

Less closely related arched furnaces of early medieval age can be seen at Derrinsallagh 3 (poorly dated, but possibly 7^{th}-9^{th} century; Young 2008c), with a large furnace/working pit pair rather similar to some of the Iron Age examples, and at Woodstown 6 (probably 9^{th} century; Young 2009b) where it is possible that arched furnace was supposed to be capable of tapping slag. Rather more contentiously, it is possible that the furnace at Farranstack (11^{th}-13^{th} century; Dowd & Fairburn 2005) was of this form.

The operation of smelting furnaces within roundhouses has been documented by Crew in the Iron Age of North Wales (Crew 1987, 1989, 1998) and tentatively for the Iron Age in Cornwall (Young 2008a). However, in Ireland the evidence is less clear. A furnace apparently occurred centrally in a roundhouse at Adamstown (Young 2005), but the roundhouse is currently dated earlier than the furnace.

Summary

Site 3-5 provides evidence for iron smelting in two distinct periods. Both sets of information are very significant, but also problematic.

In the first period (1^{st} century BC/1^{st} Century AD) there appear to have been several furnaces in Area 3, represented by [c126] and [c100], together with other possible examples. The furnaces represented by [c126] appear to have had furnace arches; [c100] appears to be a deeply truncated simple slagpit furnace. The area to the north of the smelting furnaces [c126] was used for smithing – presumably for refining the blooms produced by the smelting activity. Pit [c130] yielded a good collection of smithing fines, but it remains unclear whether this was an actual smithing hearth. Smithing is also attested by an SHC recovered from the fill of the early medieval corn drier [c81], although it is not known whether this residue is of early medieval or, perhaps more likely, of Iron Age date

The vast majority of pits in this complex yielded little by way of metallurgical residues. This is not the normal state in which a smelting furnace is left when abandoned, so it is suggested that most of the pits were not directly for metallurgical purposes. Some may have had ancillary roles (perhaps as ore roasters or charcoal-making pits), but most may have had other purposes – perhaps to do with more domestic activity.

In the second period the focus of iron production lay farther north in Area 4. Here, a large pit in the centre of a circular structure produce substantial evidence of iron smelting, but lacked the attributes of a smelting furnace. Unless it has been severely disturbed, it appears too large for a smelting furnace of this period. It is suggested instead that the furnace itself was an "above-ground" structure overlying the intensely fired subsoil to the north of the pit. The pit, in this model, would be the working hollow into which slag and other debris were raked, probably through a furnace arch, to clear the furnace and probably to allow access to the bloom. The presence of fragments of a tuyère in the pit suggests that smithing (or at least the initial bloom compaction) was being undertaken nearby. The reheating required for the compacting process could even have been undertaken in the working hollow itself.

The evidence for smithing associated with the structure in the south of the site (trench [c205] with pit [c206]) is now discounted and there is no evidence that these features were associated with metallurgical processes.

Evaluation of potential

The features associated with the Iron Age iron smelting yielded residues which could provide further evidence for the nature of the ore being exploited. The rather incomplete assemblages of smelting residues from this period mean that detailed investigation of furnace slags could not be undertaken, and only a limited campaign of analysis of ore particles and comparative slag analyses is recommended.

The early medieval iron smelting is significant for there are very few good assemblages of this age. In addition this site may provide further evidence for the shift from furnaces with bases sunken into the ground to furnaces with only the external working hollow in front of the furnace arch being dug into the ground. This style of furnace has only previously been suggested for later medieval examples, with this site being the earliest. It is recommended that a representative suite of the residues is investigated further to clarify both the nature of the ore used and as a step towards understanding the residues from this style of furnace. As with the Iron Age material from this site, only a small range of the residues which would have been produced by the furnace have been preserved, so the analytical work would be limited in its scope and would not be a large scale quantification project.

All the materials from this site are recommended for retention at this time.

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Table 1: Summary catalogue by context and sample

Area	*Context*	*Sample*	*Label*	*Wt.*	*No.*	*Notes*
area 3	1	#8		46	1	dense lump of botryoidal iron ore - good quality rock ore
area 3	23	#1		40	1	dense flow slag lobe attached to grey fired clay
area 3	24	17		14	1	sheet of vitrified material from close to blowhole
area 3	29	#2		12	1	stone
area 3	35	#1		260	1 (2)	90x65x30mm small but very dense SHC, well formed slightly concave dense slab-like top, overlying dimpled basal layer.
area 3	38	19	1mm mag retent	2	bulk	stone
area 3	42	#4		52	1	good dense flow slag with large wood impression
				154	1	block of amalgamated flow slags, some wood evidence, with contact with wall
area 3	42	104	magnetic	10	bulk	stone, IFM, 1 piece probable flake hammerscale
area 3	42	104		18	bulk	stone, one dimpled dense slag bleb
area 3	45	37	1mm mag	1	bulk	stone, charcoal
area 3	45	37	magnetic	2	bulk	stone, small ashy? concretion (on iron?)
area 3	46	29	1mm mag	2	bulk	stone, charcoal
area 3	46	29	magnetic	1	bulk	stone
area 3	47	38	1mm mag	1	bulk	stone, BOM
area 3	47	#1		20	bulk	indurated, probably fired clay
area 3	48	84	magnetic	4	bulk	fine IFM, stone, tiny amount of flake hammerscale
area 3	48	84	(retent?)	24	bulk	stone, possible ore fragments, slag debris, charcoal, rusty charcoal rich lumps, fuel ash slags
area 3	49	#1		176	1	deeply corrugated vitrified wall, ceramic has partial smooth rear face possibly suggesting a contact with a stone?
				48	1	irregular dendritic piece of sintery material - possibly an encased prill
				8	1	rounded bleb - possibly a fuel ash bleb from within sinter bed?
area 3	49	79	5mm mag	2	bulk	5 fuel ash slag droplets
area 3	49	79	2mm mag	28	bulk	stone, irregular vesicular blebs, spheroids, rusty charcoal-rich material
area 3	50	77	1mm mag	1	bulk	stone, IFM
area 3	50	77	magnetic	4	bulk	IFM, charcoal rich materials, possible ore fragments
area 3	50	77	2mm mag	6	bulk	fuel ash slag blebs, some stone

Area	*Context*	*Sample*	*Label*	*Wt.*	*No.*	*Notes*
area 3	52	30	magnetic	2	bulk	stone, small amount of slag debris and a few spheroids
area 3	52	30	1mm mag	1	bulk	stone, charcoal, IFM, possible fired clay
area 3	53	43	1mm mag	356	bulk	IFM (ore dust?), charcoal, rare spheroids
area 3	53	43	0.25mm mag	300	bulk	ore dust in rounded particles
area 3	53	43	magnetic	400	bulk	fired clay, IFM, blebby slags and ore fines
area 3	53	43	2mm mag	470	bulk	IFM, blebby flow slag fragments, spheroids including coffee beans
area 3	53	43		192	124	74 pieces of flow slag and associated material attached to lining, plus 50 coffee bean spheroids
area 3	57	46	1mm mag	2	bulk	stone, charcoal
area 3	58	71	1mm mag	1	bulk	stone, IFM
area 3	58	71	magnetic	2	bulk	stone, tiny amount flake hammerscale
area 3	58	71	2mm mag	3	bulk	stone, probable fired clay, probable slag
area 3	60	78	1mm mag	1	bulk	stone, IFM, a few pieces of flake hammerscale
area 3	60	78	magnetic	2	bulk	stone, IFM, plus small fuel ash bleb
area 3	64	50	1mm mag	6	bulk	stone, fired clay, possible ore, possible slag, BOM
area 3	64	50	5mm mag	4	bulk	mainly ashy vesicular slag droplets, some fired clay
area 3	64	50	0.25mm mag	4	bulk	mainly sand, some probable ore dust
area 3	64	50	magnetic	16	bulk	abundant slag debris, fired clay, stones, some flake hammerscale, IFM
area 3	64	50	2mm mag	8	bulk	slag in irregular vesicular blebs, slag flats, stone - but probably a furnace floor assemblage
area 3	66	#1		18	1	convex curved piece of vitrified oxidised lining, could just possibly be the side of tuyère - but oxidation and vitrification would be unusual for that. If so it would be small - c90mm diameter
area 3	66	#2		80	1	slab of lining slag
				14	1	deeply vitrified lining
area 3	68	31	magnetic	8	bulk	stones
area 3	68	31	2mm mag	2	bulk	stone, possible slag flat, possible spheroid
area 3	68	31	1mm mag	4	bulk	stone
area 3	71	#1		12	1	irregular lobate lump - probably concretion around iron but very rounded
area 3	72	60	1mm mag	4	bulk	flake and spheroidal hammerscale in moderate quantities, slag blisters, stone
area 3	72	60	magnetic	12	bulk	flake and spheroidal hammerscale, slag flats, slag debris, stone
area 3	72	60	2mm mag	14	bulk	slag flats, flake hammerscale, spheroidal hammerscale, slag debris, irregular slag blebs, fragments of black glassy lining slag
area 3	74	#1		24	3	dark Mn-rich concretions, largest shows imprints of fern on concretion surface

Area	*Context*	*Sample*	*Label*	*Wt.*	*No.*	*Notes*
area 3	74	80	magnetic	1	bulk	slag fragments, slag flat, flake hammerscale, stone
area 3	74	80	1mm mag	1	bulk	stone, BOM
area 3	74	85	magnetic	1	bulk	stone, small amount of flake hammerscale
area 3	74	85	1mm mag	1	bulk	stone, BOM, possible flake hammerscale, irregular spheroid
area 3	75	66	1mm mag	1	bulk	stone, BOM
area 3	75	66	magnetic	1	bulk	IFM, stone
area 3	76	62	magnetic	6	bulk	stone, fired clay, possible fuel ash slags
area 3	76	62	2mm mag	22	bulk	stone, fired and vitrified clay, fuel ash slags
area 3	76	62	1mm mag	4	bulk	stone, fired clay
area 3	76	69		30	1	exploding weathering iron fragment
				96	1	concretion - probably cored on a rounded slag piece rather than on an artefact
area 3	76	82	magnetic	6	bulk	stone, a few spheroids
area 3	76	82	5mm mag	10	bulk	6 pieces of concretionary furnace floor/fuel ash slag
area 3	76	82	1mm mag	4	bulk	stone
area 3	77	61	1mm mag	6	bulk	stone
area 3	80	40	magnetic	2	bulk	stone
area 3	80	40	1mm mag	1	bulk	stone
area 3	94	#1		6	1	dense flow slag piece
area 3	94	34	magnetic	18	bulk	IFM, stone, lots of tiny spheroids
area 3	94	34	magnetic	88	bulk	IFM with lots of spheroids including coffee beans
area 3	94	34	(retent?)	96	bulk	small flow slag scraps, with lots of spheroids including multiples
area 3	116/53	45	bag 2/2	1900	1	large block showing section 110 mm wide of glazed wall just below blowhole, section is 40mm high with lower lip jutting 30mm into furnace just above the level of thick dense SHC-like mass below, burr to rear, massive slag extending into hearth, very dense upper slab with smooth top, 30mm thick, flow slags descending below
			bag 1/2	116	14	slagged lining - mainly showing oxidised ceramic
				862	50	large flow slag pieces
				602	c200	small pieces of flow slag
area 3	116	48	magnetic	2	bulk	stone, fuel ash slags, corroding iron bleb
area 3	116	48	magnetic	6	bulk	stone, fuel ash slags
area 3	116	48	magnetic	16	bulk	stone, rusty concretionary furnace floor material, possible fuel ash slag
area 3	116	48		28		6 pieces of dense flow slag, 2 furnace floor concretions with dark Mn-crusts
area 3	116	48	1mm mag	2	bulk	stone, charcoal, BOM (and modern turned metal contaminant)

Area	*Context*	*Sample*	*Label*	*Wt.*	*No.*	*Notes*
area 3	116	48	1mm mag	4	bulk	stone, charcoal
area 3	116	49		1000	1	140mm wide by 60mm thick and 85mm deep very dense slag lying along rather gravelly wall contact, prilly base and apparently smooth blown top with dense slag in upper layer - is this evidence of reuse of the furnace for smithing? The block has features in common with the 1900g block from [c53/116] but they do not fit together and are probably not from the same slag cake.
				38	1	deeply melted lining with convoluted glazed surface
				190	3	rusty soft hearth base materials
				24	5	scraps of dense flow slags
area 3	132	#1		514	1	large block of flow slag with angular moulds of wood/charcoal c35mm across
area 3	136	#1		12	1	exploding lump of corroding iron
area 3	136	75	magnetic	1	bulk	stone
area 3	136	75	1mm mag	1	bulk	stone
area 3	140	81	magnetic	6	bulk	fine IFM, stone, one small spheroid, possible flake hammerscale fragment
area 3	198	#3		68	1	concretion - probably from a furnace floor context?
area 3	198	96		158	1	very dense lump - similar to piece from [c18]. Heavily Mn coated on outside. Broken face shows coarsely crystalline texture - possibly a replaced limestone?
area 3	199	101		2	bulk	burnt stone
area 3	203	#1		4	1	irregular lump of oxide - probably corrosion around iron
area 3	203	102	1mm mag	1	bulk	stone
area 3	203	102	5mm mag	1	bulk	single fuel ash slag lump
area 3	203	102	magnetic	4	bulk	stone, small amount of slag
area 3	203	102	2mm mag	4	bulk	stone, possible roasted ore particles
area 4	1	#2		6	1	small dense flow slag around small charcoal moulds
area 4	1	#3		10	2	clinker, one well flown in rounded maroon-surfaced blebs, the other is rougher with part-reacted stone clast
area 4	1	#4		26	1	rounded lump of dense clinker
area 4	1	#7		58	2	dense flow slag lumps
area 4	9	86	1mm mag	4	bulk	stone
area 4	16	#1		52	1	large block of vitrified wall or tuyère, fabric sandy like tuyère fragments from [c17]

Area	*Context*	*Sample*	*Label*	*Wt.*	*No.*	*Notes*
area 4	17	#20		4	1	medium density black blebby flow slag
area 4	17	54		154	2	2 sherds from a large tuyère, diameter appears to be about 150/160mm. Apparently shows a superficial clay layer overlying the original side of the tuyère - suggesting reapplication of clay to the face, or clay used to bond the tuyère to something else.
area 4	17	54		178	89	fine flow slags and other dense slags around small charcoal moulds
				162	9	charcoal-rich slags with a blebby, sometimes microprilly texture - probably fragments of thin crust SHC or an open-textured FB.
				154	c120	fines and dust as 162g pieces above
				2	2	slag flats
				26	2	lumps of ferruginous material with charcoal dust, quartz grains and dark soft rounded grains - presumably a furnace floor material, but not typical sinter, this is rather soft and ashy
				154	2	dense lumps of slag, one possibly from close to wall contact since curved, both open textured, granular and probably related to 162g material above
area 4	17	54	>1mm mag	250	bulk	mainly sinter-like material - ferruginous blebby ash
	17	54	0.25 mag	66	bulk	ferruginous rounded particles and other sand grade materials
	17	54	retent mag	34	bulk	ferruginous debris, charcoal-rich and sintery, some spheroids, stone
	17	54	non mag retent	10	bulk	sintery fragments, charcoal, vitrified lining
	17	54	retent mag	18	bulk	blebby materials, some rich in charcoal
area 4	17	54	mag	98	bulk	sintery material and blebby slags - mostly probably low iron
area 4	17	54		80	c150	fines - mainly blebby sintery material
				118	11	sintery charcoal-rich material in balls with flowed outer surface
				24	4	charcoal rich materials
				1	2	thin slag films
				90	60	fine dense flow slags with a couple of spheroids
area 4	17	54	0.25mag	42	bulk	IFM in rounded particles - probably mainly ore dust?
area 4	17	54	1mm mag retent	18	bulk	stone and low density blebby slags, with ferruginous charcoal-rich material
area 4	17	54	1mm mag	44	bulk	low density blebby slags and sinter, some stone and charcoal
area 4	17	55	bag 1/3	96	11	dense flow slags, black shiny, flown around small charcoal only
			bag 3/3	76	8	dense flow slags, black shiny, flown around small charcoal only
			bag 2/3	38	8	dense flow slags, black shiny, flown around small charcoal only
area 4	17	72		248	2	dense granular slags, similar to pieces in [s54] , probably from wall or floor of furnace
				22	2	lower density rusty porous charcoal-rich slags
area 4	18	#1		46	1	superficially like a block of flow lobed slag - but appears to be a manganese-rch ore, possibly a replaced limestone. Similar to material from [c198]
area 4	128	76	retent mag	8	bulk	mainly stone, one piece burnt bone, 1 piece slag
area 4	212	#1		2	2	tiny flow slag fragments

Table 2: Pits in Area 3

Fill	Cut .	Size N/S	E/W	depth	Base	residue (g)	Macro-residues	Micro-residues	Assemblage
51	124	0.45m	0.35m	0.05m		0	x	x	none
56	105	0.40m	0.35m	0.25m		0	x	x	none
70	103	0.43m	0.53m	0.26m		0	x	x	none
78	118	0.68m	0.63m	0.26m		0	x	x	none
134	135	0.47m	0.55m	0.22m		0	x	x	none
57	120	0.46m	0.44m	0.15m		2	x	no residues	none
75	131	0.64m	0.45m	0.39m		2	x	IFM only	none
45	107	0.45m	0.66m	0.20m		3	x	single possibly ashy concretion	none
46	102	0.40m	0.45m	0.16m		3	x	no residues	none
80	110	1m	0.85m	0.18m		3	x	no residues	none
77	125	0.50m	0.70m	0.23m		6	x	no residues	none
71	138	0.86m	0.60m	0.11m		12	concretion	x	none
68	104	0.50m	0.48m	0.20m		14	x	possible slag	none
136	137	0.33m d.		0.32m		14	iron	no residues	none
47	106	0.45m	0.36m	0.15m		21	x	no residues	none
66	129	0.52m	0.50m	0.16m		112	vitrified lining and lining slag	x	sparse uncertain
60	194	0.30m	0.34m	0.22m		3	x	fuel ash slag, flake h/s	sparse smithing
58	139	0.33m	0.94m	0.16m		6	x	slag, small flake h/s, fired clay?,	sparse smithing
140	201	0.37m	0.32m	0.32m		6	x	trace of smithing residues	sparse smithing
74	200	0.77m	0.55m			28	concretion	small quantity smithing fines	sparse smithing
72	130	0.55m	0.60m	0.17m		30	x	varied smithing fines	moderate smithing
64	119	0.33m	0.60m	0.19m		38	x	fuel ash slag, flake h/s	sparse mixed
50	142	0.39m	0.35m	0.14m		11	x	possible ore fines, fuel ash slag blebs	sparse smelting
203	204	0.70m	0.55m	0.18m		14	iron	possible ore, fuel ash slag	sparse smelting
48	202	0.40m d.		0.22m		28	x	slag, fuel ash slag, flake h/s	sparse smelting
76	127	0.90m	0.75m	0.31m	burnt	178	concretions	vitrified clay, fuel ash slag, spheroids	sparse smelting
49	195	0.55m	0.50m	0.14m		262	vitrified lining	fuel ash slags, spheroids	sparse smelting
132	196	0.80m	0.83m	0.20m		514	large block of flow slag	x	sparse smelting
52	101	0.62m	0.60m	0.28m		3	x	slag, fired clay, spheroids	sparse smelting
94	100	0.38m	0.34m	0.06m		208	small flow slag piece	rich assemblage of IFM (probably ore dust), flow slags and spheroids	moderate smelting
116/53	126	l=1.80m	w=0.95m	d=0.36m	burnt	6508	4.7kg of smelting slag, SHC-like FB slags	Abundant smelting fines	rich smelting

Figure 1: Pits of Area 3 colour coded by archaeometallurgical residue types.

Blue – no archaeometallurgical residues
Green – residues from iron smelting
Purple – residues from smithing present (some of these have smelting residues also)
Yellow – residues of uncertain origin

Probable iron smelting furnaces shown by back circles, with possible examples in dotted lines.

Scale bar in m. Base map from site prelim. report.

Figure 1

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