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Assessment of materials from Probus, Phase 2, Cornwall

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Abstract

The submitted assemblage comprised approximately 104kg of picked fragments of residues and sieved samples from 50 discrete archaeological contexts. The most important contexts are two furnaces, F1236 and F1334. These furnaces are apparently similar in structure. They were constructed over a pear-shaped cut, with a horseshoe-shaped footprint to the shaft, leaving a wide ramp facing onto an external ramp area. The internal diameter of the furnace chamber appears to have been approximately 0.7m to 0.8m (the precise size is unclear from the plans). The slag assemblage associated with the furnaces is typical of non-slag tapping furnaces with a wood-packed basal pit. The iron-smelting technology closely resembles that of a series of Middle Iron Age sites in the Truro area: Threemilestone, Tolgarrick and Tregurra. The presence of wide, shallow burnt pits on the Probus site is also potentially similar to the occurrence of charcoal-making pits on other sides in the same area.

One key element of the residues associated with the furnaces, is the amount of fallen furnace superstructure preserved within the pits. In both furnaces this material included fragments of block tuyères, the occurrence of which has not been documented previously in such furnaces.

Smaller pits close to both furnaces (F1360 and F1346 respectively) produced evidence for smithing in the form of hammerscale and macroscopic smithing slags.

Other negative features (pits and ditches) in the vicinity of Furnace F1236 produced smelting slag assemblages, but in at least some cases these are likely to be residual, probably indicating the former extent of slag disposal across this part of the area. An extant spread of residues (F1081) may represent the base of another slag dump to the west, comprising similar iron smelting residues.

The site has great potential to enhance current understanding of Iron Age iron production in Cornwall, and as such is of high significance.

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Methods

All materials were examined visually, using a low-powered binocular microscope where required. The identifications of materials in this report, as an assessment during which no instrumental analysis was undertaken, are necessarily limited and must be regarded as provisional.

This assessment was conducted in August 2023 and was commissioned by Naomi Payne of AC Archaeology. The materials derive from excavation work undertaken in Probus, Cornwall (ACD2489) centred on NGR [SW 9035 4748].

Results

General nature of the assemblage

The submitted assemblage comprised approximately 104kg of picked fragments of residues and sieved samples from 50 discrete archaeological contexts. The catalogue of the assemblage is present in Table 1.

Table 2 illustrates the distribution of the residue fragments by class of residue and context.

The collection includes approximately 39.2kg of fragments of the furnace structures (much of this is fired clay, but the weight includes considerable amounts of attached slag too).

The collection includes a total of 46.6kg of slags that drive from furnace bottoms, 9.6kg of slags types that are associated with the floor of furnace pits and 4.8kg of slags derived from the furnace lining. Just 3.7kg of slags were interpretable as being from smithing hearth cakes. Three contexts produced small quantities of hammerscale and two produced examples of slag flats.

16.1kg of residues were recovered from 31 contexts without clear metallurgical association.

These totals are displayed in an alternative way in Table 3. Materials closely associated with the furnace structures (lining and lining slag) were found in very small quantities in other locations – where the assemblages are dominated by the furnace bottom slags that are more durable and produced in large quantities during a smelt.

Iron smelting residues

The iron smelting residues comprised significant suites in the two furnaces, plus debris from 'furnace bottoms' both in the slag spread and as (probably residual) material in various cut features, including the 'fire pits' (likely to be Iron Age charcoal-making structures) and the ditches interpreted to be of Roman age (where they are presumably residual). The quantification of the material recovered from these different settings (Table 3) is only intended to be indicative – the differing sampling regimes between the different types of feature means that the amount of residues recovered from then are not directly comparable.

The description of the residue assemblages from the furnaces is hampered slightly by uncertainty over what amongst the submitted assemblage might have been in-situ in, or formed, the lower parts of the furnaces, and what occurred loose in the infills.

The 'clays' employed for furnace construction appear consistent – a lithic- and grit- rich material, sometimes laminated. The ceramic of the furnace wall pieces and of the tuyère sherds (see below) were broadly similar.

The basal (pit floor) residues from the furnace pits comprise small pieces of flow slags and rusty material with abundant very fine charcoal and tiny slag prills/droplets with an overall rough, granular or spiky surface texture. These indicate that the 'furnace bottom' did not reach the bottom of the pit, or that there was space forward of the FB, where small particles were able to descend to the pit floor.

The main slag mass in the basal pit of the furnace would have formed a 'furnace bottom' (FB). No intact furnace bottom was recovered. It is likely, based on the form of the furnaces, that the FBs would have been very large, approximately plano-convex slag cakes (for comparison the in-situ FB at Tolgarrick Farm was 80kg, more typical examples are around 20-30kg) but here the largest fragment was 3.4kg (from context (1260)) and the average weight of a slag particle identified as being from a FB was just 39g.

The components of the FBs include dense flow slags, often very dark in colour and where amalgamated defining the moulds of large fragments of wood (mostly split wood, with a characteristic creviced surface), isolated flow slags, prilly slags containing moulds and clasts of the charcoal fuel and dense, massive, slags from towards the pit walls and probably forming the top of the FB.

Where the FB impinged on the pit wall, the dense slags are often contained within fragments of the wall, rather than as discrete FB pieces. The interaction with the wall ranges from dense lags simply abutting the wall ceramic (areas lateral to the blast) to deep interaction between the wall and the slag, often including the formation of a burr (a bulbous area of slag attached to indurated wall material) and/or areas in which the slag intrudes the wall material either as narrow complex veins or as sheets of flow-lobed tapslag-like material. Areas close to the wall may also generate slags with a 'coralline' texture – an open, porous structure with large equant, or rarely tabular, exposed olivine crystals.

The lateral attachment of the FB to the walls indicated a dense sheet approximately 30mm thick, but this increased markedly to 60-70mm on the blowing wall. The original FB would have been thicker than these estimates because of a large amount of flow slags below the dense sheet.

In the area close to the blast, the wall may form a smooth slag-coated embayment (above) or a complex mass of lining slags and spiky iron slags (below the blast). Several pieces of wall from this area show a groove eroded into wall; it is unclear if this represents erosion during the smelt exploiting a line of weakness associated with the construction, or if it is damage from tool use during extraction of the bloom and/or slag.

In the present material a horizontal division between oxidised-fired wall material and reduced-fired wall material was very marked. It occurred at approximately the same level as the top of the FB. Although this may be associated with change in reducing conditions within the wall body, it is perhaps more likely that this line marks the approximate contemporary ground level, below which oxygen-rich air could not be drawn into the ceramic from outside the structure.

Several pieces of block tuyère were recovered from contexts (1237) and (1337). These contexts are the lower fills of the furnaces, suggesting the tuyères were associated directly with the structures. Two fragments from (1337) provide the best evidence for the morphology of the block. The two pieces appear to form an upper corner of the front face of the block. The bore is incompletely preserved but appears to be approximately 27mm diameter. The centre of the bore lies at 80mm from one lateral margin and 95mm from the probable top. The face lies at approximately 70 degrees to the axis of the block. All the edges and corners are neatly rounded (suggesting little material has been lost from its front face). The front face is partially slagged, with slight impressions of fuel particles. The sides of the block show little significant high temperature alteration.

Iron smithing residues

Iron smithing, presumably the onwards working of the blooms produced during smelting, is most certainly represented by three classes of material: smithing hearth cakes, 'slag flats' and hammerscale. The occurrence of materials similar to the floor residues of the smelting furnaces in other might include examples of fines from the bases of smithing hearths (small scall flow-slags and prills may occur in both contexts).

Smithing hearth cakes (SHCs): there are no entirely unambiguous examples of SHCs because all the probable examples have a degree of irregularity of shape, but likely examples include a 400g slightly incomplete example from context (1070), a 658g example from context (1086), two small fragments form context (1112), a dubious 268g example from context (1201), a 188g fragment from context (1238), a possible 124g fragment from (1298), a 424g cake from context (1348) together with a smaller 66g fragment,

The more convincing examples from amongst these are all formed of rather dense slag and have original weights in the range of 400g to 660g.

'**Slag flats**': these include examples from contexts (1337) and (1361). They comprise examples of slag with a flat, sometimes slightly striated, surface that is likely to have formed in contact with metal. That metal might have been the surface of a tool or the surface of a workpiece being fashioned by the smith (e.g a compacting bloom or bar).

Hammerscale: hammerscale forms from the microscopic slags present on the surface of the smith's workpiece or expelled during closure of a fire weld. There are two forms (Young 2011): the flat scale that forms largely in the solid state on the surface of the iron, known as flake hammerscale (FHS), and chilled droplets formed from the same material that has melted, spheroidal hammerscale (SHS). Both forms are very rare in the present assemblage, with FHS recorded from contexts (1098), (1347) and (1361) (only context (1347) having FHS in larger quantities) and SHS recorded only from context (1361).

A floor assemblage from context (1098) includes a small proportion of FHS and is there probably a hearth floor assemblage not a furnace floor assemblage.

Interpretation

The residues described above correspond to a coherent suite of residues formed during iron smelting in a non-sag tapping furnace with a basal pit packing of wood, together with a much lesser quantity of material from smithing.

The evidence from the two furnaces includes an unusually large assemblage of material deriving from the furnace walls in comparison with the amount of slag from the furnace bottoms. No large fragments of furnace bottom were present. This probably means that the furnaces were at least partially cleaned after there last smelts (although the dense slags attached to the walls may indicate that they had not been repaired). A largely empty furnace pit provided a trap in which the collapsed furnace superstructure was relatively well-preserved.

The presence of some evidence for smithing near to the furnaces indicates at least some bloom compaction probably took place in their vicinity. In each case a pit fill provided the evidence, but it is unclear whether these pits were themselves directly associated with the smithing (as hearths or anvil supports) or simply provided an appropriate sediment trap.

On a wider scale, spread (1081) probably indicates the presence of one slag dump, but the incorporation of residues into the later Roman ditches indicates that disposal of waste had occurred in the Iron Age onto other areas of the site too and multiple slag dumps may have existed.

Discussion

Iron smelting technology

All aspects of the iron smelting technology (except the documenting of the tuyères) can be paralleled in the Middle Iron Age sites of the Truro area (Threemilestone, Young 2007, 2021; Tolgarrick Farm, Young 2016a; Tregurra, Young 2016b, 2022a), just to the west. This is most likely to be the age of the present material.

The present uncertainty over the precise size of the furnaces and the lack of complete FBs means that it is uncertain exactly where the present furnaces lie within the size range of this furnace type (see Young 2022a, fig. 7.16 for a comparison of the Truro furnaces with a smaller example from Crawcwellt, after Crew 1998, and a larger example from Folly Court after Young 2018a and Young & Anelay in press). It is most likely that the furnaces were almost as large as the example from Tolgarrick Farm, which was approximately 800mm internal diameter.

Since the penetration of the bellows blast through the charcoal fuel bed is limited (typically to around 400mm or so), large furnaces would develop dead zones in which fuel consumption was very slow. It is likely therefore that the furnaces were 'bottle-shaped' with the part of the furnace in which the reaction was taking place being narrower than the base. This shape means the area of slag attachment to the lining is reduced (so making for easier cleaning) and allows for a large furnace arch (for easier cleaning and bloom removal).

The basal chamber/pit of the furnace was packed with split wood prior to the smelt. The purpose of this technology has been much debated but it is likely that its major function was to introduce weaknesses into the FB, permitting its easier fracturing during extraction. The presence of an in-situ FB at Tolgarrick implies abandonment of the furnace; the normal situation would be the fracturing of the FB into smaller, manageable fragments, to permit extraction and disposal – as seen at Probus.

The evidence that there may have been multiple slag dumps is important, for often on typically truncated rural sites there is little evidence for these. This provides some indications of the likely relatively large scale of the smelting operation. If the relationship inferred at Tregurra between iron smelting and charcoal manufacture is also valid for Probus, then the presence of more than one furnace and dump may indicate reoccupation of the site for smelting following repeated forestry operations (e.g. coppicing – but not limited to coppicing).

Tuyères

Tuyères are a rather poorly known feature in early British metallurgy. Most early ironworking in Britain appears to have employed a hearth with a wall with a simple perforation for a blowhole. The use of a specially pre-fabricated tuyère is less commonly encountered. The misidentification of pieces of these blowholes as tuyères complicates their published record.

Pleiner (2006, 132) described brick-shaped block tuyères as being characteristic of the Iron Age oppida of Europe. Although rare in Britain, Iron Age rectangular block tuyères are represented by examples from the Middle Iron Age for copper smelting at Four Crosses (Young 2006, 2010; Havard *et al*. 2016, illus. 17), apparently for iron working at Gussage All Saints (Spratling 1979, 129), probably for ironworking at Mucking (Dungworth & Bayley 1999) and by a late Iron Age or early Roman assemblage from Axminster (Young 2015a). A block tuyère has recently been reported from Ipplepen (Young 2022) with a face reconstructed as having been 150mm wide by 108mm and with a 20mm bore, but it is of uncertain date. Evidence for rounded tuyères was found at Threemilestone (Young 2007): the most complete specimen from the ring-ditch of Middle Iron Age House 6 (c4501) suggested an ellipsoidal face, about 150mm by 100mm. Changes in the nature of the ceramic across a gently curved sub-horizontal discontinuity may suggest the use of block tuyères in the smelting furnaces at Chudleigh (Young 2023) but the shape of the face has not been determined.

The purpose of the block tuyères at Probus is assumed to be the ventilation of the iron smelting furnaces. That the tuyères might have been employed in separate smithing hearths would appear less likely but cannot be excluded altogether. Further examination of the furnace structure in the residue assemblage as well as through the interrogation of the detailed field records and photographs is needed to provide further evidence for the location of tuyère in the furnaces.

Burnt pits

The numerous 'fire pits' located across the site bear close comparison with the charcoal pits recorded elsewhere (see Taylor 2022, 327-333, for a recent synopsis and discussion). On some sites, the date range of charcoal production is broader than the that of the associated iron making, so an extended programme of scientific data is recommended.

Location of the site

There are no known iron ore sources in the immediate vicinity of the site. The Iron Age iron production of the Truro area to the west appears to have exploited the gossan ores of the area of the later workings associated with East Wheal Falmouth (NGR [SW780 441]), suggesting that the ore was transported considerable distances to the smelting sites (likely to have locations of charcoal production).

The present site is even further (approximately 13km) from that source area but lies much closer to a ESE-trending vein system (effectively the ESE continuation of the Perran Lode system of the coastal area) that runs from NE of Ladock, to the N of Grampound Road and towards Coombe (Dines 1956, map VIIIA). There were numerous post-medieval workings in this system, with Ladock Mine ([SW 914 525]. South Terra Mine (NGR [SW 936 521]) and Boddinick Mine (NGR [SW 947 518]) within the area closest to Probus (Dines 1956, Brooks, 2011).

Whether the Truro area or these closer vein sources supplied the operation at Probus, the interesting observations about the nature of the sourcing of ore and charcoal made for Tregurra may be pertinent here too. A regional regime of iron exploitation associated with charcoal production may well be at play here.

Further work

This site is important for several reasons. The evidence for the ventilation of the furnace is highly significant; the role of tuyères as opposed to simple blowholes has long been a debate in British archaeometallurgy. The new evidence is very significant but needs clarification in the light of further detailed interrogation of the field records, particularly to try to establish their original location.

Detailed laboratory analysis of the residues would be capable of providing further evidence for the nature of the ore being exploited. Clarification of the ore would be important as a local detail, as a contribution to the regional picture and as a component of mass balance calculations.

A programme of analysis is therefore suggested, with a representative suite of analyses of residues focussing on one furnace (to ensure coherency as far as is possible – to permit mass balance calculation of yield), plus analysis of a small number of equivalent residues from other contexts to look for any broader variation.

The programme of analysis should concentrate on bulk elemental composition of the residues, rather than microstructure (since microstructural analysis of technologically similar residues has previously been conducted for both Threemilestone and Tregurra).

The programme of analysis should also include the analysis of samples of iron ores from both the vein system north of the site and of the gossan ores of the Truro area to permit provenancing. This may entail getting consent to sample material held by local museums.

It is also recommended (though not as a direct part of the archaeometallurgy post-ex process) that a suitably thorough programme of scientific dating is conducted across the range of furnaces, burnt pits (charcoal pits?) and waste dump deposits. The evidence from Tregurra suggests that the charcoal making there may have been undertaken over an extended period of the Iron Age, but that iron production may have been more intermittent. Because of the complications of pit-packing versus fuel, the dating of furnaces should not rely on single dates, but multiple dates of multiple species.

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Table 1: summary catalogue, weights in g,

context	sample	fraction	s wt	l wt	l no	notes
1046	<11>			18	15	slag scraps, larger pieces are flow slags
				<1	1	charcoal
1059			22	22	1	irregular nub of slightly prilly iron slag
1070			400	400	1	crudely plano-convex mass with one edge broken; red smooth slightly lobate top; base in several distanced rounded accumulations of slag, rough; this is probably a very crudely-formed SHC
1073	<12>			14	1	accretion-coated flow slag fragment
				0.36	1	bleb of lining slag
1076			8	8	3	vitrified oxidised fired lining
1076				466	2	dense slag from FB margin with wood parallel to edge, longest piece is 120x25mm
				26	1	completely encrusted small slag nub
1081			520	330	43	variably vitrified and slagged gravelly lining; mostly oxidised
				178	7	lining slag in massive to slightly lobate forms
				12	1	rusty prilly slag fragment
1081			1965	738	27	dense flow slags, many showing parts of wood moulds, many slightly brown on surface
				262	12	dense flow slags as above, but markedly brown/maroon on surface
				10	2	scraps of corroded iron
				798	45	dense slags with rather granular texture
				88	3	lining with vitrified surface, coarsely pebbly, slightly purple lining
				72	8	fragments of lining slags
1081			4345	1700	37	dense flow slags, many with wood moulds
				2276	55	dense slags without clear flow lobed structure
				52	4	lining slag
				40	2	slagged lining
				194	1	dense slag attached to grey wall, slag part of sheet c30mm thick with charcoal impressions on upper surface and fractured lower face

				64	1	weathered granular slag in sheet 20mm thick
1081			3115	1690	63	dense flow slags
				44	2	slagged lining
				20	5	lining slags
				1371	50	dense slag not in flow lobes, some massive, some charcoal bearing
1081			2905	1695	61	dense flow slags
				1085	53	dense slags without clear flow lobing
				102	6	intensely slagged ceramic
				16	1	glazed pebble
1083			44	44	3	vitrified oxidised fired lining
1083			675	675	3	(plus three crumbs) flow slags with wood moulds - all quite vesicular and porous
1086			658	658	1	SHC with slightly lobate margin, plano-convex, 110x120x55mm, heavily accreted, base very irregular
1088	<15>	magnetic		4.78	assm	stone
1088	<15>			8.53	60	fired clay
1094			22	22	1	flow slag
1097				86	1	dense slag with wood moulds
				48	2	heavily accreted slag - probably with fuel moulds?
1098	<16>			596	247	furnace floor debris - rough slags, flow slags - all with slightly rough coating
1098	<16>	magnetic		8.68	assm	stone, fired clay, slag (some filmy slags, but very little true scale)
1098	<16>		110	47.53	25	oxidised fired clay
				24.63	8	oxidised fired clay with dark remnant vitrified surface
				20.73	9	slagged and accreted material
				13.83	10	grey fired clay
				1.53	1	slag with possible wood impression

1099			118	118	1	crudely lobate vesicular slag with wood mould
1101			8	8	1	flow slag prill
1107			24	24	5	buff and orange, pale fired clay
1108	<19>	magnetic		2.07	assm	stone
1108	<19>			26	35	slag scraps, probably all FB material
1108	<19>			14	38	reduced fired clay
1112			158	158	2	slag fragments with rounded dimpled bases - could be dense, but small, SHC fragments
1114			10	10	2	Iron slag chips - one with ?wood mould surface, the other very weathered
1116			42	42	1	brown banded cherty rock with dark iron mineralised layers
1119	<21>			64	183	oxidised fired clay
1125	<23>		3.77	3.77	2	bog ore mottles
1125	<23>			2.3	3	fired clay, oxidised
1132			18	18	1	prilly slag
1134			28	28	9	highly fragmented weathered low density vesicular slags
1141			12	12	3	vitrified oxidised fired lining
1141			1845	116	1	accreted and total mineralised iron fragment
				820	22	dark flow slags, some with slightly reddened surfaces
				6.23	1	iron; 5mm wide tang expanding into 17mm wide blade? Small mineralised iron fragment in concretion
				4.43	1	iron; 5x7mm rectangular shaft and 17mm or more head- probably a nail
				332	1	dense slag block, forming small burr attachment

			554	11	porous dense slag, mainly charcoal rich
			1	2	lining slag fragments
			10	1	slagged fragment of oxidised lining
1145		96	96	1	fractured rounded nub of vesicular slag
1157	<26>		9.69	9	grey fired clay
1164	<28>		6.87	22	grey fired clay, many pieces have pale and dark halves
1165		18	18	1	small nub of vesicular slag
1190			482	2	dense slag with wood moulds
			230	1	dense slag lump, probably from near burr on FB margin
			86	2	lining slag
1198		110	60	1	mixture of fresh flow slag lobes with lining slag - burr region top of cake
			52	1	porous iron slag , vesicular, sacharoid
1200		2	2	1	oxidised fired lining
1200		2565	1125	6	dense slag with wood moulds, some pieces show secondary reddening
			874	3	dense , more massive slag
			178	3	coralline type slag, granular vesicular
			158	8	dense blebby/prilly slags in small pieces
			68	8	lining slag fragments
			104	3	grey ceramic with slagged surface, convex surface - possible tuyère
			52	1	dense slag in vesicular slag with smooth undulating upper surface, base rough
1201		1365	858	7	dense slag with wood moulds and flow lobes
			268	1	dense slag in small crudely plano-convex form; probably just a fragment of FB, but could be SHC; top has charcoal impressions, bottom lobate surface roughened
			62	3	lining slag
			182	1	dense irregular slightly reddened slag lump

1237	2475	2475	1	chord 210mm, depth 130mm, bowl moves in 50mm; main slag 65mm thick rests with oxidised wall behind, below less slag on bowl and reduced, probable multiple wall repairs within indurated wall attached to slag; in plan wall only curves slightly
1237		200	1	vitrified and thickly slagged oxidised fired lining
		2135	2	friable and prilly slag around large wood moulds, mostly not typical very dense flow slags
		386	1	thick and complex angular block of lining slag
		606	1	tapslag like flow slag extending away from oxidised and vitrified lining - possibly a tuyère tip
1237		686	7	vitrified and thickly slagged oxidised fired lining, with similar internal material
		182	1	thick angular block of lining slag
		398	3	rusted slag fragments, some slightly prilly, some granular
		2250	1	large block from side of pit, 150mm tall, oxidised wall going grey to base; heavily indurated wall, mass of slag at (?) foot of wall, shows some wood mould surfaces
1237		6060	1	chord 290mm, dense slag cake 100mm tick overlain by 60mm of complex lining slag, extends 120mm into hearth (but starts behind wall?)
1237		840	25	approximate number of fragmented brown material - probably equivalent to sinter faces - includes small prills
		392	6	vitrified and thickly slagged oxidised fired lining
		46	1	lining slag piece with slightly dished surface
		1200	6	dense massive slag fragments
		48	3	simple clean flow slags
		636	9	flow slags involved with messy rusty slags
1237		1535	74	flow slags involved with messy rusty slags
		108	5	dark friable gravelly sinter?
		24	2	vitrified stones
1237	1762	328	1	dense large flow slags surrounding wood moulds
		178	3	oxidised fired gravelly pinkish fired clay
		278	3	dense flow slags in tapslag like flows, one has fired clay on upper face, two show fuel moulds
		164	1	messy block of porous material - probably slag intruded into fired clay
		814	1	large block from burr region of furnace, tapslag like flows cut wall and overlain by fired clay, overlain by dense sheets down wall
1237	2795	1255	72	rusty prilly slags, lots of fine charcoal debris
		674	1	dense irregular block from burr region, slag probably old fracture on front, slightly prilly below and flattish top, wall red above, grey below; gravelly

			358	29	furnace wall fragments, variable vitrified/slagged, mostly oxidised fired
			60	1	dense dark sandy indurated material
			122	2	dense rusty slag lumps
			14	1	quartz pebble
1237		6775	6775	1	chord 330mm, height 150mm, extends 120mm into furnace. 90mm below redux line, 60-70mm above, one end shows big slag build up at wall foot, the other more fluid with multiple tapslag like intrusions into wall, appears to be fractured 40mm thick sheet with slightly prilly base extending forward of pit wall
1237		1370	298	3	marginal sherds of a tuyère
			56	5	probable additional fragments from the tuyère
			440	1	slagged ceramic, just possibly tuyère tip, face with deep incision or eroded cleft, below cleft slag is thick, above cleft slag has cleaved off
			392	4	dense slags with wood moulds
			6	1	fragment of lining slag
			206	6	granular slag/sinter
1238			1685	112	vitrified and thickly slagged oxidised fired lining
			214	1	dense slag adhering to oxidised fired clay - lateral margin of FB?
			342	34	prilly slags and 'messy' charcoal bearing slags
			56	5	lining slag fragments
1238	2 of	1489	1365	20	hearth ceramic, mostly laminated clay with angular grit; one piece shows an abrupt undercut in the vitrified surface; mostly oxidised fired
			124	1	prilly slag fragment with fuel/wood contact surfaces
1238	3 of	2300	1430	38	variably vitrified and slagged gravelly lining; mostly oxidised; one piece shows curious rounded indent in glassy slag surface
			480	17	lining slag in massive to slightly lobate forms
			200	8	rusty prilly slags, lots of fine charcoal debris
			188	1	fragment of SHC, dense lower crust to 25mm, vesicular, overlain by grey slag with abundant gravel debris
1238		416	416	18	flow slags, from dense material with wood moulds to finer flows with much lining input
1238		2000	1273	51	vitrified and slagged oxidised fired lining, gravelly, slagged surface varies up to 30mm.
			384	10	lining slag fragments, gravelly
			134	11	rusted slag with charcoal
			144	2	dense flow slags

				80	1	dense slag with somewhat granular texture
1243			74	74	1	vitrified oxidised fired lining
1260				1435	1	150x130mm large piece of furnace wall gently concave, slagging up to 40mm thick, presumably near blowhole
				812	1	rusty mass of prilly charcoal baring slag - could be upper part of FB or much less likely a very irregular SHC; rust suggests this had a high metal content originally
				260	1	dense slag with wood moulds
				66	1	slag with large charcoal or wood
				18	1	fragment of rusty slag, spalled from another larger piece
1260				3390	1	large piece of FB with wood moulds, 210x190x100mm
1265			256	256	3	crudely lobate dense slags, one with wood impression
1270			42	42	1	vesicular slag with fuel moulds
1298				124	1	heavily encrusted small puck with fuel dimples on top, dense; could just possibly be SHC fragment
				106	1	heavily encrusted porous slag
1298			58	40	1	vitrified oxidised fired lining
				18	1	vitrified and slagged stone
1333	<33>			4	38	fired clay, oxidised
1335	<34>			168	9	small dense slag fragments, mostly or entirely from FBs
1335	<34>		398	194	77	fired clay, oxidised
				204	285	slag, mostly in very small pieces of highly vesicular pale material
1335	<34>	>10mm	2020	2020	assm	mostly oxidised fired clay, thin veneer reduced below slightly slagged surface, rare pieces of lining slag, ceramic fine, rarely white/orange laminated, grit present but not dominant
1335	<34>	magnetic		4.74	assm	stone, fired clay, slag
1336			36	36	6	pale grey vitrified fired lining

1336			504	216	1	dense slag, mixture of flow lobes and coarse crystals, in contact with grey ceramic wall
				24	1	small lobe of flow slag with wood impression
				24	1	green glazed ceramic and stones
				128	1	dense lining slag apparently below curved grey ceramic - probably a tuyère base
				54	1	slagged surface on grey ceramic - has one very smooth face - if original could be tuyère
				50	8	lining slag
				12	1	granular slag, only slightly lobate
1337	<35>	2 of	378	92	1	corner of tuyère (presumably from back, since no high-temperature alteration?
				120	10	lining slag and slagged lining
				162	80	fired clay
1337	<35>	magnetic		8.33	assm	stone, fired clay, slag
1337	<35>		2410	226	8	flow slags
				42	2	indurated sediment
				58	1	vesicular lining slag
				2086	1500	(approximate number) small fragments of rough slag, flow slag, some lining-related material
1337	1 of 6		4145	3325	1	290mm chord, 180mm high, large piece of wall with step - ?shaft/pit junction or level of top of FB; main vitrified face overlies earlier similar one, has lots of sloughed lining slag on ?lower edge,
				286	1	dense slag with some charcoal
				448	1	angular block of burr type slag
				56	6	small pieces probably fractured from large block
1337	2 of 6			1701	12	slagged lining and lining ceramic
				338	1	block of ceramic with 95 degree angle between slightly dished face with maroon surface slag veneer and almost planar face fired grey; internally oxidised fired; from side of tuyère block; conjoins 456g block below
				608	1	contact of slag sheet, c. 30mm, with reduced fired wall; presumably lateral to furnace
				1300	7	porous FB material, lots of wood moulds, charcoal and some prilly sections
				125	1	dense flow slags around wood moulds
				55	1	thin fragment of slag from mass with dimpled base
				65	2	two pieces of slag with planar but gently lineated surfaces; one thick one just a film; detached from a bloom surface or a tool??
1337	3 of 6		4035	404	13	fragments of lining slag

				1420	42	slagged lining and lining ceramic
				106	1	granular or fragmental slag/clinker
				116	1	slag with moulds of fuel attached to reduced fired lining
				190	6	small dense irregular slag pieces
				794	2	FB fragments with well-preserved wood moulds
				74	2	dense flow slags
				624	1	irregular block - slag veining into wall at burr?
				276	2	dense slags against wall, one possibly burr
1237	4 of 6		4425	304	6	vitrified and thickly slagged oxidised fired lining
1337?				366	11	angular fragments of lining slag
				1085	8	charcoal/wood bearing FB fragments
				1935	3	contact between FB margins and wall - hot contact but probably lateral to blast
				714	1	large block from wall - well slagged and deeply vitrified to purple in hollowed shape, orange fired clay behind - from just above tuyère?
1337	5 of 6			456	1	further part of the tuyère block, centre of bore 80mm from margin and 95mm from top; face at 70 degrees of so to axis of tuyère; conjoins 338g block above
				236	1	gravelly ceramic, grey on one side of the slab, reddish on the other - no real surface, but could just be part of tuyère
				1045	1	large block of wall, with slag-surface embayment; appear to be multiple generations of clay involved
				1360	1	rusty lump of charcoal bearing slag, 130x150x60mm, plano-convex lump with upper mass of obscured slag
				738	16	deep lining slag layer on furnace ceramic
				198	2	lumps of crudely lobate slag with remnants of wood(?) moulds
1337	6 of 6		2620	2605	1	accumulation of granular/prilly slags against slightly vitrified wall
1347	<36>			7.33	24	slag debris
1347	<36>			27.5	165	grey fired clay
1347	<36>	magnetic		2.82	assm	stone, slag, moderate amount of FHS
1348			944	314	6	dense slags with wood moulds and or flow lobes
				138	6	porous iron slags with charcoal moulds
				424	1	slightly incomplete very dense plano-convex cake, 95x75x49mm, base rough, top with deeply impressed moulds, slightly two layer, but both upper and lower parts very dense
				66	1	elongate dense slag - possibly spall from similar dense plano-convex cake

F1353	no context		108	62	2	irregular dense slags
				42	2	flow slags
				4	1	lining slag
1361	<37>	magnetic		4.98	assm	stone, clay, slag, small proportion of FHS and some SHS
1361	<37>			46	8	fired clay
				36	1	slag with minor burr like interaction with oxidised fired wall
				10	1	highly accreted slag fragment
1361	<37>	slag		86	3	vitrified lining
				1996	442	flow slags, slags with charcoal and other FB component debris, from moderately large pieces down to fine debris; heavily accreted, and coated in clay, much is rusty
				4.4	1	slag flats
1364				22	1	vitrified lining slag
				4	1	very worn tapslag-like sliver with a maroon surface
1376			186	184	1	very dense slag with large rounded vesicles and fuel moulds
				2	1	burnt stone
1391	<39>			46	141	reduced fired clay
1443			332	332	1	dense tapslag-like mass, very wide flow lobes (>50mm) forming dense mass, flow surfaces reddened, one side appears to curve around obstacle - but it isn't entirely certain this obstacle was wood

Table 2: residue types by context (excluding material in processed samples, except where indicated by 'y' = present in sieved sample) Orange fill = smelting furnaces, blue tone = potential smithing-related features.

context	'furnace bottom'	pit floor	lining slag	lining	SHC	scale	slag flat	iron	tuyere	total	Context notes
1046	18									***18***	Lower fill fire pit F1045
1059	22									***22***	Same as 1056 (upper fill ditch 1055, probably a continuation of F1042)
1070					400					***400***	Lower fill ditch 1069
1073	14		0.4							***14.4***	Lower fill pit F1072
1076	472			8						***480***	Upper fill ditch 1075
1081	11885		322	620				10		***12827***	Spread of slag and charcoal
1083	675			44						***719***	Single fill ditch 1082
1086					657					***657***	Third fill fire pit F1084
1088				9						***9***	Lower fill fire pit F1084
1094	22									***22***	Single fill pit F1093
1097	134									***134***	Upper fill hearth F1095
1098	23	605		87		y				***715***	Cut no. for posthole
1099	118									***118***	Single fill posthole F1098
1101	8									***8***	Single fill posthole F1100
1107				24						***24***	Fill/lining pit F1106
1108	26			14						***40***	Lower fill pit F1108
1112					158					***158***	Fill curvilinear ditch terminus 1111
1114	10									***10***	Fill curvilinear ditch terminus 1113
1116										***0***	Single fill pit F1115
1119				64						***64***	Charcoal-rich lower fill pit F1117
1125				2						***2***	Lower fill fire pit F1124
1132	18									***18***	Single fill tree throw F1131
1134			28							***28***	Lower fill fire pit 1133
1141	1706		1	22				127		***1729***	Upper fill ditch F1138
1145	96									***96***	Upper fill ditch F1143
1157				9						***9***	Lower fill firepit F1156
1164				7						***7***	Upper fill fire pit F1163
1165	18									***18***	Upper fill fire pit F1163
1190	712		86							***798***	Lower fill ditch F1188
1198	112									***112***	Lower fill ditch seg 1197
1200	2335		120	106						***2561***	3rd fill ditch seg 1197

1201	1040			62	258					***1360***	Upper fill ditch seg 1197
1237	7287	6823	774	17741					y	***32625***	Lower fill furnace pit F1236
1238	1654		920	5753	188					***8515***	Upper fill furnace pit F1236
1243				74						***74***	Middle fill pit F1241
1260	4546			1435						***5981***	Middle fill pit F1258
1265	256									***256***	Single fill ditch seg 1264
1270	42									***42***	Fill gully F1269
1298	106			58	124					***288***	Fill curvilinear ditch terminus 1297
1333				4						***4***	Single fill oval pit F1332
1335	168		204	2214						***2586***	Upper fill furnace F1334
1336	252		50	242						***544***	Fill furnace F1334
1337	9714	2234	2248	10463	1415		65		y	***26139***	Fill furnace F1334
1347	24			28		y				***52***	Fill burnt pit F1346
1348 (6?)	452				490					***942***	
F1353	104		4							***108***	Cut no. for gully
1361	2042			132		y	4			***2178***	Single fill posthole/pit 1360
1364	4			22						***26***	Single fill gully F1363
1376	184			2						***186***	Single fill ditch F1375
1443	332									***332***	Single fill ditch seg 1442
totals	*46631*	*9662*	*4757*	*39246*	*3690*		*69*			***104192***	

Table 3. Tables of relative abundance of slag class by origin. Note that the sampling regimes were different across the different locations, so these numbers are merely indicative.

Residue class:	furnace bottom	floor residues	lining slag	Lining and other structure	Smithing hearth cake
a) Total weight in g					
Dump (1081)	11885	0	322	620	0
Furnace [1236]	8941	6823	1694	23494	188
Furnace [1334]	10134	2438	2298	12919	1415
Other contexts	15671	605	239.4	2213	2087
b) % of slag class					
Dump (1081)	25%	0%	7%	2%	0%
Furnace [1236]	19%	69%	37%	60%	5%
Furnace [1334]	22%	25%	50%	33%	38%
Other contexts	34%	6%	5%	6%	57%
c) % of total assemblage					
Dump (1081)	11%	0%	0%	1%	0%
Furnace [1236]	9%	7%	2%	23%	0%
Furnace [1334]	10%	2%	2%	12%	1%
Other contexts	15%	1%	0%	2%	2%
d) Total % of assemblage	45%	9%	4%	38%	4%

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