GeoArch

Report 2009/49

Evaluation of archaeometallurgical residues from the N9/N10 Waterford-Kilcullen, Site 6-9, Ballykeoghan, Co. Kilkenny (E2500)

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15th November 2009

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Dr T.P. Young

Abstract

This site yielded 31kg of picked archaeometallurgical macro-residues, almost entirely derived from iron smelting, together with approximately 2kg of finer-grained residues recovered from sieved/flot samples.

The iron-smelting residues are indicative of smelting in a non slag-tapping, slagpit, furnace. Such furnaces have a basal pit to collect the slag produced during each smelt, and a low shaft-like superstructure. The remains of basal pits of two of these furnaces were identified. A well preserved slagpit [c043] contained 18.3kg of apparently in-situ smelting residues. It appears to have had an internal size slightly greater than 0.45m diameter. The residues in this furnace probably represent the entire residue assemblage left after the furnace's last use. A second basal pit from a smelting furnace [c048], yielded about 200g of furnace bottom fines, and is interpreted as being highly truncated. Furnace [c048] is given as 0.40 x 0.50 x 0.10m. The relatively large size of the slagpits ([c043] and [c048]) suggests that these furnaces may be early Iron Age in date. Similarly-sized furnaces have been dated to between the 5th and 1st centuries BC. Their association with "possible late Bronze Age" pottery may provide further circumstantial evidence for an early date.

There were also three larger features with indications of burning and considerable amounts of charcoal, which are tentatively interpreted here as the bases of charcoal-making kilns. The first, pit [c017] from near the southern limit of the site (close to furnace [c043]), was 1.6m in diameter. Its upper fill [c018] contained 13.7kg of redeposited iron smelting residues together with slight traces of smithing micro-residues. Two similar features with in-situ burning ([c063] and [c065]) lay in the centre of the cutting. Pit [c063] was large (1.55x1.50m), with an oxidised base on which lay a dense layer of charcoal [c052] containing 242g of small slag pieces. The second of these features [c065] has a complex and poorly preserved morphology, was 2.4x1.6m and produced no archaeometallurgical residues.

Within the cluster of features in the centre of the site, pits [c087], [c098], [c141] and [c150] did not yield certain residues from metallurgical processes, but did yield small particles of fuel ash slag that might have been derived from a wide variety of pyrotechnological processes, even from a domestic hearth. Pits [c080] and [c142/3] produced very small quantities of hammerscale, but it is possible this is intrusive. The lack of iron slags within the features of the central "structure" may suggest that this is not coeval with the iron-making, although the provisional interpretation of this building as being a charcoal store certainly cannot be excluded.

Contents

1. 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.

2. Results

2.1 Description of Iron Smelting Residues

2.1a From smelting furnaces:

The *in-situ* iron smelting residues are represented by substantial remains in furnace [c043] and a lesser quantity in the more heavily truncated furnace [c048].

Furnace [c043] contained a total of 18.279kg of residues, of which 1790g were fine-grained residues from [c047], the basal charcoal-rich layer and which were recovered by sieving. These fine-grained materials included fine flow slags (delicate prills, blebs and spheroids), thin ferruginous crusts on fine charcoal debris and fine-grained (<2mm) ore material, some of which was bound into "sinter". The abundance of small (<10mm) dense slag spheroids was particularly remarkable.

Field recording of the contexts above [c047] shows what appears to be a dense slag flow down the blowing wall to the NW of the pit. The assemblage from [c045] (the fragmented slag mass contained within silt [c024]) includes approximately 9.1kg derived from a charcoal-rich slag block extending across the furnace. This block appears to have been about 0.45m in diameter and corresponds to what is commonly termed a "furnace bottom" (FB). The block includes a substantial "burr", where hot slags have reacted with the furnace wall below the blowhole to form a slag-filled concavity in the wall. This burr is likely to have lain on the NW side of the furnace. Also within [c045] is a further 7.4kg of slags which have descended below the FB (although they may have still been in physical continuity with the FB). They form substantial blocks of flow slag showing flow around large pieces of wood (probably equivalent to the "burnt timber" recorded within [c047]), and flow down the blowing-side wall.

The deposits containing slag were overlain by final fill [c044] which included fired clay, probably derived from the collapse of the superstructure.

Thus the slag mass appears to have been of about 16.5kg, divided into 9.1kg of charcoal-rich slag above and 7.4kg of coarse flow slags below. The fine detached residues in the furnace pit total approximately 1.8kg.

Furnace [c048] was only preserved to a depth of 0.1m (compared with 0.5m for furnace [c043]). Here, a charcoal-rich deposit [c049] was comparable to [c047] in furnace [c043]. The deposit contained approximately 200g of fine-grained residues rich in fine flow slags, spheroids and amorphous material (possibly ore).

Alongside the approximately 0.5m diameter slagpit furnaces were two features of approximately 1.5m diameter: pit [c017] 12m east of furnace [c043] in the south and pit [c063] 7m north of furnace [c048] in the centre of the cutting.

Pit [c017] was filled with a thin charcoal-rich basal layer containing small quantities of broken fragments of slag, which was in turn overlain by [c018], a brown sandy silt with limestone boulders and containing 14.3 of residues.

2.1b From other possible metallurgical features:

The two other features with significant quantities of residues are large and somewhat more problematic.

Pit [c017] was 1.6m in diameter. Its upper fill [c018] contained 13.7kg of mainly iron smelting residues together with slight traces of smithing micro-residues. The residue assemblage contained a significant quantity of generally large blocks of variably vitrified ceramic from the superstructure of a furnace. Some of these gave a suggestion of an overhanging blowhole region, possibly even a tuyère; other fragments may also have been from an overhanging length of wall. The complex curvature of some pieces provides a hint that the furnace may have been bottle-shaped.

The majority of the residues were broadly similar to the macroscopic slags recovered from the smelting furnaces described above, but with a marked bias towards larger blocks of slag (particularly FB fragments and down-wall flows) with very few of the small isolated prilly flow slags.

The basal context of the fill of [c017] was charcoal-rich deposit [c032]. This contained a very small assemblage (62 pieces, 52g) of small broken slag fragments. These appeared to include both charcoal-rich and flow slags, indicative of iron smelting.

Pit [c063] was also large (1.55x1.50m), with a partially-oxidised base on which lay a dense layer of charcoal [c052] containing 242g of small slag pieces. These residues mainly comprised fragments of iron-poor slags, with a strong influence from the hearth/furnace wall, but there were five pieces of denser flow slags. They are probably residues from iron smelting, but are not certainly so.

2.1c From other contexts:

A single small fragment of flow slag was recovered from the topsoil [c001].

2.2 Description of Iron Smithing Residues

Smithing is represented in Area 9 only be microresidues; there were no certain macroscopic smithing slags. A 686g block of slag from [c018] might possibly be interpreted as an SHC, but equally might be a fragment broken from a FB.

Extremely sparse assemblages of flake hammerscale were recorded from pit [c018] and probably pit [c080]. A small quantity of possible spheroidal hammerscale (not withstanding that small slag spheres were unusually common in the smelting residues on this site) was found in [c144], the fill of pits [c142/3].

A rather more significant collection of microresidues came from [c093]. This deposit is described as a spread of charcoal 0.5m in diameter and 0.04m thick, 4m to the NW of furnace [c043]. This assemblage was

rich in small slag fragments and contained some flake hammerscale. Although the original interpretation that this represented a waste dump from the furnace cannot be excluded, the suggestion of smithing residues might also hint that this could be a strongly truncated smithing hearth.

2.3 Description of other pyrotechnological residues

Coal Clinker: four pieces of clinker (coal-burning residue) were recovered from topsoil. Such material may derive from as variety of coal-fuelled processes, including metallurgical ones, but the most common source in agricultural areas is from the former use of steam-powered equipment (e.g. traction engines)

Other Fuel-ash slags: fuel-ash slags are a class of residue formed by melting, or partial melting, of the incombustible (inorganic ash) component of fuel. The term is currently also widely used to cover residues formed largely of silica-rich material (e.g. soil or sand) which has melted, or more commonly partially melted, under the influence of the alkalis in the fuel-ash. Fuel-ash slags in this sense are typically very low density, highly vesicular materials containing grains of quartz and other detrital minerals, bound together by varying proportions of calcium (and/or potassium) rich glass. In most circumstances fuel-ash slag particles are small, often also so because of their fragility, and blebby.

In this study, typical fuel-ash slags were recovered from [c071], [c097], [c139] and [c149]. Rather similar materials occurred in [c052] along with other materials more typical of the base of an iron smelting furnace.

2.4 Description of the metallurgical features

2.4a The furnaces

The two clear examples of slagpit furnaces ([c043] and [c048]) have rather wide pits. The precise widths of [c048] are uncertain because of truncation, but a size of 0.40 x 0.50 x 0.10m is given at the surviving level, which is likely to be a minimum size. For [c048] understanding of the working volume of the pit is slightly hampered by the lack of a direct measurement.

The pit was interpreted by the excavators as being lined with grey clay, but such clays are sometimes merely the reduced-fired natural. The pit typically shows an inner reduced fired ring and an outer oxidised zone – probably suggesting that the furnace actually draws air from the sediment into which it is cut. The "cut" recognised by the excavators measured "0.67m east-west, 0.51m north-south and 0.50m deep". The thickness of the possible lining [c046] is given as 0.05m, giving a theoretical slagpit size of 0.57x0.41m. The slag cake within the pit ([c045]) is given as being 0.45m diameter and this should provide a minimum for the slagpit diameter. Both examples then are likely to have their long axis at least reaching about 0.50m, with the perpendicular axis perhaps slightly less.

Photos and plans of [c043] suggest the prominent "birds-foot" stalactitic flow (probably the 388g piece from sample #14) close to the NW wall probably represents downwards flow of slag close to the wall at the NW of the burr, which appears to have lain towards the SW side of the furnace, which would have therefore been the location of the bellows. The E-W long axis of the pit is therefore slightly oblique to the furnace orientation.

2.4b The possible charcoal kilns

The site contained three features with oxidised-fired bases, which are much wider and shallower than the smelting furnaces. These are here tentatively interpreted as the bases of charcoal-making kilns.

Pit [c017] was 1.6m in diameter. Its upper fill [c018] contained 13.7kg of mainly iron smelting residues together with large stones; clearly not an in-situ deposit. The base appears to have been fired across its entire extent.

Pit [c063] was also large (1.55x1.50m), with a base on which that was oxidised over only part of its extent and on which lay a dense layer of charcoal [c052] containing small slag pieces.

(Note: The description of c52 is rather confused in the supplied draft prelim report. It is listed in the table of contexts as a fill of pit c150, this should be c063. In the running text several references are made to furnace c052 – this should be c063)

Pi t [065] has been badly disturbed and is apparently cut by a large number of later stakeholes and postholes. It measured 2.4 x 1.6m.

2.4c Charcoal deposits

A substantial charcoal deposit occurred as feature [c107]. It has been argued in the prelim report that this might have been a store, protected from the elements by a structure represented by the various postholes of the cluster in the centre of the site. Whilst such an interpretation is entirely reasonable, there were no significant metallurgical residues in any of these features that would tie the structure the metallurgical activity.

A small charcoal deposit [c093] in the south of the area yielded some microresidues, at least some of which were from smithing. Although there are few morphological details from this small deposit, it is possible it represents a truncated smithing hearth.

3. Interpretation

The size of the two slagpit furnaces was discussed above. Comparison of both size and style of residue assemblage can be made with the highly truncated furnace [c209] in Area 10. The furnaces in Area 3 (Young 2009c) are of a similar, or slightly smaller size, but apparently possessed furnace arches. A tentative developing chronology for Iron Age furnaces would suggest that furnaces with the wider simple slagpits, as Area 9, are likely to be earlier than the slightly smaller arched furnaces (and other possible furnace types) which seem to appear in about the 1st Century BC.

Furnaces with wide slagpits (>0.40m) are known outside the current road scheme from:

Adamstown 1 (Co. Waterford): Slagpit :0.53 x 0.47m and 0.15m surviving depth. (Young 2006)

Ballydavid AR26 (Co. Tipperary), six furnaces with slagpit diameters >0.40m. Associated 14C dates suggest a date in the 3rd-1st centuries BC. The

apparent 8th-5th century BC date for the isolated furnace c157 is very early. (Young 2009b)

Cherryville 12 (Co. Kildare): 320-200 cal BC. Four slagpits 0.45 - 0.50m diameter. (Young 2008a)

Cloncollig (Co Offaly) The pit (007).is described as being 0.57 x 0.60m and 0.32m deep. A 14C date on oak charcoal from the basal layer of the furnace gave a date of 261 – 94 cal BC (Young 2008b)

Clonrud 4 (Co. Laois). The working dimensions of the two slagpits (0.41m x 0.39m and 0.46m x 0.41m) are moderately large. Two dates suggest 4th-1st centuries BC (Young 2008e)

Derryvorrigan 1(Co. Laois) appears to have working diameters of approximately 0.40m (Young 2008d).

Leap 1 (Co Laois). F007 has a diameter of 0.40m. It is not directly dated, but there are earlier Iron Age 14C dates from adjacent features (Young 2009a)

Lismore-Bushfield 1 (Co. Laois). A cluster of 5 furnaces with diameters >0.40m. Furnace 3 gave a 14C date on alder charcoal of 90BC to AD80. (Young 2008f)

Morrett D (Co. Laois): 170 cal. BC- 30 cal AD and 770-410 cal. BC for charcoal pits, 370-110 cal BC and 400-200cal BC for ring ditches. (Young 2005)

Newrath Site 35 (Co. Kilkenny): 400-200 cal. BC and 350-40 cal. BC (Eogan pers. comm. 2006)

Tullyallen 6 (Co. Louth): Slagpit: 0.47 x 0.50m and 0.18m deep. (Young 2003)

Other Iron Age sites appear to have smaller diameter furnaces. Those at Derrinsallagh 4 (Young 2008c) appear to be mainly approximately 0.30m working diameter (ignoring all arguments about whether any lining is present within a broader cut). The example with a furnace arch that was excavated in detail (Young 2008f) was rather irregular in plan but was approximately 0.36m diameter at the level of truncation (although slightly wider towards the base because the pit sides were overhanging). These smaller furnaces seem to appear from the 1st century BC and continue well into the first millennium AD.

Two other examples of these early wide furnaces have contained in-situ residue assemblages: Tullyallen 6 with 17.5kg (Young 2003) and Adamstown 1 (with 18.6kg, Young 2006). These bear close comparison with the 18.3kg of residue from furnace [c043].

Apparently complete residue assemblages are also known from two slightly smaller diameter Iron Age furnaces: Derrinsallagh 4 [c397] with greater than 21 kg (Young 2008f) and Derryvorrigan [c092] with 21.5kg (Young 2008d).

These figures certainly give an indication of the amount of slag produced during a smelt, but it is unlikely that all the slag was removed from pit walls, nor all the fines from the pit base, between smelts. The weight produced during a single smelt may therefore be a little less. None-the-less, the weight of slag suggests that a very substantial bloom was generated.

Evidence for the superstructure for the furnace was provided by the ceramic material in [c018]. Such evidence is vital for it supplements the limited evidence provided by most furnaces. The ceramic fragments suggested a fairly thick walled structure with numerous repairs.

The blowhole area appears to have abruptly overhung the pit below – jutting into the furnace perhaps 10-20mm. Although this might be seen as evidence for a protruding tuyère, at Adamstown, a zone of overhang was suggested by fired clay adhering to the top of the FB over a substantial length of its margin. Several other pieces of fired superstructure suggest the presence of an overhang. One neatly fired and vitrified surface is curved to be concave in one direction and convex in the perpendicular direction. Such a piece might be from a "bottle-shaped" furnace, in which an overhanging and inward-sloping lower section continued up into a central narrower, more vertical-sided upper section. A similar shape was suggested, on rather better evidence, for furnace [c397] at Derrinsallagh 4 (Young 2008f).

The furnace materials include substantial evidence for repair, possible failed repair, and possibly the loss of substantial pieces of superstructure into the furnace during its operation. The dumping of material in [c017] might have been part of regular furnace clearance between smelts, but the damaged superstructure suggests it might also have been associated with either demolition, or more likely a fairly substantial repair of the furnace superstructure.

Deposit [c018] also contained a large number of large limestone boulders. Whilst these may be a separately-sourced set of dumped materials, there is slight possibility that they are integral to the furnace debris. There are examples of the use of large stones in the superstructure of furnaces, albeit not in Iron Age Ireland. They have been used as a protective kerb or step in some large furnaces (e.g. the medieval furnaces in Coed y brenin, Wales) and as part of the shaft itself, particularly in clay-poor settings (e.g. early medieval Iceland)

Smithing is not well represented on the site, with just inconclusive microresidue evidence and no macroscopic smithing slags (apart from a single doubtful SHC from [c018]. The microresidue evidence derives from two separate areas – the SE end of the posthole cluster in the centre of the site, and a patch of charcoal [c093] close to furnace [c043] in the south of the site.

The three large burnt features ([c017], [c063] and [c065]) are difficult to interpret. Pit [c065] was lacking any archaeometallurgical residues. It is complicated by the apparently later stakeholes and postholes which cut it and the original morphology is uncertain. Pit [c063] had a partially burnt base, and a charcoal-rich fill bearing a very small quantity of slag. Pit [c017] had a slag- and stone- rich backfill, above a basal charcoal-rich layer. The size of these features suggests that they might be smithing hearths (although they are a little large for this; smithing hearths are more commonly around 1m diameter) or charcoal kilns. Their proximity to the metallurgical activities makes the interpretation as charcoal kilns attractive. Kilns on other sites have been recorded with slag-rich fills; presumably they formed convenient sites for dumping waste on their abandonment.

4. Summary

Site 9 provides evidence for iron smelting in two slagpit furnaces ([c043] and [c048]), whose morphology suggests an early Iron Age date. The furnaces were of the slagpit variety, with evidence from material dumped in pit [017] suggesting they may have had a "bottle-shaped" superstructure.

Smithing is not well represented amongst the residues, and although [c093] might represent evidence for smithing this is far from certain.

The large burnt features ([c017], [c063] and [c065]) are tentatively suggested to have been charcoal-making kilns, providing the fuel for the smelting operations.

5. Evaluation of potential

The combination of the material in-situ in furnace [c043] and those dumped into adjacent feature [c017] provide an excellent suite of materials with which to define the nature of iron smelting on this site.

Such an assemblage would reward detailed investigation and analysis. The completeness of the suite of materials (lacking only the actual iron produced itself!) would permit the potential for construction of a mass-balance for the furnace, allowing calculation of the amount of iron being produced (following the methodology of Thomas & Young, 1999a and 1999b). The actual productivity of these early furnaces is still an unknown, and is an important research goal.

Any such analytical investigation should examine all the materials involved (FB, flow slags, slag fines in the pit, furnace ceramic and ore), with chemical compositions obtained for a wide suite of examples, and textural/mineralogical studies conducted on representative examples of the various slag types.

All the materials from this site are recommended for retention.

References

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. Evaluation of slag from Tullyallen 6, Co. Louth (00E00944). *Geoarch Report 2003/10*. 2pp. + 2 figs.

YOUNG, T.P. 2005. Evaluation of archaeometallurgical residues from the Heath-Mayfield N7 development (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635). *GeoArch Report 2005/12*. 28pp.

YOUNG, T.P. 2006. Evaluation of archaeometallurgical residues from sites on the N25, Co. Waterford (Woodstown 6, Adamstown 1,2,3). *GeoArch Report 2006/15*. 38pp.

YOUNG, T.P. 2008a. Archaeometallurgical residues from Cherryville Site 12, Kildare Bypass. 01E0955 *GeoArch Report 2007/24*. 33pp

YOUNG, T.P. 2008b. Evaluation of metallurgical residues from Cloncollig 2, Co. Offaly, NTB06, A033/E2850137. *GeoArch Report 2008/09*. 4pp

YOUNG, T.P. 2008c. Evaluation of Archaeometallurgical residues from the M7/M8 Contract 2: Derrinsallagh 4 (E2180). *GeoArch Report 2008/23*.

YOUNG, T.P. 2008d. Evaluation of Archaeometallurgical residues from the M7/M8 Contract 2: Derryvorrigan 1 (E2193). *GeoArch Report 2008/26*.

YOUNG, T.P. 2008f. Evaluation of Archaeometallurgical residues from the M7/M8 Contract 2: Lismore-Bushfield 1 (E2220). *GeoArch Report 2008/27*.

YOUNG, T.P. 2008e. Evaluation of Archaeometallurgical residues from the M7/M8 Contract 3: Clonrud 4 (E2167). *GeoArch Report 2008/30*.

YOUNG, T.P. 2008f. M7/M8 Contract 2. Detailed recording of furnace C397, Derrinsallagh 4 (E2180), *GeoArch Report 2008/34*.

YOUNG, T.P. 2009a. Evaluation of archaeometallurgical residues from the M7/M8 Contract 1: Leap 1 (E2131) *GeoArch Report 2009/03*

YOUNG, T.P. 2009b. Evaluation of archaeometallurgical residues from the M8/N8 Cullahill-Cashel: Ballydavid AR26 (E2370), *GeoArch Report 2009/30*, 7 pp.

YOUNG, T.P. 2009. Evaluation of archaeometallurgical residues from the N9/N10 Waterford-Kilcullen, Site 3-5, Milltown/ Ballynamorohan, Co. Kilkenny (E2499), *GeoArch Report 2009/38*, 12 pp.

Table 1: Summary catalogue by context and sample. #= find.

c	*s*	*name*	*wt*	*no.*	*notes*
1	#3		24	4	glassy lobate clinkers, well flowed. Post-medieval steam engine residues?
1	#6		4	1	flow slag bleb
17	18		458	1	very dense block of stacked flow lobes and wall contact - probably from wall just bellow burr
18	#1		304	1	Block of dense stacked flow lobes around large charcoal, possibly in contact with both wall and floor?
			454	13	smaller flow slag fragments very similar to above block
			164	1	deeply vitrified oxidised fired ceramic block
18	#2		102	1	low density slightly concretionary material? Material between two large wood moulds c120mm long, with squared sections
18	3	magnetic 0.25mm	9	bulk	mainly stone, but contains a small proportion of flake hammerscale
18	3	magnetic 1mm	15	bulk	mainly stone, but has a very of slag debris in small amounts, a few spheroids, some slag sheets and some probable flake hammerscale (but very little)
18	8		66	bulk	5 pieces of oxidised fired clay, 3 pieces of vitrified clay, 1 piece vesicular slag, 1 stone plus bits/dust
18	8		378	4	variably slagged oxidised fired vitrified lining
			140	1	buff coloured lump of fired but unaltered lining, gravelly
			42	6	small fragments of oxidised fired lining
			742	1	lump from burr region - shows slagged reduced lining - but face covered in accreted debris of oxidised clay
18	9	*bag 1 of 2a*	1310	2	adjoining mass from furnace wall - show oxidised wall overlain by vitrified surface - then wedge like repair, also with vitrified surface, terminating downwards in cross cutting vitrified surface - suggesting repair has largely fallen out. Forms are of wall about 200 wide and 140 high
			212	1	block of pale vitrified vesicular ceramic with complex purple surfaces
			184	6	flow slag pieces with good dense prills around large moulds
			998	5	dense flow slag bocks with one smoothish concretionary surface - presumably a wall or floor contact
			74	1	vitrified ceramic, pale gravelly, but not intensely altered as material above
			64	1	irregular block of dense vitrified material - probably a ceramic/stone mixture, very dense - so may be from burr area
			450	16	dense flow slag prills and associated fragments
			686	1	SHC-like block of slag, dense above becoming more openly prilly below- probably from central part of FB
			168	2	deeply vitrified oxidised wall fragments - probably part of the repaired face seen above
			110	4	charcoal rich slag fragments
			32	4	various lining slags and possibly vitrified stone
			64	1	curved piece of deeply vitrified reduced lining with very neat curved surface
			54	20	small slag fragments from sieved washings

c	s	name	wt	no.	notes
18	9	*bag 2 of 2a*	952	1	large block from FB on blowing side. Shows arcuate ceramic protruding into furnace with burr behind, laterally the wall shows a non-wetted contact with a pile of flow lobes. The top of the FB is smooth and has a small patch of glassy material on top - clearly indicating supply of wall material and probably blowing location
			922	1	block with possibly over-hanging oxidised fired wall, with pendent rounded mass of white ceramic with maroon surface
			536	1	rounded, contorted mass of white ceramic with purple glaze
			230	1	highly vesicular pale ceramic with purple glaze
			232	1	vitrified oxidised fired ceramic, with multiple vitrified surface - probably part of same face as two large blocks below
			122	1	deeply vitrified and vesicular pale ceramic with maroon surface
			110	1	slab of densely vitrified pale gravelly ceramic with maroon surface - curiously appears to be vitrified on both surfaces - though one side shows more flow
			144	1	piece with dense flow slags running of at right angles to a ceramic (reduced surface) - could be foot of wall, but probably from base of overhanging blowhole or tuyère - overhang is just possibly curved?
			258	1	dense irregular rounded mass of charcoal rich slag (at least on surface) - may be contorted
			434	1	block of dense slag with slightly lobate top with a suggestion of being blown - but surface weathered. Base concretionary with fine ash and charcoal/wood. Could be fragments from top of FB - or apparent blown surface may just be a flow surface and this is a basal flow
			166	16	fragments of broken flow slags - all dense
			78	6	fragments of more lining dominated material
18	9	*bag 1 of 2b*	704	1	block of charcoal rich slag with one extensive smoothish though bumpy surface - possibly a wall contact from a side away from the blowhole?
18	9	*bag 2 of 2b*	814	1	block of slag with large charcoal fragments, one smoothish accreted surface is probably top of FB, with prilly lower face below - about 60mm thick
			558	1	piece from near lip of FB, full of very large charcoal- shows narrow band of wall reaction with reduced clay attached, and below that are flowed prills
			686		dense slightly rounded lump of massive charcoal-rich flow slags- probably from near wall contact
			58	4	flow slag fragments
32	57	slag	56	bulk	62 small fragments of slag, some charcoal rich, some probably from flow slags, probably residual smelting slag fragments
39	10	magnetic	4	bulk	mainly stone, some very highly magnetic oxide particles, but no slag
45	14		6175	2	major piece of FB, 180x300x120 burr area with radius 150mm, strong reaction with side to 100mm down, then raises off ceramic. Base prilly.
			238	52	debris from FB above
45	14		796	1	dense classic flow slag between large moulds of up to at least 120x40x25
			958	1	lump of charcoal rich FB material with prilly base, contains wood moulds of c30mm section
			794	1	upper massive FB-like charcoal-rich material grading down into stalactitic prills of flow slag
			506	1	curved piece of flow slag with high density axially, hinting this is a piece off the wall
			4	1	flow slag blebby piece

c	s	name	wt	no.	notes
45	14		3075		mainly rather rubbly flow slag material, but 936g (7 lumps) are probably from the FB area - include 2 plano-convex lumps - each of about 100g which look like small SHCs
			3555		mixture of dense flow slags and ashy sheet-like material - probably from floor - some of which is in rather SHC-like shapes, but others clearly not
45	14		388	1	classic dense descending prill mass, with hint of wood moulds
47 (24 on bag)	17		252	bulk	as 502 g material below - but dominated by poor flow slags, including some which appear to be drips of lining material
47 (24 on bag)	17	magnetic	502	bulk	mainly thin ferruginous crusts on very fine charcoal debris, but also spheroids (including many multiples and coffee beans). Quite a lot of small quartz grains also bound in, together with possible ore. Some poor flow slags in ashy matrix,
47 (24 on bag)	17		314	bulk	picked good dense flow slags in delicate prills
47	17	non-magnetic metal waste	34	bulk	almost entirely 5-10mm spheroids
47	17	metal waste	82	bulk	small pieces of blebby flow slags
47	17	magnetic 5mm	76	bulk	Mainly "sinter", with probable ore grains of up to about 2mm. Some slightly more slaggy material with fine charcoal inclusions
47	17	magnetic 1mm	530	bulk	fine grained "sinter", plus substantial amounts of material rich in fine charcoal debris. This sample is very rich in spheroids, some multiple, but mainly perfect.
48	#1		80	55	assemblage of fine flow slags, spheroids and fragments of related vesicular slags - good furnace base assemblage
48	#2		8	1	small concretion around elongated iron piece (nail shank?) - now completely exploded
49	19	metal waste	16	4	dense flow slags in small prills
49	19	magnetic 1mm	100	bulk	furnace floor material - spheroids, blebs and rather amorphous debris that is probably ore-related
49	19	magnetic	8	bulk	mainly stone, contains a few fine grained slag fragments plus a moderate number of maroon coloured grains that may be fired ore
49	19	magnetic	3	bulk	stone, some charcoal, no slag
52	25		242	c90	rather scrappy assemblage of probable furnace floor material, some dense flows, mainly hollow - the breakage of which leads to formation of slag sheets. Lots of poor quality blebby slags ranging into fuel ash and lining slags. Several pieces appear to show a black glass overlying a ferruginous charcoal rich material. Several pieces are agglomerated. One spheroid and one shiny flake provide a hint of smithing - but this assemblage is probably from smelting.
66	37	magnetic 1mm	8	bulk	mainly stone, a couple of slag fragments and a few pieces of probable dense ore
67	31		3	bulk	stone
71	35	magnetic 1mm	3	bulk	mainly stone, with a few fuel ash slag particles, plus some sheets - one probably a slag flat – the other arguably true flake hammerscale

c	*s*	*name*	*wt*	*no.*	*notes*
82	38	magnetic 1mm	8	bulk	mainly stone, some charcoal, a few pieces of possible BOM
86	43		4	15	tiny fragments of fuel ash slag. Mostly dark grey and highly vesicular with relict very fine quartz grains. Some strongly foliated suggesting partial melting of shale. Two pieces are more homogeneous vesicular slightly green glass. One piece shows red surface colour. Probably not metallurgical
93	44	magnetic 1mm	3	bulk	almost 50% slag debris including a small quantity of flake hammerscale
97	45	magnetic 1mm	4	bulk	mainly stone, some slaggy particles, but these are of a clinkery appearance and maybe fuel ash slags (and non metallurgical)
107	51	magnetic 1mm	6	bulk	mainly stone, possible Mn concretion, some very fine highly magnetic material of uncertain origin (not hammerscale)
131/133/135	47	magnetic 1mm	4	bulk	stone and charcoal with one irregular slag droplet
131/133/135	47	magnetic 5mm	1	1	siltstone
139	52	magnetic 1mm	3	bulk	mainly stone, some very highly magnetic particles of uncertain nature, a few scraps of fuel ash slag
144	53		5	bulk	mainly stone, but a few good spheroids and a very small number of other slag fragments, plus a couple of very strongly magnetic particles with a maroon colour that are probably roasted ore
149	67	magnetic 1mm	6	bulk	almost entirely natural stone, some charcoal and couple of pieces of fuel ash slags (clinkery appearance, slightly red, highly vesicular)

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