GeoArch

Report 2025/13

Assessment of archaeometallurgical residues from Penrhyn Quarry (HD24-001)

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10th September 2025

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Abstract

This excavation produced evidence for iron smelting in a small bloomery furnace, apparently dating to the beginning of the early medieval period.

The furnace, an associated pit, and other adjacent deposits produced a modest archaeometallurgical residue assemblage totalling 38.5 kg. Preservation was highly variable, with some material appearing very fresh but other material was extremely poorly preserved. It is assumed that this differential preservation is associated with the location of the residue with respect to the groundwater level.

The residue assemblage is unusual in many respects. Approximately 41% of the residues were flow slags, probably largely slags tapped from the furnace. The majority of this material showed no reddening of the surfaces of the flow lobes. This is normally an indicator that the slags had not been tapped outside the furnace. However, the presence of a high proportion of manganese may reduce the degree of reddening – and that may be a factor here. The flow slags typically suggested flow in a narrow space – there were no big tapslag cakes; the largest block of flow slag weighed 300g.

Approximately 51% of the material appeared to be slags that had cooled in the furnace without flow and nearly 5% of the residue assemblage comprised narrow slag rods.

These features, taken together, suggest that the technique of operating the furnace involved a high degree of manipulation, including rodding through the arch into the internal slag to encourage slag flow and the rapid removal of any slag which did tap from the furnace. The unusual layout of the waste pit at right angles to the axis of the furnace and channel can be viewed as an elegant solution to allow the smelter safely to kneel or stand close to the furnace to perform this manipulation.

Parallels can be seen with the technique indicated for assemblages from some furnaces of Roman age. Thus, the Penrhyn Quarry smelting site may be viewed as showing a continuation of practice from the Roman period into the early medieval.

The assemblage can also be paralleled by early medieval material from Cefn Graianog (Gwynedd) and Llandre (Ceredigion), dated to within the 7th to 9th centuries. The evidence from Penrhyn Quarry now allows these sites to be viewed as showing further continued use of the same technique into later centuries, rather than as a re-introduction of slag-tapping techniques, as had previously been supposed.

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Methods

Background

This assessment was commissioned initially by Jane Kenney, with responsibility subsequently transferring to Stuart Reilly of Heneb (the project spans the period of transition from the Gwynedd Archaeological Trust to the successor organisation, Heneb. The materials described and assessed here arise from excavations undertaken on land at Penrhyn Quarry, Bethesda, Gwynedd (Project (G2534/HD24-001))

Assessment

All submitted materials were examined visually in August/September 2025, using a low-powered binocular microscope where required. They have been catalogued (Table 1) and assessed. No instrumental analysis has been undertaken,

Results

General

The furnace, an associated pit, and other adjacent deposits produced a modest archaeometallurgical residue assemblage totalling 38.5 kg.

This residue assemblage almost entirely derives from bloomery ironmaking but is unusual in many respects. It has been divided here into five broad classes of material: flow slags, slag rods, rough/granular internal slags, slag bowls and furnace ceramic (Table 2).

The abundant flow slags (41% of the assemblage) have morphologies closely resembling tapslags (i.e. slags that have been tapped from the furnace to cool outside the structure) but thy lack the typical maroon surface colour of tapslags. Some 5% of the assemblage comprises slag rods. A very high proportion of the residues appear to have cooled inside the furnace (51% of the assemblage).

Details

Flow slags: approximately 41% of the residues were flow slags, probably largely slags tapped from the furnace. They were divided into two groups – those with smooth upper surfaces and those with rough surfaces. Flow slags with smooth surfaces may occur in both slag-tapping and non-tapping furnaces. The rough-surfaced flow slags would be more typical of flows travelling through the fuel or ash bed – and are accordingly more common in non-tapping furnaces than in tapping furnaces.

A high proportion of the flow slags showed no reddening (which is normally an indicator that the slags have been tapped and cooled in the open air outside the furnace) of the surfaces of the flow lobes. However, the presence of a high proportion of manganese may reduce the degree of reddening – and that may be a factor here. The flow slags typically suggested flow in a narrow space – there were no big tapslag cakes (the largest block of flow slag weighed only 300g) and many had a rather narrow shape in plan.

Slag rods: 30 pieces of slag rods, weighing a total of 1.9kg (4.8% of the total) were recovered. The rods showed rough or dimpled surfaces, probably indicative of cooling in an ash bed. They wee generally 15-25mm in diameter. Similarly-sized tool marks occurred on the base of internal slag bowls.

Rough/granular slags: these slags typically occurred in rather irregularly rounded lumps. The degree of weathering prevents close description of the surface textures, but this group includes both apparently granular slags (perhaps reflecting a coarse-grained olivine) and some that appear rough because of a higher degree of fine porosity.

Some of the slags with this surface texture, perhaps those that had formed towards the front of the furnace, had intercalated flow slags.

Slag bowls: most of the slag bowls are interpreted as examples of slags forming in the base and against the lower sides of the furnace. In some examples, however, an alternative origin as smithing hearth cakes cannot entirely be excluded.

Context (4015) produced a relatively complete example (albeit in three fragments). The detailed morphology of the base suggested that it had formed against the angle of the base of the wall. It seems possible that these denser internal slags are associated with the rear, blowing, wall of the furnace, with fresh slag descending close to the wall.

Furnace lining: pieces of the furnace ceramic were relatively rare (just 3% of the assemblage). In general, they provided little information on furnace construction or morphology. Most of the furnace ceramic derived from the floor of the furnace (4042); here one fragment showed an evenly vitrified front face, but the rear shows an arcuate discontinuity in the underlying ceramic that might just represent the margin of a pre-formed tuyère block.

Distribution

The residues derived from seven contexts from the excavation plus the Testpit 32.

Little information about the fill of the furnace removed during excavation of the testpit is available at the time of wirting. Just 92g of residues (12 pieces) were included within the submitted material. The base of the furnace (4042) produced 700g of furnace ceramic.

The fill of the channel to the furnace (4041) contained 639g of residue (18 pieces). This was interpreted during excavation as a deliberate blocking. There seems little reason why that channel might have been blocked after a smelt had been completed, and so the material may simply represent a pile of material left there during furnace clearance, or even slags redeposited to that location later. On the other hand this might be a suitable location for a fulcrum to provide solid leverage during the extraction of the bloom.

The pit [4017] had lower dark charcoal-rich fill (4040) and upper pale fill (4016) (also extending through the channel). Context (4040) produced 7.4kg of slag (714 pieces) and (4016) 1.2kg (250 pieces).

The vast majority of the assemblage derived from the 'occupation deposit' (4015) and the overlying peat (4007), which between them account for 73% of the assemblage.

Given the small size of the context assemblages, the proportions of the residue facies in the different contexts (Table 3) are mostly reasonably consistent. However, the early contexts within the pit and furnace show an assemblage with slightly more internal slag with respect to flow slag than do the later spreads.

Interpretation

The assemblage is characterised by a low proportion of flow slags that may have been tapped from the furnace, by the ambiguous evidence for tapping, and by the presence of slag rods.

The presence of slag rods implies that the furnace was intended to tap slag. The presence of a high proportion of flow slags in narrow amalgamations suggests the passage of those flow slags into the channel. That those slags were not strongly reddened by oxidation could related to two different factors:

- firstly, it is possible for a furnace to be operated with the tapping channel full of burning charcoal. In this method the channel is heated so the slag would flow further and the slag would be at less chance of oxidation. However, the rodding of the furnace base would have to be undertaken largely unsighted.
- secondly, it may be that the colour change is inhibited by the presence of large quantities of manganese in the slag

In either case slags like those at Penrhyn could result.

The slag rods indicate a process that involves considerable active interaction with the progress of the smelt by the smelter.

The remains of the furnace are slight, but the form of the channel and external pit with their 'L' shape in plan, is striking. This arrangement would allow the waste removed from the furnace to be moved sideways into the pit and out of the direct line of the smelter's activity.

The furnace is moderately small (note: the dimensions discussed here have mostly been digitised from the Post-excavation Project Design, Kenney 2024, figure 14 – for which the scale bar is erroneous: it is 2m, not 1m, in length, but the marginal coordinates are correct). It was 'D' shaped, with the dimensions (Kenney 2024, 26) 0.47m by 0.38m and was 0.12m deep. The straight section of wall to the south was 380mm wide. A straight and locally overhanging, rear wall is likely to be indicative of the side from which the furnace was blown (and in this case corresponds to the direction of maximum space for the bellows).

The channel was not quite perpendicular to the straight wall, was 260mm wide and 130mm deep. It was oxidised over much of its length (approximately 320mm, but only across its whole width for the first 170mm), before the apparent blocking on the edge of the pit – which extended away from the axis of the furnace at right angles along the inside of wall (4014).

The intense scorching of the channel to 170mm outside the basal pit of the furnace may be indicative of the approximate thickness of the furnace superstructure.

Interestingly the excavation records appear to indicate that no superstructure survived around the periphery of the furnace pit and indeed its shallow depth hints at a degree of truncation. Parts of the vitrified interior face of the furnace were recovered as context (4042) lying directly on the floor of the pit.

This has implications for the degradation of the furnace. Firstly, the pit must have been cleared of all its contents at the end of the last smelt to have taken place, and secondly that collapse (or demolition) of the furnace happened before any other significant deposit had accumulated within it.

The channel is short, but perfectly adequate to provide a location for the cooling of the very modest tapped flow slags. Once solidified, they could be easily moved aside into the pit. Having the pit extending off-axis would allow the smelter, probably kneeling in the entrance to the structure, to use a poker through the arch of the furnace without having to do so above the hot slag, charcoal and other waste. The total distance from a reasonable position to stand or to kneel in the entrance through the wall to the back of the furnace interior is only approximately1.4m, so makes a safe and comfortable position to work when using a poker of only around 1m in length. It is a very elegant solution to the need for access to manipulate the contents of the furnace in the technique apparently being used here.

After a smelt, presumably both the furnace and the pit would be emptied and cleaned. It is likely that there was a dump (or dumps) of waste somewhere adjacent the location. It would seem likely The plot of slag distribution (Kenney 2024, Figure 18) hints that the slag may, at least in part, have been piled against the inner side of wall (4014). that degradation of that dump provided the spread of slag-rich material that eventually covered the features. The pale upper fill of the cut feature may even similarly represent an earlier redeposition of the outer parts of the degrading clay superstructure to the furnace. Thus the 'occupation layer' may represent simply a later redistribution of the slag (and even perhaps the layer on which it had been dumped), rather than a later occupation event – which

would simplify interpretation of the radiocarbon dates. The current dates (SUERC-133902 (GU71296R), 1601 ± 18 BP for oak bark from (4040), calibrating to cal AD420-540; SUERC-133903 (GU71297R), 1476 ± 18 BP for oak bark from (4040), calibrating to cal AD560-650; SUERC-133906 (GU71298R), 1750 ± 17 BP for Rosaceae charcoal from occupation deposit (4015), calibrating to cal AD240-370) have the oldest age from the stratigraphically highest deposit, but this would be resolved by such redeposition.

Discussion

The residues from this site are of great importance since they occurred in association with the physical remains of the associated furnace and because they document a very poorly known technology.

Two other Welsh sites have produced rather similar assemblages: Llandre (Ceredigion; Young 2016, Jones *et al.* 2018) and Cefn Grainog (Gwynedd; Young 2015a, 2015b; McNicol 2016).

Llandre produced a small assemblage (4.6kg) from a waste deposit and a possible furnace. The makeup of the assemblage was very similar to that at Penrhyn, As at Penrhyn Quarry, there were flow slags with both shiny (42% of the assemblage) and rough (7% of the assemblage), in this case gravelly, surfaces. Slag rods were present but were counted within the rough-surfaced flow slags. Residues that were either 'furnace bottom' slags or just possibly smithing hearth cakes comprised 12% of the assemblage. Some 30% of the assemblage was provided by slags that could not be closely identified and 6% by furnace lining. Finally, 2% of the assemblage was provided by fuel ash slags, possibly from an ashy or sintered deposit on the base of the furnace.

The slag was recovered from two cut features within the interior of the enclosure. The lower deposits in the enclosure ditch produced a date 1563±32 BP (UBA-30455) which calibrates to cal. AD 420–560 at 95% confidence on a single oat grain. The metallurgical waste deposit produced a rather younger date of 1221±37 BP (UBA-24080), which calibrates to cal. AD 690–890 at 95% confidence.

Analysis of slag samples from Llandre suggested that the smelting had exploited a manganese-rich bog iron ore (the slags contained around 7% MnO) with a moderate phosphorus content (the slags contained 0.3% P_2O_5).

At Cefn Graianog multiple zones with features rich in archaeometallurgical residues were identified within an unenclosed settlement. This site has not been fully reported upon, so the dating is not properly refined. The initial archaeometallurgical work focussed on a small amount of microscopic material from the 2012/3 seasons (Young 2015a) that was tentatively interpreted to represent material from non-slag tapping furnaces. This activity was subsequently dated to the 7th-9th centuries. A second round of work examined the more abundant macroscopic material from the 2014 season (totalling 23kg) much of which apparently derived from a slag-tapping process. This assemblage derived from a further four complexes (buildings?) beyond that identified in 2013. One had very little evidence for metallurgy, one had smithing residues, one had smelting residues and one both.

The smelting residues from Cefn Graianog (Young 2015b) were dominated (41% of the assemblage) by varieties of flow slags, including individual prills and slag droplets, as well as aggregated flow slags morphologically resembling tapped slag. A few examples of these flows showed a degree of reddening and one showed deformation, with half of the flow inverted onto the other indicating manipulation of the semi-solidified flow. There was a small quantity of fragments of narrow slag rods and runners (1% of the total assemblage). Intriguingly, the assemblage included approximately 2.4kg of iron ore, but unfortunately this project never moved to the analysis phase..

These two sites form, together with Penrhyn Quarry, a group with very similar characteristics, indicative of a common smelting technique and tradition. They stand in contrast to the slightly later assemblage from South Hook, Dyfed (Crane & Murphy 2010; Young 2006, 2010), which showed larger and wider tapslag flows (up to 0.6 x 0.2m and 3kg) and a complete lack of slag rods. This technology is more similar to, but not identical with, the variety of slag tapping furnace that became widely employed across southern Britain from the 11th (and possibly 10th) century.

The significance of slag rods has been much debated over recent decades but finds of rods attached to internal slag bowls and a consistent relationship between their recovery and a particular style of Roman furnace has now clarified their origin.

They form as slag infills of holes created by the insertion of a rod or poker into the basal chamber of a bloomery furnace and particularly into the mass of slag that may chill there (commonly referred to as a 'furnace bottom'). Repeated insertions may eventually develop complex multi-rod slag masses as the smelter attempts to permit liquid slag to flow freely away from the base of chamber and out of the furnace.

Such a technique appears to be particularly prevalent in the use of the large Roman furnaces, including those commonly referred to as 'domed' furnaces in the Weald and elsewhere (e.g. Young 2022), and those that produced the 'Cardiff-type' slag assemblage found around the Forest of Dean and South Wales (e.g. Young 2014, 2021). Not all Roman furnaces appear to have been operated in this way, but it is becoming clear that a significant proportion were. These Roman technologies are also notable for the relatively low proportion of the slag that ends up as tapslag of conventional appearance (ranging from 28% at Moat Farm Newent, 29% at Kingswood and 33% at Lydney B Phase II to 45% at Cardiff Castle; Young 2023, Young 2017, Young 2021b, Young & Kearns 2011 and Young 2021b respectively). This proportion is directly comparable with that observed at Penrhyn Quarry.

The previous interpretation of the technology of the Llandre and Cefn Graianog sites was to see them as potentially providing evidence for the onset of slag tapping techniques, within a region that had been using non-tapping furnaces. That interpretation can now be rejected in favour of seeing these sites instead as using a technique persisting from the Roman period.

If the Penrhyn Quarry smelting is viewed as a part of this tradition, extending back to the 1st century AD in other areas, itself perhaps of approximately 5th - 7th century date and followed by the Llandre and Cefn Graianog smelting in the 7th-9th centuries, then the site may form the first direct intermediate evidence for the continuity of the technique.

Further work

These materials are capable of providing further information of archaeological significance, including providing information on ore provenance, reaction chemistry and the likely character of the iron product.

A programme of laboratory analysis is proposed, closely following the suggestion outlined previously – with minor adjustment, now that the archive of material has been catalogued.

The assessment found no certain evidence for smithing microresidues being present in the bulk samples in any significant quantity, nor much potential macroscopic evidence for the onward working of the iron. The 645g iron-bearing slag cake from (4007) <81> might potentially be from smithing and certainly contained iron; it is recommended that SEM investigation of this piece is substituted for the investigation of the two samples of microresidues suggested in the provisional design.

It is recommended that the focus of the laboratory work is provided by the bulk elemental analysis of examples of the various residue facies that are best-preserved (which will be examples in the most part from (4007)). Microstructural investigation by aSEM will be limited to key pieces where this technique can provide additional information.

Samples should be chosen as follows:

6 bulk analyses (by XRF/ICP-MS)
- 1 x flow slag
- 2 x 'rough' slag
- 2 x bowl slag
- 1 x hearth lining

3 SEM mounts
- 1 x 'rough' slag
- 1 x bowl slag
- 1 x bowl with iron/SHC

References

All GeoArch reports are available for download from: https://www.geoarch.co.uk/report%20library/

CRANE, P & MURPHY K., 2010, Early medieval settlement, iron smelting and crop processing at South Hook, Herbranston, Pembrokeshire, 2004–05. *Archaeologia Cambrensis*, **159,** 117-196.

JONES, I., WILLIAMS, D. & WILLIAMS, S. (with contributions by W. Curruthers, R Madgwick, and T.P. Young), 2018. Early medieval enclosure at Glanfred, near Llandre, Ceredigion. *Archaeologia Cambrensis* **167**, 221-243.

KENNEY, J 2024. Penrhyn Quarry, Bethesda, Preliminary Report and Post-excavation Project Design. Heneb Report 1790.

McNICOL, D., 2016, Cefn Graianog Quarry, Gwynedd. Assessment of Potential for Analysis Report. Gwynedd Archaeological Trust, Report 1312.

YOUNG, T.P. 2006. Evaluation of archaeometallurgical residues from South Hook LNG terminal, Dyfed (52787). *GeoArch Report 2006/14.* 12pp.

YOUNG, T.P. 2010. Archaeometallurgical residues from the South Hook LNG Terminal. *GeoArch Report 2010/03*, 54 pp.

YOUNG, T.P. 2014. Roman military control on iron-making in South Wales. Pp. 215-226 *In*: B. Cech and Th. Rehren (Editors), *Early Iron in Europe,* Instrumentum Monographies.

YOUNG, T.P. 2015a. Assessment of archaeometallurgical residues from Cefn Graianog, G1598 (2012-13). *GeoArch Report 2015-09.* 4pp.

YOUNG, T.P. 2015b. Assessment of archaeometallurgical residues from Cefn Graianog, G1598 (2014). *GeoArch Report 2015-19*. 23pp.

YOUNG, T.P. 2016. Archaeometallurgical residues from Llandre, Ceredigion. *GeoArch Report 2016/36*. 19pp.

YOUNG, T.P. 2017. Ironworking residues from Kingswood, Gloucestershire (ACW451). *GeoArch Report 2017/06*, 93pp.

YOUNG, T.P. 2021a. Archaeometallurgical residues from Cardiff Castle. *GeoArch Report 2021/03*, 108pp.

YOUNG, T.P. 2021b. Analysis of archaeometallurgical residues from Lydney B North, Phase II. *GeoArch Report 2021/11*, 53pp.

YOUNG, T.P. 2022. Archaeometallurgical residues from Bexhill. *GeoArch Report 2022/09*, 234pp.

YOUNG, T.P. 2023. Assessment of archaeometallurgical residues from Moat Farm, Newent (MFN22). *GeoArch Report 2023/30*, 22pp.

YOUNG, T.P. & KEARNS, T. 2011. Evaluation of metallurgical residues from the New Interpretation Centre, Cardiff Castle, Cardiff [ST181765]. *GeoArch Report 2011/02*, 27 pp.

Table 1: catalogue of submitted materials. Assm = assemblage of small particles

C	F	label	item wt	item no	notes
TP32	79		50	7	rough slags
			20	3	smooth surface flow slags
			22	2	rough surfaced flow slags
4006	1	slag	12	2	smooth surfaced flow slag
4006	2	slag	23	3	smooth surface flow slag
4006	6	slag	82	4	smooth surfaced flow slag
			6	2	rough, porous slag
			6	1	stone/concretion
4006	47	slag	86	5	smooth surfaced flow slags
			112	1	block of brown weathered slag with flow lobes emerging from front; base also shows lobe contacts; with inclined base; base passes into gravelly material on one edge - approaching burr?
			25	3	rough slags
			2	assm	dust and debris
4007	3	slag	17	2	smooth surfaced flow slag
			8	1	rough, porous slag
4007	4	slag	60	2	smooth flow slag
			9	1	dense smooth charcoal mould bearing slag
			11	1	low density vesicular slag, possibly from a rod
4007	5	slag	9	assm	dust and debris
			41	1	foot of wall dense slag with hint of non-wetted flow lobes on one side
4007	7	slag	130	6	smooth surfaced flow slag
			70	1	rough, porous slag
4007	8	slag	29	6	low density rough slag
			18	5	smooth surfaced flow slag
			3	assm	dust and debris
4007	9	slag	34	5	smooth surfaced flow slag
4007	10	lag	10	1	rough flow slag
			6	1	porous, rough slag
4006	11	slag	41	1	smooth surfaced flow slag

4007	12	slag	377	1	indurated and vitrified sandy gravel with some slag adhering, presumably from lower part of blowing wall, may be multilayer
			120	1	dense slag block, probably foot of wall FB
4007	13	slag	55	1	charcoal mould rich slag, in the form (probably) of a channel, 40mm wide by 25mm deep
			15	1	smooth surfaced flow slag
4006	14	slag	68	1	granular rough slag lump
			11	2	granular slags containing flow lobes
4007	15	slag	29	1	smooth surfaced flow slag
4007	16	slag	58	2	granular slag containing flow slag lobes
4007	17	slag	181	5	smooth surfaced flow slag, one large piece 124g is possibly reddened and like tapslag cake
			19	10	low density, porous, rough slags
			7	assm	dust and debris
4007	18	slag	14	1	smooth surfaced flow slag
4007	19	slag	26	1	smooth surfaced flow slag (probably reddened)
4007	20	slag	8	1	rough slag now crushed
4007	21	slag	56	6	rough slags
			15	2	smooth surfaced flow slags
4007	22	slag	7	1	porous, rough slag
4007	23	slag	29	1	smooth surfaced flow slag with occasional fuel dimples on upper surface
4007	24	slag	88	1	smooth surfaced flow slag, in narrow V-shaped runner base
4007	27	slag	24	3	smooth surfaced flow slag
			17	1	rough slag
4007	28	slag	27	2	rough slags
4007	25	slag	46	1	smooth surfaced flow slag
4007	26	slag	41	3	smooth surfaced flow slag
			30	2	rough surfaced flow slag
4007	29	slag	484	1	dense slag block, appear to be foot of wall, wall finely dimpled, lower slag has large rounded vesicles,
4007	30	slag	18	1	slag/concretion attached to stone

			4	1	rough slag
4007	31	slag	27	2	dimpled slag fragments
4007	32	slag	26	1	dimpled/granular slag lump
4007	33	slag	7	1	dimpled slag lump
			15	1	smooth surfaced flow slag
			30	2	rough slag lumps containing flow lobes
4007	34	slag	91	1	granular slag piece of irregular form
4007	35	slag	23	3	rough-surfaced flow slag
			13	2	rough slag
4007	36	slag	22	1	smooth surfaced flow slag
			30	1	rotten/burnt stone
4007	37	slag	65	1	dimpled/granular slag lump (moderately fresh)
4007	38	slag	48	1	pad of homogeneous slag in contact with more granular material (below?)
			12	4	rough slag debris
			20	1	rough-surfaced flow slag
			8	1	stone
			6	1	low density pale slag with large vesicles
4007	39	slag	40	2	dimpled rough slag lumps
			16	2	smooth surfaced flow slag
			2	1	rough slag or concretion
4007	40	slag	16	2	smooth surfaced flow slags
4007	41	slag	16	1	rough-surfaced flow slag
			29	1	dimpled slag lump
			74	1	twisted sheet of burr attachment (needs cleaning)
4007	42	slag	222	13	smooth surfaced flow slag
			200	14	rough/dimpled slags
4007	44	slag	236	7	smooth surfaced flow slags (fresh)
			95	8	rough slags
			3	assm	dust and debris
4007	45	slag	6	1	smooth surfaced flow slag
			24	4	rough slag
			10	3	slag balls or small concretions

4007	46	slag	25	1	dimpled/granular slag lump (moderately fresh)
			7	1	smooth surfaced flow slag
4007	48	slag	4	1	poorly prilly rough slag
4007	49	slag	60	5	rough slags, some dense
			34	3	smooth surfaced flow slags
			30	2	rough flow slags, lobes embedded in other material
4007	50	slag	176	10	smooth surfaced flow slags
			122	11	rough slags, some in bulbous lobes
			3	assm	dust and debris
4007	51	slag	160	2	pieces with vitrified indurated wall (burr) abutted by rusty slags
			130	5	smooth surfaced flow slags
			56	4	rough slags
			126	1	block that appears to have two merged slag rods/tool marks
			27	2	stones
			23	assm	dust and debris
4007	53	slag	5	1	dimpled surface, probably from smooth surfaced flow slag
4007	54	slag	139	10	rough flow slags
			29	3	smooth flow slags
			51	10	rough slags
			7	assm	dust and debris
4007	55	slag	19	3	indeterminate slag fragments
			3	2	poor flow slags
4007	56	slag	400	15	dimpled slag nubs
			145	21	other rough slags
			228	23	smooth surfaced flow slags
			11	1	burr-like fragment
			23	assm	dust and debris
4007	57	slag	68	11	smooth surfaced flow slags
			21	4	poor flow lobed material
			180	5	dimpled/granular rough slag lumps
			28	1	vitrified oxidised fired wall
			7	assm	dust and debris
4007	58	slag	568	19	rough slags, includes many pieces with dimpled surfaces
			455	21	smooth-surfaced flow slags, some slightly reddened?

			17	assm	dust and debris
4007	59	slag	160	5	dimpled slag lumps
			139	3	dimpled material passing up into flow-lobed top
			264	11	smooth surfaced flow slags
			23	2	rough flow slags
			47	1	piece of basal crust to 15mm with tubular vesicles
			36	9	other rough slags
			5	assm	dust and debris
4007	60	slag	326	34	rough slags, includes many pieces with dimpled surfaces
			220	17	flow slags
			18	assm	dust and debris
4007	61		210	19	smooth surfaced flow slag
			252	11	rough/granular slags
			140	10	rough surfaced flow slags and flow slags with fuel mould contacts
4007	62		267	1	side of deep cake/bowl, base is large tool mark, c25mm across, 20mm deep, overlain by 30mm dense slag, top looks a little like unroofed vesicles
			40	1	fragment of c25mm rod, low density
			392	8	dense flow lag with smooth surfaces
			200	8	rough slag with internal prills or other evidence for flowage
			138	3	rough/granular slag lumps
4007	63		141	5	rough slags
			122	3	rough surfaced flow slags
			170	4	smooth surfaced flow slags
4007	64		162	6	rough surfaced flow slags
			58	5	smooth surfaced flow slags
			122	1	vitrified oxidised lining
			232	1	lip of slag bowl with indurated, almost burr-like contact; crust 25mm thick
			30	1	rough slag lump
			45	1	finger-like dense slag flow lobe; smooth below partial rough coating - could be tip of runner
			51	1	dense slag rod; 22mm wide by 15 deep
			75	1	elongate dimpled lump, possibly including rod/tool mark
4007	65		21	3	smooth surfaced flow slag
			79	1	curved piece, 90x35x30mm, appears to be slagged ceramic or stone; one face less vitrified, object has internal radius c80mm and is 25mm wide
4007	66		4	1	vitrified lining
			16	2	smooth surfaced flow slag
			29	3	rough surfaced flow slag
			16	3	rough slag

4007	67	23	1	slag spike; dense flow slag in single prill coming to a point, possibly reddened
		18	1	complexly vitrified lining fragment
		100	7	smooth surfaced flow slag
		46	2	dimpled/rough/granular slag
		66	1	dimpled low-density slag; probably from upper margin of plano-convex cake
4007	68	73	1	extremely dense slag spike, formed of prilly/dimpled slag - probably tip of rod insertion (fresh)
		188	5	smooth surfaced flow slags
		16	2	rough surfaced flow slags
		87	5	rough/granular slags
		47	1	rough/granular slag in lobate form - coalesced tool marks?
4007	69	182	1	fragment of slag bowl with large fuel moulds; dimpled curving lower contact
		48	1	flow slag prill encased in rough slag
		90	1	smooth surfaced flow slag
4007	70	134	4	rough slags
		11	1	rough slag with morphology suggesting it is the base of tool mark or rod
		507	11	smooth surfaced flow slags (fresh) (largest piece 185g)
		22	3	rough slags with signs of flow
4007	71	293	2	large pieces of low-density, nodular, furnace bottom material
		87	1	elongate piece with prill of smooth surfaces, flow slag overlying two parallel dimpled rods
		100	1	part of a dense plano-convex cake; internal texture similar to more complete example from (4015); lots of moulds of fine charcoal dust,
		143	1	(broken in 2) slag runner, main fill 50x20mm, with up to 15mm of rough slag on top
4007	72	275	14	smooth surfaced flow slags (fresh)
		42	1	slagged vitrified oxidised fired wall
		111	1	110mm long slag rod, rather rectangular section, 25-35mm wide, 17-30mmdeep
		65	1	dense flow slag with dimpled surface, possibly a rod fragment
		34	1	rough surfaced slag, possibly tip of rod
		40	1	dimpled slag lump
		32	1	rough slags with flow lobes
4007	73	100	5	rough surfaced flow slag
		200	8	smooth surfaced flow slag
		19	2	rough slag
		13	1	vitrified oxidised lining
4007	74	47	2	rough/dimpled/granular slags
		42	2	dimpled, prilly rough slag with fuel moulds
		166	8	smooth surfaced flow slag (fresh)
4007	75	309	25	smooth surface flow slags
		30	1	slag peel from oxidised fire wall
		60	3	dense flow slags with rough surfaces

			80	9	rough slags with signs of flowage
			152	11	rough/dimpled/granular slags
			75	2	fragments of slag rod, 45mm and 30mm wide
4007	76	stone	10	1	burnt stone, well glazed in wood ash glaze
4007	77		81	9	flow slags with rough surfaces or fuel contacts
			16	3	smooth surfaced flow slag
			61	3	rough granular slag pieces
4007	78		49	2	rough slags
			6	1	smooth surfaced flow slags
			3	2	rough slags with signs of flow
4007	81		645	1	partly exploded plano-convex block; iron bearing furnace slag or SHC; 120x70x70mm; top very slightly dished, rusty; base shows dimpled or microprilly slags
			100	1	possible margin of plano-convex slag with raised lip; not even impossibly part of object above; dimpled slag base, rough on top
			56	1	rounded low-density rough slag lump
4007	83		300	3	smooth surfaced flow slag
			343	1	dimpled slag sheet - probably includes multiple rod like tool fills
			148	1	irregular lump of dense dark slag, dimpled base fuel impressions on top
			6	2	small fragments probably broken from above pieces
4007	83		286	8	dimpled rough slags (fresh)
			105	3	rough slags with indications of flow
			340	13	smooth surfaced flow slags (fresh)
4007	84		67	1	large lobed smooth surfaced flow slag (fresh)
4007	86		49	3	smooth surfaced flow slag (fresh)
4015	87		18	2	rough/granular slags
4015	88		65	1	large lobe of smooth surfaced flow slag (fresh)
4015	89		55	4	rough slags with some flow lobes
			10	1	rough/granular slags
4015	90		173	17	rough/granular slags
			168	4	smooth surfaced flow slags
4015	91		139	23	rough/granular slags
			195	9	smooth surfaced flow slags
			69	7	rough slags with some lobing
4015	92		58	7	smooth surfaced flow slags

			22	5	rough slags with some lobing
			132	8	rough/granular slags
4015	94		44	7	poor rough flow lobes and rough slag containing flow lobes
			8	1	possible small rough rod fragment
			43	1	straight smooth flow slag or rod termination
			66	2	smooth surfaced flow slag
			84	7	rough and dimpled slag
4015	95		139	13	smooth surfaced flow slag
			26	1	smooth surfaced flow slag on dimpled runner, 35mm wide and 15mm deep
			94	9	rough slags with flow lobes and other indications of flow
			118	10	rough/granular slags
4015	96		124	9	smooth surfaced flow slag
			75	6	rough/granular slags
			23	3	rough/granular slags containing poor flow lobes
			10	2	lining with attached slag/concretion
4015	97		812	1	plano convex cake in three fragments; probably from foot of wall rather than bottom of pit; where weathered, shows abundance of very fine charcoal debris, base dimpled and with fine charcoal debris, top is fracture not original, probably furnace slag not SHC
4015	98	slag	333	18	smooth surfaced flow slag
			46	1	smooth surface flow slag lying on a dimpled slag rod
			41	1	rough surfaced slag rod overlain by small lobes of smooth slag
			24	1	rough slag with an arcuate core - could be a rod but uncertain
			146	12	rough and dimpled slags
			34	2	dense flow slag-like slags but lacking any external surface, so cold be puddles
			9	1	hearth lining?
			5	1	rough surfaced slag prill
4015	99	slag	480	16	smooth-surface flow slags
			147	10	rough slags
			38	1	possible hearth lining
			32	1	probable slag rod, dimpled base, flowed top, 20mm diameter maximum
			53	1	dense slag fragment, possibly a worn rod fragment
			16	3	rough slags with some poor flow lobes
4015	100		43	5	smooth surfaced flow slags
			40	13	rough/granular slags
			67	8	rough surfaced flow slags and rough slags with some flow
4015	101		84	4	smooth surfaced flow slag
			6	1	oxidised fired vitrified lining
			83	4	rough/granular slag
			19	3	rough slag containing flow oboes

			10	1	small fragment of dimpled dense crust - probably from a dense flow slag
4015	102		287	20	smooth surfaced flow slag
			94	19	rough/granular slag
			23	5	rough slag containing flow lobes
			33	1	smooth surfaced flow slag overlies rough tube - just possibly a rod fragment
			2	1	rough flow lobe or rod
4015	103		29	1	rough/granular slag
			182	8	rough surfaced flow slags
			189	12	smooth surfaced flow slags
4015	104	slag	63	5	dense flow slags
			72	1	granular slag lump, perhaps from base of bowl
			19	5	poor flow slags in rough matrix
4015	105		434	28	smooth surfaced flow slag
			58	5	rough surfaced flow slags
			157	11	rough/granular slags
4015	106	slag	300	1	part of channelled flow slag cake - resembles proper tapslag but only slight hint of reddening
			312	2	rough slag lumps with possible rod-like components
			46	1	low density, charcoal mould-rich, tubular lump
			100	1	slightly dimpled almost plano-convex lump, very porous
4015	107	slag	359	21	smooth surfaced flow slags
			121	3	dense slags - unclear if from flow slags or a puddle
			38	3	rough slags with hint of flowage
			254	6	large pieces of rough slags
4015	108	clay	9	1	vitrified oxidised lining
4015	109	slag	133	2	large lobed dense flow slags, smooth surfaced
4015	110	slag	217	6	lumps of irregular rough/granular slags
			178	4	very dense but rough surfaced flow slags
			66	4	smooth surface flow slags
			23	1	possible very narrow slag rod
			11	1	dimpled slag piece, possibly a flow slag
4015	111	slag	264	5	dense slag that has flowed and is smooth-surfaced. Not classic flow slags though
			72	7	poorly developed and rough surfaced flow slags
			126	6	dimpled, variably dense, variably charcoal bearing, irregular rough slag pieces
4015	112	slag	360	8	dimpled, variably dense, variably charcoal bearing, irregular rough slag pieces
			165	4	dense slag, all with some indications of flow

			35	1	sheet of rough slag, possibly showing tool mark, or rounded foot of wall
4015	124 <6>	magnetic	9	assm	mostly stone
4015	125 <6>	slag	40	16	rough slags
			8	2	rough surfaced flow slag
			1	1	rusty concretion
4015	126 <8>	magnetic	30	assm	mostly slag, commonly rusty
4015	127 <8>	slag	6	4	rough slag
4015	128 <10>	magnetic f	46	assm	mixture of stone and slag debris
4015	129 <10>	slag	44	19	rough slag debris
			8	1	stone
4015	130 <12>	magnetic fines	319	assm	mixture of stone and slag debris
4015	131 <12	slag	100	15	smooth surfaced flow slag
			211	78	amorphous slag fragments
			8	assm	dust and debris
4015	132 <14>	slag	146	11	rough surfaced flow slag
			62	16	smooth surfaced flow slag
			86	33	rough slags
			2	2	stones
			1	assm	dust and debris
4015	133 <14>	fines - magnetic	211	assm	mostly slag
4015	138 <17>	magnetic fines	293	assm	mixture of stone and slag debris
4015	139 <17>	slag	43	7	smooth-surfaced flow slag
			19	8	rough flow slags and dimpled material
			8	4	rough slags
			22	9	concretionary material
			<1	2	charcoal
4016	80		53	4	rough slag with flow lobes
			25	1	broken in 2, rough slag rod low density, 20x8x75mm
			54	4	smooth surfaced flow slag
4016	118 <2>	slag	28	58	rough slags
			21	19	flow slags, including spheroids
			3	assm	dust and debris

4016	119 <2>	slag	465	46	smooth surface flow slag
			470	114	rough slags
			41	5	iron-rich concretions
			3	1	lining?
			18	3	concretions
			1	1	stone
			30	assm	dust and debris
4016	120 <2>	furnace lning	8	1	lining or stone?
			19	1	dimpled slag with iron
			12	1	lining, probably from burr region with slag
4016	111 <2>	magnetic	1839	assm	dark, rusty fine material - much concretionary but some may be sinter
4018	123 <4>	magnetic	6	assm	mostly stone
4023	122 <3>	slag	1	2	charcoal bearing rusty concretions
4040	113	slag	475	24	smooth-surfaced flow slag
			195	2	plano-convex lump, flow slag on top, prilly slag with charcoal below
			114	2	basal slag with possible tool marks
			168	18	low density slags - rusty FB fragments
			56	assm	dust and bits
4040	115		430	1	large FB fragment
			295	14	rough slag lumps, mostly probably FB fragments
			333	11	smooth-surfaced flow slag
			71	assm	dust and bits
4040	134 <5>	magnetic	1146	assm	fine material, mostly fine slag debris?
4040	135	slag	800	84	smooth-surfaced flow slag
			283	34	rough flowed slag
			211	2	furnace bottom fragments with attached wall
			43	1	furnace bottom fragment with charcoal
			152	4	stones
			14	2	slag with oxidised lining attached
			820	170	rough, massive and porous slags
			87	assm	dust and bits
4040	135 <15>	slag	700	66	smooth-surfaced flow slag
			81	15	rough flowed slags
			869	247	rough slag lumps
			40	assm	dust and bits

4040	135	slag	1092	12	poorly preserved FB fragments, some large
			350	2	slag lumps with a component of coarse, rough flow lobes
			149	2	rounded concretionary lumps
			20	1	stone or vitrified sand
			5	2	slag prills
			46	1	porous slag rod, 27mm diameter, 70mm long
			100	1	dimpled slag sheet with possible upper impression of slag rod
			56	assm	dust and debris
4040	136 <15>	furnace	6	3	thin sheets of vitrified oxidised lining
4041	116	slag blocking channel	440	13	low density prilly slag mass - presumably FB
			160	1	rusty low density slag lump, not obviously prilly
			39	4	smooth-surfaced flow slag
			78	assm	dust and debris
4042	114	floor of [3204]	700	15	ceramic, one large piece shows vitrification over flat face including possible tuyère, better seen to rear
			294	assm	dust and debris

Table 2: facies of archaeometallurgical residue by context. Weights in g.

C	flow slag				rod		rough/granular				bowl		?bowl/SHC		furnace ceramic		total	
	smooth		rough				with lobes		without lobes									
	wt	no	wt	no	wt	no	wt	no	wt	no	wt	no	wt	no	wt	no	wt	no
TP32	20	3	22	2					50	7							*92*	*12*
4006	203	14					112	1	31	5							*346*	*20*
4007	6505	320	855	57	1300	16	893	51	4913	284	2554	17	693	2	336	8	*18049*	*755*
4015	4061	228	999	59	272	9	598	59	3281	328	847	2			72	6	*10130*	*691*
4016	540	69			25	1	53	4	517	173	12	1			11	2	*1158*	*250*
4040	2313	187	364	49	260	4	713	22	3119	444	641	3			20	5	*7430*	*714*
4041	39	4							600	14							*639*	*18*
4042															700	15	*700*	*15*
total	*13681*	*825*	*2240*	*167*	*1857*	*30*	*2369*	*137*	*12511*	*1255*	*4054*	*23*	*693*	*2*	*1139*	*36*	*38544*	*2475*

Table 3: proportion of residue facies (by weight) by context.

Context	Tapped	Rod	Internal	Lining	Total wt (g)	Context notes
TP32	45.7%	0.0%	54.3%	0.0%	*92*	
4006	58.7%	0.0%	41.3%	0.0%	*346*	modern silt run off
4007	40.8%	7.2%	50.2%	1.9%	*18049*	peat: finds believed to come from (4015)
4015	50.0%	2.7%	46.7%	0.7%	*10130*	occupation deposit over Pit 4017
4016	46.6%	2.2%	50.3%	0.9%	*1158*	upper fill Pit 4017 and channel to furnace
4040	36.0%	3.5%	60.2%	0.3%	*7430*	lower fill Pit 4017
4041	6.1%	0.0%	93.9%	0.0%	*639*	blocking in channel
4042	0.0%	0.0%	0.0%	100.0%	*700*	concreted material on floor of furnace [3042]
total	41.3%	4.8%	50.9%	3.0%	*38544*	

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