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Assessment of archaeometallurgical residues from Lydney B North (LYF17)

Dr Tim Young
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Abstract

This collection (154 pieces, weighing 51kg, from 40 distinct contexts) was of material hand-picked during excavation.

Although the excavations revealed the bases of two bloomery furnaces with their associated tapping pits, together with a contemporary slag dump, these deposits were, unfortunately, barely sampled; the majority of the submitted residues were residual in later medieval contexts.

The site and its residue, are, however, significant, for despite the importance of the iron industry in the Forest of Dean during the medieval period, there have been no smelting sites of this age investigated archaeologically in Dean. Some comparison may, however, be made with medieval sites that smelted ores from adjacent sectors of the Bristol Channel Orefield, as well as with contemporary examples smelting different types of ore.

The collection was entirely of residues from bloomery iron smelting, mostly slag that had been tapped from the furnace. The tapped slags show some variation in the geometry of the slag collection, possibly correlating with variations in texture. In general, dense, low-porosity tapped slags with well-formed flow lobes and rivulets, occurred in thin sheets, whereas high-porosity slag tended to be found within deeper slag cakes, often with flow-lobes preserved only in their upper part.

The occurrence of highly porous tapped slags is more reminiscent of, although not identical to, residues from 13th-15th century smelting of low-grade Carboniferous claystone ironstone ores, than it is of examples of smelting of Forest of Dean ores from other periods. Further investigation of the residues is recommended to characterise the slags with differing porosity and to evaluate the potential controls. Such analysis would also potentially shed further light on yield and production for the smelting operation and the provenance of the ore employed.

Contents

Methods

All materials were examined visually with a low-powered binocular microscope where required. As an evaluation, the materials were not subjected to any high-magnification optical inspection, not to any form of instrumental analysis. The identifications of materials in this report are therefore necessarily limited and must be regarded as provisional.

The examined materials are listed in Table 1.

This project was commissioned by Jacky Sommerville, of Cotswold Archaeology.

The site was visited twice during excavation in September and October 2016. The assessment of residues was undertaken in autumn 2017.

Results

Description of residues

The submitted materials (154 pieces, weighing 51kg, from 40 distinct contexts) comprised pieces hand-picked during excavation. All the submitted materials were either certainly residues from bloomery iron smelting, or were probably so.

The summary catalogue of the material is presented in Table 1 and the distribution of slag classes by context in Table 2.

Bloomery iron smelting residues

Most of the collection comprises slags tapped from a furnace. There are three main classes of flowed slag material:

1. **conventional dense tapped slags**, with a very low degree of vesicularity resulting in a high bulk density. These slags have well-developed flow lobes and rivulets, visible on the surface and through the cross-section. The surface of these materials shows marked reddening from surficial oxidation. The flow lobes show a range of sizes, ranging from 40mm down to less than 8mm. Dense tapped slags comprised almost half the total assemblage (24kg out of 51kg). The most significant element of these tapped slags was a large but fragmented flow (sample <19> context (1644)) weighing 8kg, found inverted, lying obliquely on the north side of the tapping pit of furnace [1639]. Some dense slags show internal brecciation. Dense tapped slags mostly occur in thin sheets and relatively thin plano-convex cakes. The base of the cakes variably shows contact with fuel (shown by dimples), subsoil (shown by silt/sand-impregnated and indurated surfaces, commonly with small pellets of grey substrate caught-up amongst the basal flow lobes) and in rare case probably stone (represented by flows with planar bases with non-wetted surfaces). In some cases, the base of the flows shows a marginal zone where it rests on substrate, but centrally on fuel, sometimes with lateral penetration of flow lobes into the fuel bed. Some examples of large flow slag blocks (dense and composite) show altered rear faces, with reddening and ablation of the surface, entering the porosity. Some of these examples show a very superficial thin layer of what appears to have been a very fluid slag, which flowed down the rear face and not the base of the block.

2. **vesicular tapped slags**, in which the high vesicularity results in a low bulk density. The development of the vesicles, attributed to degassing, removed internal evidence for flow lobes. In some cases, the top of vesicular slag bears remnants of flow-lobe morphology, but in others the top has a subdued, almost planar, morphology. Approximately 8kg of material was referred to this category, but most vesicular slag was originally part of **composite slag cakes**, in which the upper part of the cake was formed of dense conventional tapslag. Such composite tapped slags, comprise a further 13.5kg of the assemblage. The composite cakes rang up to approximately 120mm in thickness and commonly show a ‘V’-shaped cross-section.

3. **deflated flows**, with the usual combination of a thin (typically less than 40mm) sheet-like form, a reddened or glazed upper surface and vesicles of various sizes opening onto the upper face, often show a morphology which is suggestive of collapsed flow-lobes. These rather variable materials are interpreted as having formed close to, or within, the tap-arch of the furnace. As the slag flowed into the tapping pit it left behind the slag tubes through which it had flowed, which then deflated. This remnant slag continued to be subjected to blast escaping from the furnace, resulting in ablation, oxidation and softening, as well as deflation.

There are a few pieces that are provisionally interpreted as slags which cooled internally in the base of the furnace. These **internal slag crust** pieces show evidence of hot interaction with the substrate and may locally be rich in charcoal, above the basal crust. Certain discrimination, however, between slags which cooled against the floor of the furnace itself, as opposed to the floor of the arch or tapping pit, is not possible.

There are a few small fragments of slag **rod** or runner, including one (from (1341)) suggestive of a small flat-topped runner connecting with the margin of a small slag bowl. Such runners and rods have been rather controversial objects, but it is likely that many are simply the slag fills of holes created by 'rodding' through the fuel waste on the furnace and tap arch floor.

Indeterminate residues

There was a small quantity (0.6kg) of materials that are classed here as **indeterminate**. Although they exhibited no diagnostic features that might allow them to be assigned to either smithing or smelting, there were no features which gave strong reason to interpret them as suggesting the assemblage contained a contribution from any process other than bloomery iron smelting.

Lining

There was single slab of vitrified oxidised furnace lining up to 40mm in thickness, that was almost planar over a 105mm by 150mm area.

Iron ore

Two small fragments of iron ore were recovered. These were typical examples of Forest of Dean iron ore (Sibly 1919; Thomas 2000) and are likely to have had a relatively local origin.

Coke

A single piece of broken coke (the carbonaceous residue remaining from incomplete coal combustion) was recovered from context (1240), the fill of posthole [1239]. Coal was not employed in bloomery iron smelting, so this piece will have an origin in a different process, most likely a non-metallurgical process.

Distribution of residues

The distribution and overall quantity of residues is not documented by a hand-picked collection. The collection is biased towards small quantities of residual residues collected from later, often structural, contexts.

The area to the southeast of the manorial complex close to the furnaces contained a slag spread that may have been the base of a primary slag dump. Much slag had been moved to provide levelling deposits for later structures.

The residue most closely associated with the structural remains of the furnaces was a large but fragmented flow (sample <19> context (1644)) weighing 8kg, found inverted, lying obliquely on the north side of the tapping pit of furnace [1639].

The furnaces

Of the two furnaces on the site, one was encountered by the assessment trench and the other was excavated fully during the current project. Full review and interpretation of the morphology of the furnaces is recommended for the analysis stage of the project, and so only brief comment is to be here. Furnace [1639] was constructed over one end of a trench approximately 1.5m in length, 0.37m wide below the shaft, widening to 0.5m wide at the tapping pit, and deepest in the area just in front of the shaft. In this central area there were remnants of a stone lining present on one side of the trench. Below the shaft the furnace base was shallow (although probably truncated) 0.37m in diameter (although not perfectly circular) and possessed a flat, almost horizontal floor, apparently with a slight lip on the side facing the tapping arch. The pit wall on the SW side was strongly indurated, and this probably indicates the side from which the furnace was blown. The furnace was immediately adjacent to the less well-preserved furnace [1642] (encountered in the Wessex Archaeology evaluation trench), which it probably replaced. Furnace [1642] was deeper than furnace [1639].

The tapping pit [1640]/[[1710] of furnace [1639] contained a large tapslag block (sample <19> which, despite being fractured, was complete, but inverted. This approximately 8kg block is described more fully above.

Interpretation

The evidence described above from the residues and from the furnaces is coherent and suggests an episode or episodes of iron smelting prior to construction of the manorial complex. The technology and current dating evidence is compatible with documentary evidence for iron-making in Lydney in the late 13th century (Nicholls 1866, 20).

The tapped slag evidence suggests that large slag blocks were moved so that their fractured rear faces were heated by the blast escaping through the tap arch (leading to some slag flowage on and around the detached face). The tapped slag blocks may have been moved in order to create space for formation of a new block, and/or to make room for extraction of the bloom. Since the furnaces were reasonably large (internal diameter of 0.37m at the base), it is unlikely that only a single tapped slag block of 5-8kg would be formed in a smelt; it would be much more likely that several blocks would have been formed in succession.

Although the block may have been emplaced there coincidentally, the large slag block found on the northern side of the tapping pit of furnace [1639] had most likely been 'flipped' out of the pit, to allow further operations there.

The existence of two types of structure within the tapped slag blocks is reminiscent of the situation at the medieval bloomeries in Shropshire investigated by Young and Poyner (2014). There, the tapped slags in both water-powered and manually-blown bloomeries showed vesicular lower parts, often with a planar upper surface, followed by formation of more conventional flow-lobed tapslags. It was argued that rapid tapping of slag from the bloomery did not permit degassing of the slags.

Discussion

The Lydney site adds significantly to understanding of the development of medieval iron smelting. Although it is commonly assumed that medieval bloomery iron smelting is thoroughly understood, this is not the case.

The type of furnace represented by furnace [1639] (and possibly also by furnace [1640]) was constructed over a slightly-tapering trench, of which the narrow end lay below the shaft and wider end formed the tapping pit, and of which the deepest part is approximately central (just outside the original outer part of the tap-arch). The presence of some stone edging is common – often as a footing for the tap-arch, but also commonly, as here, forming a hard margin to the proximal part of the tapping pit. The variation in oxidation and induration indicate that the furnaces were blown laterally (in the case of furnace [1639] from the southern side).

The trench-built furnaces appear in southern Britain in the 9th or 10th century (when they were just one of a number of smelting technologies), with 9th or 10th century examples at Churchills Farm, Hemyock, Devon (Young 2015c) and 10th or 11th century examples at South Hook, Pembrokeshire (Crane & Murphy 2010; although this site differs in employing furnaces blown from the back wall, opposite the tap-arch).

Between the 11th and 13th centuries the technology appears very stable. Sites from this period are known in southwestern Britain from Churchills Farm, Hemyock (where the late phase is known from residues rather than structures), Tisbury, Wiltshire (author's unpublished data), Torr Quarry, Somerset, (Young 2014) and Ned's Garden, Shropshire (Young & Poyner 2014; interpreted from residues).

During the 13th-14th centuries, furnaces became typically larger, with substantial tapping pits and with covered elongate tapping channels. No furnaces of this period are known from southwestern Britain, but from further afield they have been excavated at Oakamoor, Staffordshire (Wessex Archaeology 2004) and from sites in Coed y Brenin, N Wales (Crew 2009). By the 15th century, the power of water to operate bellows began to be realised and a major shift away from iron smelting on commonly ephemeral sites close to charcoal (and ore) supplies to smelting on powered locations in river valleys commenced.

Despite the enormity of the bloomery iron industry in the Forest of Dean throughout a span of time from the Iron Age to late Medieval, there are very few furnace examples excavated under modern conditions. In the surroundings of the Forest there are excavated Roman furnaces at Woolaston (Fulford & Allen 1993), Weston-under-Penyard (Jackson 2012) and Kingstone (Young 2012). Early medieval furnaces are known from Clearwell Quarry (Pine *et al.* 2009) and Yorkley (Young 2015a). There are none of medieval age at all.

In the wider area of the Bristol Channel Orefield (Young 2000; Young & Thomas 1998, 1999), of which the Forest of Dean forms just one part, the site at Torr Quarry, Somerset, mentioned above, worked very similar ores to those of the Forest of Dean. At Torr Quarry, the furnaces are poorly-dated at present, and include both examples built over trenches, but also some with broader tapping pits. The tapped slags at Torr Quarry were investigated through a limited programme of analysis. The slags included conventional, dense, well-flow-lobed tapslags, plus a suite of relatively iron-poor slags from within the furnace bases, including examples of a dense basal 'puddle', apparently trapped within the concave furnace base. At Torr Quarry, several tapping pits contained in-situ flows sampled in their entirety:
- for tapping pit [131150] associated with furnace [131161]/[131163] there was an in-situ tapped flow (131149) weighing approximately 16kg.
- for tapping pit [13291] associated with furnace [13287], three successive flows were sampled, the upper two (13290 and 13295) in their approximate entirety and they weighed 15kg and 14kg respectively.

In one of the rather similar furnaces at Tisbury also contained a trapped basal puddle. The drip gully surrounding the post-built smelting building at Tisbury had been backfilled with tapped slag cakes of a rather uniform size of 10-12kg.

One of the pragmatic factors separating the Torr Quarry furnaces from those of Tisbury or Lydney, is that the most of those at Torr Quarry were constructed onto limestone bedrock, so narrow trenches were more problematic to create and tapping pits harder to clear.

Neither the assemblage from Tisbury nor that from Torr Quarry has been noted as containing vesicular slags with a lack of preservation of internal flow lobes (though for neither site has a complete inventory of residues been completed). Vesicular slags were, in contrast, in at least equal abundance to dense varieties of tapped slag in assemblages from Ned's Garden, Shropshire (Young & Poyner 2014) and Cutacre, Salford (Young 2015b), of 13th and 13th-14th century age respectively. The assemblage of slag from Oakamoor contained a large proportion of pale slag with a 'frothy' texture (pers obs). This textural difference has so far been linked with the use of claystone ironstones from the Carboniferous coal measures. The vesicular slag facies at Lydney was not as highly vesicular as those from Ned's Garden or Oakamoor; none of the Lydney material could be truly described as 'frothy'. In view of the occurrence of even moderately vesicular material at Lydney (which did not smelt claystone ores), however, an alternative interpretation should be sought. Three factors might be implicated in a highly-vesicular slag – an enhanced gas content, a high viscosity, and rapid accumulation. It seems a likely hypothesis, that rapid slag tapping of large slag volumes initially inhibits degassing, which then occurred after tapping, resulting in disruption of any primary texture.

Further work

Although much of the submitted assemblage was not stratigraphically-associated with the furnaces and associated features, the assemblage is sufficiently coherent that its further investigation would still be valuable. In particular, characterisation of the tap slags to investigate the significance of, and controls on, the variation in the vesicularity. A small programme of analysis (both elemental and textural) of slag samples of various textures is recommended. This programme would include samples from slag cake from furnace [1639], as well as comparative examples of other textures from different contexts.

Trace element analyses of the samples of iron ore would also be able to be compared with a database of ore samples collected from the Forest of Dean (Thomas 2000; Young 2000; Young & Thomas 1998, 1999).

The analyses would also contribute to the development of a mass balance description of the smelting (after the methodology of Thomas & Young 1999a, 1999b and Young 2016) with the intention of clarifying yield and production.

The lack of closely-dated medieval smelting slag from the Forest of Dean means that the collection from Lydney North is of regional importance and as such should be deposited as an integral part of the site archive with the receiving institution.

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Table 1: summary catalogue, listed by bag and context.

context	sample	sample wt.	item wt.	item no.	item description
1228		2240	366	1	large slab of vitrified oxidised fired lining; up to 40mm thick; contains blebs and almost layers of opaque green glass as well as more usual materials; almost planar, 105x150mm
			1870	1	170mm x 180mm, by up to 60mm thick, dense slag sheet; base rough and complex with central rough void; internally much good flow slag material; top deflated and blown with open large voids and some small vesicles, blown smooth and oxidised; base shows abundant small ceramic pellets; probably tapped slag left deflated in furnace mouth/floor
1228		632	674	6	fragments of conventional tap slag
			4	1	grey flow slag prill
			20	1	indeterminate iron slag fragment
			34	1	reddish iron ore fragment, mostly dense but has attached fine fragmental material - unclear if this is natural or has been accreted after crushing
1240		1	1	1	coke
1253		56	56	2	tap slag fragments, somewhat corroded
1329		896	292	1	block from margin of thick tapslag cake
			534	1	slab of classic thin tapslag; well-developed rivulets and lobes; base mostly rough with lobes showing on one side; maximum of 35mm thick.
			50	2	fragments of thin tapslag sheet with fine rivulets
			20	1	40mm long fragment of 20mm diameter slag rod; turns to semi-circular at mid-length, with surface dimpled not rough as elsewhere.
1329		366	364	1	fragment broken in 3 of highly vesicular slag with strongly maroon surface; irregularly lobate dimpled base with possible tapslag clasts; presumably this is another deflation sheet, although very different from some of the others
1330		3250	558	2	fragmented block, most of 40g of bits probably belong here; top slightly concave, with narrow elongate flow lobes, strongly reddened, suggesting flow away from source above; flows overlie more conventional tap slag, with intervening dense zone.
			442	1	slab of tap slag, thin, with very low-angle margin; top shows wide flat surfaces and large tabular cavities, rather than discrete flow lobes; margin shows well-formed dense almost burr-like surface dipping inwards to 45mm thick, then sudden upward jump to dimpled surface - probably a fuel contact; 25-30mm thick slab above dimpled base.

context	sample	sample wt.	item wt.	item no.	item description
			1915	1	190mm across and 80mm thick large black, probably a furnace bottom slag; the base is irregular, has 20mm thick lower crust, with displaced blocks up to 40mm thickness; most of interior is rather rubbly material; base suggests some hot interaction with substrate; strongly suggests internal cake, rather than tap pit and probably not (though not certainly) from smithing.
			294	1	low-angle cake margin; top obscured by rough slags containing much fine charcoal; slag massive with rounded vesicles towards the top; the base is rough, except towards the margin, where pale green flow lobes extend down from margin along base; base covered in sandy charcoal rich layer - presumably soft layer on furnace or tapping pit base.
1330		248	218	1	40mm tap slag flow, probably flown into fuel, since lobes project at various levels and piece has irregular cavities
			30	1	tap slag fragment
1330		5100	4365	1	large block of tapped slag; vesicular, but flow-lobed structure seems to have survived; top has very broad lobes with internal voids; rear face shows blown fracture surface and base shows some evidence of superficial flow from this face onto original base - showing blast hit rear of moved slag block; dense flow lobes may extend forward of, and over, a less well-formed, possibly brecciated, core; base rough, sides not seen.
			704	1	margin of a flow slag block; top smooth if slightly broken surface; base rather prilly; generally appears rather vesicular
1334		292	292	1	fragmented piece of tap slag sheet; c30mm thick; with narrow rivulets, mostly around 7-8mm; base shows similar rivulets
1338		14	14	1	tapslag fragment.
1339		1056	304	3	fragments of classic, very dense, tapslag
			420	1	up to 35mm thick slag sheet, fractured into 4; base rough, shows pelletal silt with much charcoal in a series of irregular lobe-like areas; body is vesicular iron slag, possibly with some internal brecciation; top shiny irregularly planar slightly glassy-looking slag; unclear if this is an odd external flow or a furnace slag
			244	1	rounded bulbous mass of slag with some flow lobes, plus some amalgamated prilly areas, with mostly dimpled prilly contacts with fuel and one bulbous irregular rounded surface, probably a crude flow lobe
			80	3	indeterminate slag fragments of similar appearance to the slag of the 420g sheet fragment
1341		922	314	2	conventional tapslag pieces
			58	3	indeterminate amorphous iron slag blebs and fragmentary blebs
			128	1	skillet handle-like fragment of thin slag sheet with maroon top extending into a narrowing flat-topped runner (60mm narrowing to 35mm, 20mm decreasing to 10mm thick); top of runner rough; runner carries small FAS fragments and has similar material on top; base shows some degree of non-wetted lobes

context	sample	sample wt.	item wt.	item no.	item description
			416	1	unusual biconvex piece of highly vesicular (frothy) slag; one surface shows a few poorly developed greenish lobes, the other is rough; maximum thickness is approximately 55mm
1345		110	110	1	irregular tapslag fragment
1391		42	42	2	very dense worn tapslag fragments
1394		1480	916	2	blocks of highly vesicular iron slag; preservation good; original surface abraded; vesicles show glassy linings and there are some glassy clasts, both hint at dense (basal?) layer, but definite way-up features not observed
			256	1	irregular slag runner fragment; probable way-up would mean flat base with pale ceramic silts and rather rounded bulbous upper lobes; lower surface in this case shows well developed skin to lobes with dark colour and wrinkled surface; 100mm long, 40mm deep and 45mm wide
			150	1	margin of conventional dense tapslag cake with rather large lobes
			160	1	margin of a tap slag cake comprising a single large bulbous lobe with a strongly reddened surface
1395		206	206	1	cuboidal fragment of tap slag, with extremely strongly reddened large flow lobes
1395		1730	980	11	fragments of conventional maroon-surfaced dense tapslag
			90	2	worn green/grey lumps of iron slag, probably abraded tapslag
			104	1	fragment of slag with prilly irregular base and smooth top with a series of broad hollows and rises; possibly another deflated slag, although top is distinctly maroon in this example
			434	1	unusual slag sheet fragment, 140mm x 80mm x 30mm, one face of the sheet shows green-surfaced elongate hollows and holes - not unlike the deflation samples; the other shows a planar, slightly maroon wrinkled surface with some vesicular slag adhering in places; internally very dense and suggestive of a single flow; the irregular green is probably, but not certainly the base
			118	1	irregular vesicular slag fragment; mostly greenish but some reddening on one wispier surface; probably a vesicular tapped slag
1417		62	22	1	dimpled indeterminate slag lump
			40	1	tapslag fragment broken into 6
1424		590	148	4	fragments of conventional tapslag

context	sample	sample wt.	item wt.	item no.	item description
			282	1	slab of probable tapslag; with highly shiny basal with non-wetted surface and hints of flow lobes, planar, probably a stone contact; 15mm dense layer; the upper rather weathered surface probably showing the remains of large rounded vesicles - all now open
			162	1	irregular dense weathered lag block, probably from a tap slag block that has lateral flow of lobes into fuel?
1430		10	10	1	dense conventional tap slag fragment
1437		2470	2470	1	large block of tap slag cake; 160mm x 170mm and 100mm thick; lower 60mm appear more massive and irregular, upper 40mm appear to be layered thin tapslags; lower parts include various fired clay fragments; prills moderately narrow; probably deeply weathered
1443		378	128	1	dense tap slag fragment; 35mm sheet, with top not preserved
			244	1	margin of highly vesicular (frothy) tapslag cake; base rough; top not preserved but upper part shows large open tabular voids, suggesting cores of flow lobes
1453		132	132	3	thin tapslag fragments
1456		200	120	1	dense worn tap slag sheet overlying more vesicular material
			80	1	strongly vesicular iron slag
1510		648			(worn looking assemblage)
			212	11	worn conventional dense tap slag fragments
			282	5	worn dense slags without indication of flow lobes - but which may be tap slags
			128	1	tapped slag fragment with planar maroon top over thin (20mm) sheet of dense slag with vesicular base; may possibly be the upper layer of a composite cake
			20	1	ore fragment, curved crust with exterior showing laminated structure with yellowy ochre between streaks of denser material; interior shows blocky and slightly brecciated dense ore, with some areas showing outlines suggestive of replace of rhomboidal crystals
1520		948	252	4	fragments of conventional tap slag
			694	1	unusual block of vesicular iron slag; shows joined large convoluted lobe attached to base of a fragment from the margin of a thick vesicular slag cake with flow lobed top; upper flow seen to about 65mm thick, but total block thickness is about 95mm

context	sample	sample wt.	item wt.	item no.	item description
1523		30	30	3	abraded tapslag fragments
1540		26	26	1	small length of isolated tapslag prill (finger-like)
1560		48	48	1	tapslag fragment
1563		246	244	3	worn tapslag fragments; the largest has an almost flat top with possible unroofed voids; dense, non-wetted base and small clasts of fired clay
1623		1090	466	3	worn tapslag fragments
			616	1	irregular fragment with rough base overlain by rather chaotic, possibly brecciated tapslag lobes; details obscured by altered surface
1644	19	7820	7820	1	fragment single fan-shaped tap slag cake; at least 470mm long originally and 270mm wide, max thickness 65mm; rivulets show variegation between green and glassy, and maroon and matt; some hint of green lobes being covered by maroon; appearance of classical tap slag with rivulets up to 20mm wide, some very lightly wrinkled but most not; thins towards proximal end; base mostly shows flow lobes and is dimpled, but rough in deepest part suggesting no covering fuel on pit base here; internally very dense, apart from large voids, and flow lobation remains intact
1644	19	284	276	3	tapslag fragments, one has a smoothly-curved rough basal contact, with micro-dimples
1656		768	766	1	large worn block, probably from core of tap slag cake, but lacking clear flow lobed structure; approximately 80mm thick
1656		134	26	1	tap slag fragment.
			106	1	irregular fragment of vesicular slag; top is smooth and wispy; could be a irregular tapslag fragment or a furnace slag; indeterminate.
1667		886	50	2	small fragments of conventional tapslag
			496	1	large block of presumed tapslag; rough base overlain by 20mm dense slag, then by zone with large cavities, some open, top irregular with large open cavities; green colour with only minor reddening; unclear if unusual tapslag or if possible deflation and lack of reddening suggest this formed within the furnace
			338	2	irregular rounded blocks/lumps of dense slag - probably both tapped slag lumps

context	sample	sample wt.	item wt.	item no.	item description
1667		1940	1245	1	asymmetric bowl of vesicular slag; maximum 75mm thick; top with large rounded lobes, locally strongly reddened; base roughened with scattered small charcoal clasts; 150mm wide fragment, 80mm long, probably margin.
			696	1	80mm thick block of tap slag; slag contains possible contact with sandstone; includes some small lobes of melted lining; top shows typical tap slag texture but with tiny blebs (some elongated) suggesting splashing of very fluid slag onto surface of flow.
1682		2	2	1	small slag bleb in charcoal-rich accretion
1690		68	68	1	worn fragment of dense slag sheet with largely non-wetted base; dense almost vesicle-free body, 25mm thick; top with some large worn vesicles
1764		716	218	1	40mm thick abraded fragment of grey-coloured tapslag flow in cuboidal block.
			88	1	tapslag fragment, vesicles large and tabular with very shiny pale surfaces, possibly olivine, grey, abraded.
			54	1	elongate, finger-like, abraded pale grey tap slag prill.
			356	1	abraded large but thin block of tapslag; upper surface very irregularly lobate; base in several large rounded lobes; internally vesicular.
1774		1865	706	1	highly weathered possible furnace bottom piece; charcoal-rich; dimpled base - details unclear.
			1160	1	large block of porous slag; porosity of rounded voids and charcoal up to medium size 40mm across; one surface shows well-developed lobes, with impressed pale fired silt and a sandstone clast - it is unclear if this surface is a top with overlaid debris, or a non-wetted lateral contact; 90x60x150mm; broken in two.
1774		2700	2660	1	large block of weathered slag accreted onto slabs of sandstone; probably forms part of a 70mm thick bowl of slag; base shows crude large dimpled lobes, actual flow-lobing not seen on block, but most likely to be tapped slag, but too accreted to be certain
1834		232	232	1	dense tapslag fragment, flow appears to carry a large pre-existing tap slag fragment at an angle to the main accumulation
1835		166	166	1	abraded fragment from margin of tapslag cake.
1878		1460	1190	1	very dense block from towards margin of slag cake, wedge-shaped; way-up not entirely certain; flat top for 90mm in from what remains of margins, where overlain by more vesicular material; base rough; 20-30mm thick very dense, 100mm long and 140mm wide
			244	1	conventional tapslag but with strongly and finely wrinkled surfaces to upper lobes

context	sample	sample wt.	item wt.	item no.	item description
1878		1260	690	1	margin of a dense slag cake; top horizontal smooth (probably flow lobe surface) near margin, but inwards overlain by vesicular material; internally vesicular, but still dense; basal 10-15mm crust; base finely dimpled (although worn) with hints of lobes towards margin; 65mm max thickness seen, 130mm wide and 75mm long
			560	1	extremely dense sheet fragment; base smooth with slight parallel low ridges, probable non-wetted surface, almost planar, with small fired silt clasts; body is 20-30mm of extremely dense coarse slag; upper part has large vesicles with internal glassy surfaces; probably a major tapslag flow but other possible solutions exist
1908		20	20	1	small greenish flow slag prill
1918		5210	5210	1	large block of tapped slag; approximately 200mm length surviving, 230mm wide and 110mm deep; slag somewhat weathered hence disintegration; asymmetrical section - one side steeper than other, both somewhat sandy contacts; top is irregularly and rather coarsely flow-lobed; internally highly vesicular, including long tubular vesicles extending up through large part of thickness; with some charcoal; flow lobes for upper plate that is dense, c15-20mm thick;, some hints that upper plate may show slight brecciation; broken furnace side face shows one very large void that seems to show lightly blown surface - possibly suggesting blast was able to reach this part of face? some fired clay fragments embedded in upper surface

Table 2: summary of residues by context and class.

context	sample	context notes	conventionals	vesicular t/s	composite t/s	deflated f/s	internal	rod	indet	lining	ore	coke	total
1228		demolition deposit	678			1870			20	366	34		*2968*
1240		fill of posthole 1239										1	*1*
1253		demolition deposit	56										*56*
1329		demolition layer	876			364		20					*1260*
1330		wall, n-e corner	1100	2619	4365		442						*8526*
1334		stone wall	292										*292*
1338		demolition debris	14										*14*
1339		demolition layer	548						500				*1048*
1341		make-up layer	314	416				128	58				*916*
1345		slag-rich layer	110										*110*
1391		demolition rubble	42										*42*
1394		demolition deposit of 1367	310	916				256					*1482*
1395		demolition deposit of 1367	1276	118		538							*1932*
1417		pit fill 1417	40						22				*62*
1424		pit fill 1423	592										*592*
1430		pit fill 1431	10										*10*
1437		pit fill 1434			2470								*2470*
1443		culvert fill 1445	128	244									*372*
1453		stone surface	132										*132*
1456		ditch fill 1455		80	120								*200*
1510		possible surface	494		128						20		*642*
1520		backfill pit 1518	252	694									*946*
1523		posthole fill 1522	30										*30*
1540		foundation cut fill	26										*26*
1560		modern deposit	48										*48*
1563		ditch cut (!)	244										*244*
1623		dump deposit	1082										*1082*
1644	19	demolition material	8096										*8096*
1656		stone wall	792	106									*898*
1667		stone wall, C	1084	1245	496								*2825*
1682		padstone							2				*2*
1690		padstone	68										*68*

context	sample	context notes	conventional ts	vesicular t/s	composite t/s	deflated f/s	internal	rod	indet	lining	ore	coke	total
1764		pit fill 1765	360	356									*716*
1774		dovecote masonry	2660	1160			706						*4526*
1834		wall	232										*232*
1835		posthole fill 1837	166										*166*
1878		pond fill	1994		690								*2684*
1908		stone spread							20				*20*
1918		ditch fill 1917			5210								*5210*
		totals	*24146*	*7954*	*13479*	*2772*	*1148*	*404*	*622*	*366*	*54*	*1*	*50946*

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geoarchaeological, archaeometallurgical & geophysical investigations

Unit 6,
Western Industrial Estate,
Caerphilly,
CF83 1BQ

Office:	029 20881431
Mobile:	07802 413704
Fax:	08700 547366
E-Mail:	Tim.Young@GeoArch.co.uk
Web:	www.GeoArch.co.uk