

# Evaluation of slags from Lydney (FML04), Gloucestershire

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## Abstract

*The total collection comprised some 9.3kg of slag and associated materials from 16 contexts. Reasonable assemblages were derived from Trench 10 (0.6kg), Trench 37 (3.7kg) and Trench 44 (5kg). These sample weights are relatively low, so if fully sampled, the contexts are unlikely to have been deposited immediately adjacent to iron-smelting operations. The assemblages were dominated by slags certainly or probably generated during bloomery iron-making. None of the macroscopic slags was certainly from a bloomsmithing or blacksmithing process. None of the adhering concretionary material was observed to contain flake hammerscale (an indicator of smithing), although coal was a frequent clast in these materials (coal is not used in bloomery iron smelting, but may be used in smithing).*

*The overall collection is unusual for an assemblage of iron-making slags in containing only a low proportion of typical, dense, low-vesicularity, bloomery tap slags. These materials comprise 0% in Trench 10, 43% in Trench 37 and 6% in Trench 44. In contrast slag "runners" and rods comprise 18% in Trench 10, 0% in Trench 37 and 37% in Trench 44. Despite the small sample size this suggests either a significant taphonomic difference between Trench 37 and Trenches 10/43, or an underlying technological difference.*

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all the specimens. In one case the accretion also include a small piece of botryoidal goethite iron ore.

### Trench 34

Contexts 3407 and 3408 yielded pieces (possibly broken fragments of the same piece) of a curious mauveish fired clay sheet, tempered with small quartzite grains and abundant organic matter. One part of the material appears to be attached to a more normal orange fired clay on one side. This may represent a rather unusual furnace or hearth lining.

### Trench 37

Context 3704 yielded a single large block (900g) of extremely dense bloomery tap slag.

Context 3705 yielded a very large block (1.8kg) of slag, but this was so encrusted with iron-pan material as to make certain identification possible. It is likely to be either a piece of massive furnace slag, or a piece of bloomery tap slag. A smaller block (350g) was of a more straightforward bloomery tap slag. A series of small slag pieces may have all derived from a single block of highly vesicular slag, likely to have been a bloomery furnace slag. A nub of burnt coal was also present.

Context 3706 yielded a single block of conventional dense bloomery tap slag.

Context 3708 yielded two small pieces probably of bloomery tap slag, together with a larger (235g) piece of slag, which despite having a slightly lobate upper surface might be part of slag cake from within a bloomery furnace.

### Trench 44

Context 4403 yielded an assemblage dominated by slag runners with highly vesicular slags. The typical size appears to be 40-60mm wide, but narrower pieces are present. The maximum length seen is 200mm, but the original length of the runners is not known. Other pieces of slag are of similar texture and may represent parts of small slag cakes generated at the end of the

## Technique

Specimens were weighed and then inspected using a handlens or low-power binocular microscope. The specimens were supplied washed, and only in a small number of cases required further cleaning.

The samples were catalogued and where possible interpreted on the basis of their overall morphology. No specimens were cut, nor were any chemical or mineralogical analyses employed, for this evaluation report.

## Results

### Trench 10

Context 1004 yielded a small amount of slags of uncertain origin, but which might possibly have an origin in the iron-working rather than iron-smelting process.

Context 1007 included an assemblage in which the larger specimens are likely to be from iron smelting. The context notes indicate "copious" slag inclusions, so it is unclear whether these six specimens represent the entire assemblage. One characteristic of this assemblage was the presence of small coal particles in the iron-pan material accreted on the outside of almost

runners. A small piece of dense tap slag flow in the form of a narrow "finger" is also present, as is a small fragment of blue glassy slag of the kind known as "fuel-ash" slag.

Context 4407 has an assemblage dominated by slags formed within the bloomery furnace. These include two blocks of very dense slags with large charcoal inclusions (345 and 460g) as well as a very corroded specimen (180g) which appears to be from the zone of secondary reduction below the bloom, in which the furnace slags are further reduced to iron where in direct contact with pieces of charcoal. Smaller slag pieces may be degraded pieces of dense tap slag. The assemblage also included a small (10g) piece of brecciated goethite iron ore.

Context 4411 yielded a small scrap of indeterminate slag.

Context 4416 contained a single piece of low density slag with much included ash, probably from the basal part of a smelting furnace, but similar materials can be formed in smithing hearths.

Context 4417 contained an assemblage of mainly rather indeterminate materials, but also a curious double slag tube, with two individual slag tubes/rods of subcircular cross section, each about 25mm across.

Context 4418 also had a piece of slag rod of similar diameter, some degraded tap slag pieces and a small piece of blue glassy fuel-ash slag.

Context 4424 has only a single piece of possible tap slag, but also an 85mm length of iron bar with section 20 by 6mm.

## Discussion

The material from trenches 10 and 44 is somewhat atypical of slag assemblages from slag-tapping bloomery sites, in that there is a predominance of slags which solidified within the furnace and of slag runners in a vesicular material, and a dearth of dense, low vesicularity conventional tap slags.

Current understanding of the details of bloomery operation is rather too superficial to explain fully such an assemblage, but it is noteworthy that a rather similar assemblage was recorded from the iron smelting operation at the Chesters Villa, Woolaston, dated to a period after the mid third century, and lying only some 7km SW of the present site (Fulford and Allen 1992). At Woolaston the furnaces appear to have been tapped via "U"- or "V"- shaped runners, 0.4 – 0.6m in length, which may, or may not, have terminated in hollows for the accumulation of slag cakes.

The same assemblages also occasionally contain small pieces of "fuel ash" slags. These blue glassy materials are easily recognisable, but have not been adequately explained. They do not appear to be common products of experimental bloomeries, but some experiments at high blowing rates do produce small quantities of low-iron glasses immediately adjacent to the bloom, although these are not typically of quite such a brilliant blue colour.

The narrow slag rods present in the assemblage have also been recorded on many sites around the Forest of Dean hinterland. One school of thought has suggested that these may be slag plugs produced during tapping

of liquid iron; the liquid iron cooling to produce cast iron which would then be decarburised to make steel. This suggestion is highly controversial (bloomeries are normally thought to produce only solid iron blooms, and cast steels are not well evidenced before the Saxon period; Mack *et al.* 2000), and given the abundance of these materials, it is perhaps more likely that they represent some flowage through holes, perhaps in the tap arch block, either as a deliberate small scale tapping or perhaps following use of a rodding tool to break the slag crust, or some similar manipulation of the sub-bloom slags.

In contrast to the slightly curious late Roman assemblages, the small collection from Trench 37 has a predominance of dense conventional tap slags. Although this may be simply a taphonomic difference (particularly given the small sample size), it remains possible that this is a real technological difference, and it may be no coincidence that these contexts are possibly to be assigned Medieval ages.

## Further Investigation

The larger assemblages from Trench 44 might be worth characterising through chemical analysis of representative material. The accumulation of such analyses from different smelting sites helps build-up the broader picture of smelting technology. However, acquiring those data from sites with a larger suite of slags, ores and lining materials would be preferable; the utility of the analytical data in this case would be limited by the small sample assemblage size.

## References

- Fulford M G and J R L Allen, 1992. Iron-Making at the Chesters Villa, Woolaston, Gloucestershire: Survey and Excavation 1987-91, *Britannia*, **23**, 159-215.
- Mack I., McDonnell G., Murphy S., Andrews P. and Wardley K. 2000. Liquid Steel in Anglo-Saxon England. *Historical Metallurgy*, **34**, 87-97.

Context	Weight (g)	Notes
<b>602</b>	5	grey fired clay with organic temper and grog
TRENCH 10		
<b>1004</b>	70	agglomeration of corroded material including slag, coal, slag spheres and fired clay. Could be slag or iron inside or maybe it is just smithy floor accretion.
	90	piece of deformed dense slag attached to and flowed over by wall with vitreous layer. Might be a burr but not clearly so.
	25	elongate piece as 1
<b>1007</b>	135	dense slag, piece is in form of slab 50x40x25mm thick but original orientation unknown, internal texture is very dense but includes charcoal and may be brecciated
	65	nub c.40mm diameter, with irregularly lobed surface. Accretion includes lots of coal
	35	small irregularly lobed/dimpled piece with accretion including lots of coal
	25	piece of hearth lining, broken in 2, coal present - probably in fabric but may be accretion. Clay orange in rear going mauve near surface, with thin veneer of Fe slag
	105	runner fragment? Broken in 2, curved surface with dense crust to 8mm?, becoming solid towards one end, but very vesicular. accretion shows much coal.
	25	small nub of vesicular slag, corroded material includes goethite botryoid and coal
TRENCH 34		
<b>3407</b>	45	fragmented piece as 3408, on opposite side to main smooth surface 1 end appears attached to conventional fired clay backing. Tempered with small rounded quartzite grains and organics - may be a thin protective furnace lining
<b>3408</b>	10	piece of sheet of dark mauveish fired clay, probably with slightly vitrified surface
TRENCH 37		
<b>3704</b>	900	block 70 x 90 x 90mm thick of conventional dense tap slag cake, thins to 50mm on one side suggesting it is part of semicircular section cake
<b>3705</b>	350	broken piece of tap slag cake, 50mm thick, very steep edge, in two pieces
	10	coked coal, in 2 pieces
	85	irregular fracture bounded piece of slag with abundant vesicles and other holes, 40x35x25mm

1765	very dense slag block large coated in accreted debris. 130x100x100mm. Could be furnace slag, but not clear enough to tell without cutting
55	as 3
35	as 3
40	as 3
25	as 3
55	as 3
20	as 3
<b>3706</b>	45 40 x 35 x 10-20mm thick slab of conventional tapped slag with multiple lobes in sheet form
<b>3708</b>	45 piece from edge of dense lobed tap slag flow, 20mm thick with vertical edge, 45mm long, 20mm wide
20	triangular fragment of a single lobe layer, 10mm thick, from a tap slag, lower surface probably fractured off larger cake
235	very dense slag with lobate top 50mm thick, slab 30 x 70mm, overall form uncertain, possibly suffered contortion during removal
<b>TRENCH 44</b>	
<b>4403</b>	785 200mm length of slag runner, roundedly triangular in cross section, apparently from widened obliquely ellipsoidal original hole. No good free surfaces, base slightly arched, slag vesicular and "dirty" looking. 50mm deep, 40mm wide at one end widening to >65mm.
505	150mm length of runner, main flow transversely elliptical, 55 x 37mm, widens at one end to 80mm, loses centre and nearby gains free top with rather plastic looking lobes, presumably this end is internal.
150	95mm length of narrow, lobed runner. 43mm wide by up to 32mm tall. Still many vesicles but denser than larger pieces.
35	85mm length of moderately dense runner, crescentic section, 18mm wide, 10mm deep, with adhesions to concave side extending up 7mm
105	rather messy appearing cake of slag 60 x 55 x 10-25mm thick. Limited lobation of upper surface, broken in two
95	75mm length of runner, semicircular section 20mm deep by 30mm wide, upper part locally almost lobate, very vesicular and "messy looking"
110	part of fractured cake, lower surface has charcoal dimples, upper dominated by large ?vesicle 50x 25. Main cake 20mm thick, dense.
50	50mm length of finger of "normal" tap slag, dimpled lower surface, mainly single lobe 10-15mm thick by 12-30mm wide, proximally with second lobe on top.
5	blue fuel ash slag with encrustation
<b>4407</b>	200 irregular cake, 85mm long x 58mm wide, 30mm thick proximally?, 10mm distally, internally full of irregular vesicles, basal dense crust 4mm in places, top locally smooth but irregular, base rough, very dense, base corroded but probably dimpled
180	irregular fragment 80x60x40mm thick of highly corroded material with big charcoal remnants - probably secondary reduction material
460	110x60x70mm irregular very dense slag block containing large charcoal moulds
34-5	2 pieces and some bits of broken dense slag block with very large (and well-preserved) charcoal inclusions 110x50x60mm in total
75	dense nub bounded by fractures 40mm diameter, internal shows flow lobes, so probably a tap slag
70	dense nub 35mm diameter, possibly from runner
40	irregular fragment of dense flow with extremely large internal cavity

15	small fragment of tap slag with single lobe thickness (8mm) surviving
15	flow lobe of dense slag
15	flow lobe of dense slag
10	small nub of brecciated goethite ore
5	fragment of flow lobe
5	pottery (black burnished ware)
<b>4411</b>	10 small fragment of broken vesicular slag
<b>4416</b>	80 50x50x30mm rounded piece of low density slag full of well-preserved charcoal, much of pore space has ashy material contained within.
<b>4417</b>	250 fragment of burr 55mm deep x 60mm wide, very dense, but plenty of included charcoal, burr c50mm radius in plan 675 rather corroded rounded block of uncertain nature - may be corroded iron rich furnace/earth slag or might be "smithy floor" accretion (needs cutting...) 105x70x90mm
260	bilobed slag runner in three pieces. Suggests origin as two separate tubes, 23wx22d and 25wx35deep, whole is 48mm wide x c40mm deep max and 100mm long, each lobe has crescentic dense layer and concave top, tops not lobed, but irregularly flowed, frothy and sandy.
25	small highly weathered nub of uncertain nature
35	triangular piece of flat slab, 40mm wide x 9mm thick, top very smooth with raised edges, base irregular, slag with rounded vesicles and moderately dense
25	30x20x25mm small nub of broken lobate slag with adhering pale fired clay (probably runner fragment?)
<b>4418</b>	90 80mm length of slightly flaring slag rod, 20-25mm diameter, wider end has more open vesicular core, may have been more semicircular originally and one side has been crushed in when plastic
55	nub of very dense slag with some large ellipsoidal vesicles up to 20mm, 35x30x20mm
10	irregular piece with flat side - possible corrosion products broken off an artefact
20	triangular cross section of flow edge in dense tap slag with central open vesicle, top within a single lobe?, base slightly dimpled, 35 long x 15 x 18mm deep
5	blue fuel ash slag with incipient drip
<b>4424</b>	50 piece of iron bar
25	adjoining piece to 1 with adhering corrosion, bar totals 85mm long, 20mm wide, 6mm thick, end may be oblique
85	v dense slag with smooth top, ?raised edges and large internal void, 55x45x30mm thick
5	coked coal
10	2 pieces of corrosion as attached to 2