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# Assessment of archaeometallurgical residues from the N69 Rea to Tullig Road Realignment Scheme, Cloonnafinneela 1, Co Kerry (11E0354)

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## Abstract

*Cutting C included several features of archaeometallurgical significance, including a slag dump (c008, c009, c010), the upper layer of which (c008) sealed two shallow pits (c013 and c015). Immediately to the south of the dump there was a small arc of stakeholes. The dump was dominated by residues from iron smelting in a non-slag tapping, 'slagpit' style of furnace. The furnace was not seen, but is likely to have lain on the upslope (SW) side of the dump, just outside the excavated area, but adjacent to the pits and stakeholes. In total, approximately 35kg of residues were sampled from the site. A sample of* Alnus *charcoal from the dump (c008) gave a 14C age of cal. AD432-595 (SUERC-38751).*

*The dump context c008 contained a very large quantity of residues, of which 24.6 kg (an estimated 5%) were sampled by collection of macro-residues (the largest assemblage from the site). It is not known how representative were the samples, but the deliberate macroscopic residue collection has an unusual composition with (by weight) about 46% of large flow slag blocks and 31% furnace ceramic, the remainder being other classes of slag and concretionary materials. In contrast, environmental samples from the same context produced residues (total 3.3kg) with 66% finely fragmented flow slags, 10% furnace ceramic/ slagged ceramic and 23% of other slag types – a much more 'normal' style of assemblage. The environmental sampling also produced a very small proportion of hammerscale.*

*Hammerscale was a much more significant feature of the assemblages from the cut features sealed below the slag dump, where it was associated with concretions bearing abundant straw. Both flake hammerscale (much of moderate thickness) and a lesser amount of spheroidal hammerscale were present. This is good indication that at least the initial stages of bloom compaction were undertaken on the site. It remains uncertain whether the shallow pits were directly associated with the smithing, but this is possible (either as cut features or worn hollows in the floor). Similarly, the significance of the straw is uncertain – it may have been a floor covering, but it might have been employed as an organic fill for the slag pit. The flow slags from the site lacked the characteristic textures associated with the large pieces of split wood that are the more normal slagpit packing in Ireland.*

*The survival (and excavation) of slag dumps associated with early bloomery iron smelting in Ireland is unusual – and the site is very important for that reason.*

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# 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, nor to any form of instrumental analysis. The identifications of materials in this report are therefore necessarily limited and must be regarded as provisional. The summary catalogue of examined material is given in Table 1.

Stratigraphic and site details in this report are based on Long (2011).

The project was undertaken for Rubicon Heritage Ltd.

# Results

## Description of residues

*Preservation*
In general the slags are only moderately well-preserved, probably as a result of leaching by groundwater flow through the deposits. The more open-textured materials are particularly badly altered, whereas some examples of the dense flow appear, at least superficially, to be much fresher.

*Flow slags*
The flow slags from the picked metallurgical samples were mainly in the form of large blocks of birds-foot morphology. These stalactitic forms of slag are the solidified remains of sites at which large quantities of slag have descended from close to the bloom down into the underlying slagpit. They form close to the blowing wall of the furnace – so may be spatially associated with the burr and may adhere to the wall.

More isolated flow slags include a few examples of slag spheroids, but many more of prill and flow fragments from the environmental sample residues. A few flow slag fragments represent multiple horizontal flows, and therefore closely resemble tapslags. They are clearly distinguished however by a lack of haematisation of the surface layer; interaction with the air when hot normally causes the upper surfaces of tapped slags to turn slightly purple or maroon. Such a distinction is, however, subtle and may cause misidentification of such flows – possibly including the supposed tapslags from the medieval furnace at Farranastack (Dowd & Fairburn 2005), one of the nearest known furnace sites to Cloonnafinneela.

One reason that these horizontal flow slags so closely resemble tap slags is that they do not in general show the textural indications of flow around, and constrained by, large pieces of wood. Instead the slags show neat rounded flow lobes. Flow around large pieces of wood is a characteristic of the slag pit slags from most Irish slagpit furnaces. The absence of definite examples of this texture on this site provides a hint that the pit-packing may have been undertaken in a different way from usual. One possibility is provided by the abundant straw in the concretions. Straw-filled slagpits are unusual in Ireland, but are not unknown, occurring for instance in early medieval contexts at Camlin (Co Tipperary; Young 2011a) and possibly at Clonfad (Co. Westmeath; Young in press b).

Several of the birds-foot structures are directly overlain by a dense slag 'puddle' with a smooth upper surface. These have been described here as 'modified' birds-foot structures. This precise identification of the origin of the 'puddle' is not certain, but the texture, including the very abrupt transition from 'puddle' to descending prill suggests that the original source of the descending prills has been modified by a later high-temperature event. It is possible that a slag puddle existed between the bloom and the blowhole, but it appears more likely that the upper surface of the slag below the bloom has been modified by subsequent heating.

Many, if not most, of the birds-foot structures show an intimate association with oxidised fired clay. It is not clear whether these examples are simply where debris from the wall around the blowhole has fallen and been swept with the down-flowing slag, or whether the slag was actively breaking up a zone of ceramic on the lip of the slag pit.

*Furnace slags*
Various pieces of slag rich in charcoal and sometimes with a rather granular or prilly internal texture are interpreted as slags which formed below the bloom, possibly as part of a furnace bottom (FB). These slags often lack clear diagnostic criteria for their identification and so some of the indeterminate slags may also be FB fragments.

*Furnace superstructure*
The superstructure of the furnace is represented by a large number of fragments of fired and vitrified ceramic. None of the fragments shows any clear morphological features relating them to specific locations within the furnace, but the general high degree of vitrfication suggests that these pieces come from the areas of the furnace close to the blowhole which suffer most damage (both during the smelt and during the removal of the bloom) . There are no examples with actual blowhole margins, nor any sherds from tuyères.

Where the pieces preserve good evidence for convexity (a significant number are complicated by an origin in the zone close to the blowhole where the shaft has undergone some erosion by the reaction and others show signs of plastic deformation) the pieces have a simple curvature, so a broadly cylindrical shaft seems likely.

The ceramic was formed from a very gravelly clay suggesting that the clay required (or was given) rather minimal treatment prior to use. There were no clear signs of organic temper.

Firing of the clay included both reduced and oxidised fabrics, as is usual. The oxidised fabrics are likely to be from close to the blowhole, or from high in the shaft. Other parts of the structure are reduced fired. In most examples of oxidised fired wall, the zone immediately below the glassy surface is reduced – often with a slightly lilac colour.

The reduced fired zone in this superficial location has a slightly unusual texture (presumably due to the firing properties of the local clay). The clay is finely fissured to give a slightly clotted texture (individual 'clots' just 1-2mm across) bounded by thin films of glass penetrating down into the underlying ceramic.

Much of the superficial glass is strongly devitrified and altered. In many instances iron-rich crusts lie on the glaze and it is sometimes unclear whether these are

weathered remnants of slags, or are post-depositional concretions.

Some of the material shows indications of plastic deformation – and it is unclear whether these are the result of furnace lining being pulled hot from the furnace during furnace clearance, or whether they represent examples of wall failure in use.

*Burrs*
There are several examples of structures identifiable as burrs. These are rather open, concavo-convex examples, typical of slag-wall interaction in smelting furnaces, rather than the smaller, slag-filled structures more typical of smithing hearths.

*Possible smithing hearth cakes (SHCs)*
There were two possible SHCs from c008. Neither was a certain identification. One was a complete slag piece weighing 396g, the other a broken slag piece weighing 404g and estimated to be about 85% complete if it were to be reconstructed as a symmetrical SHC (i.e. would have had an original weight of c. 475g).

Both cakes were of rather low density – one apparently with a high proportion of charcoal, the other with substantial internal voids. These cakes would be atypical of bloomsmithing slags in general, which tend to be rather dense SHCs.

*Smithing microresidues (fines)*
Smithing was rather more convincingly demonstrated by the occurrence of smithing microresidues. These were dominantly flake hammerscale, but also included some spheroidal hammerscale, but no examples of slag flats were noted.

The flake hammerscale was, in general, moderately thick, which would be expected from the need to heat blooms, or bloom fragments, for a moderately long period between forgings.

The assemblage is quite different from medieval sites where there was more general smithing being undertaken, at which the flake hammerscale is dominantly very thin (due to the short periods of heating required when forging small artefacts compared with blooms) and where slag flats appear to be a major component of the assemblage (e.g. Coolamurry, Co. Wexford; Young 2008a).

*Concretions*
The assemblage includes two classes of material described as concretions.

The first class was fine-grained material dominated by moulds and mineralised fragments of straw. The straw moulds were marked by prominent longitudinal striations. This material commonly contained hammerscale. These materials will have formed within the dump, or more likely, within a 'floor' layer associated with the smithing.

The second group of materials described here are more problematic. The specimens are friable and very heavily weathered – precluding certain identification. They include slag fragments, charcoal and, characteristically, fragments of pale green clear glass. It is unclear whether these are actually slags or concretions (i.e. materials formed concretion by secondary iron minerals after deposition).

The variable nature of the inclusions within these friable materials strongly suggests that they too are concretions. but there is a possibility that they represent furnace floor deposits. One interpretation might be that these represent a build up from around the anvil – and that the green glass is an iron-poor slag broken from the surface of the raw bloom.

### Distribution of residues

The majority of the material examined derived from the slag dump. There was no noticeable difference in the residue assemblages from the different contexts (c008, c009 and c010). The assemblages from the fills of the underlying features (c014 and, c016) also contained similar fragmented smelting residues to the overlying deposits, but contained an increased abundance of concretions (particularly in c014 those containing straw) and an increased abundance of hammerscale.

C008 produced a 14C date on alder charcoal of cal. AD 432-595 (SUERC-38751).

## Interpretation

Despite the superficial differences between samples taken in different ways, the site shows a good homogeneity of material. The evidence indicates the use of a non-slag tapping furnace, with strong flow of slag away from the bloom in particular areas generating birds foot structures, which in turn lead to neatly lobate cross-floor flows. Immediately below the bloom there was probably a rather friable, charcoal rich slag mass (that might be termed a furnace bottom – FB).

This general style of furnace is common in Ireland from the early Iron Age, possibly lasting as late as the early post-medieval period in some places. There are aspects of this furnace residue which is, however, unusual. Well developed birds-foot structures and neatly-lobate cross floor flows suggest that the slag flow was not being significantly impeded by any filling of the slag pit. Most early furnaces in Ireland show moulding of the slag flows around a pit filling of split wood. No evidence survived from the smelting slags for the nature of the pit filling; although concretions within the dump deposit contained significant amounts of straw this could not be related directly to the slag pit fills.

The second unusual feature of the site was the presence of hammerscale within the main slag dump (c008, c009 and c010) and particularly in the fills of the underlying features (C014 and c016). Such a pattern might conceivably be caused by downwards percolation of the fine hammerscale through the dump, to accumulate in the lowest levels, but it is probably more likely that the distribution is original ,and that the features below the later parts of the dump represent an area in which smithing was undertaken (or close to an area of smithing). Smithing areas may contain deliberate cut features (e.g. smithing hearths, bases of wooden anvil blocks), but may also commonly contain hollows worn by the smith operating repeatedly in the same areas.

The general absence of smithing slags of normal aspect (just two rather doubtful examples of SHCs) may suggest that the smithing was undertaken in such a way as to not produce SHCs – with the most likely

scenario for that being that the smelting furnaces were themselves used for reheating the bloom. Such a proposition might account for the odd upwards termination seen on the birds-foot structures. Reheating blooms in the furnace would not be desirable for extended periods of smithing, but might suffice just to compact the bloom – and perhaps to split it (after the manner of the split blooms from Co. Fermanagh, Evans 1948).

## Summary

This site represents an excellent example of an iron smelting operation, probably located to take advantage of local bog iron ore and woodland resources. The furnace(s) was a non slag-tapping 'slagpit' furnace and the waste dump has an unusually rich assemblage of fragments from repair of the clay shaft superstructure.

The residues also include some evidence for smithing – particularly in terms of microresidues. This probably indicates that only minimal smithing was undertaken on the site – probably just the immediate bloom compaction which is best undertaken when the bloom is still hot from smelting.

The product of the site would probably have been compacted blooms, either of the split form seen in the examples from Co. Fermanagh mentioned above (Evans 1948), or the rounded form of other examples (e.g the blooms from Brothers and Carrigmurish caves, Co. Waterford). Although it is possible that the local community might have fully refined the iron elsewhere, it is also possible that the compacted blooms would have themselves been used for trade or exchange. Young (2011b) has argued that the character of medieval smithing slags in Ireland demonstrates movement of iron in an incompletely refined form.

The site did not yield any of the large slag cakes and tuyères that are considered typical of bloom refining operations in the Irish early medieval period (e.g. Young in press) – though whether this is a function of the minimal use of smithing on the site or whether of the early (mid 5$^{th}$ to 6$^{th}$ century) date is not clear. A late 6$^{th}$ to mid-7$^{th}$ century iron production and bell-making site at Gortnahown, Co. Cork (Young 2009a) also produced no evidence for the use of tuyères. The earlier (probably 5$^{th}$-7$^{th}$ century) phases at Camlin 3 (Young 2011a) produced little material that was certainly from ceramic tuyères, although they were abundant in contexts probably of 8$^{th}$ to 9$^{th}$ century age. Similarly the late7$^{th}$ to 8$^{th}$ century site at Ballinglanna North (Young 2009b) provided evidence for both very large slag cakes and tuyères. The 7$^{th}$-8$^{th}$ century phases at Clonfad (Young in press) also produced similar evidence

The organisation of the site, with an apparently relatively isolated location, close to both potential ore and woodland resources, is what is commonly assumed to be typical for much of the early smelting in Ireland, but which is rarely found preserved (truncated isolated slag pits are far more typical). The site was not completely excavated and it is likely the furnace location itself lay outside the excavated area, although the arcuate cluster of stakeholes might potentially have been associated with the furnace setup – perhaps as a mounting for the bellows or a bellows return spring, or alternatively may have been a structure for materials storage.

Although such sites are rare in Ireland, isolated bloomeries with slag dumps of approximately this size are relatively well-known in Britain (perhaps because of their recognition in intensively ploughed areas). One model for the British examples (where local bog ore deposits are less common) is that they were constructed to follow the coppice rotation - with the woodland providing charcoal until the transport distances grew and it was easier to construct a new bloomery in the next area to be coppiced and charcoaled. In Ireland, both the moving exploitation of the bog ores and of the woodland resources may both have contributed to the use of such sites. Such revisiting of the resource over time may be reflected in the younger, but still early medieval, 14C date from the nearby charcoal pit (in trench C, 35m from the smelting operation, dated to cal. AD 723-740 / 770-900 / 918-950, SUERC-39752).

In summary, the site provides an exceptional example of an early medieval smelting operation, of probable 5$^{th}$-6$^{th}$ century date. The presence of evidence for at least some primary smithing, but the absence of evidence for ceramic tuyères and large slag cakes, sets the assemblage apart from most 7$^{th}$-8$^{th}$ century sites interpreted to have been undertaking bloom refining.

## Assessment of potential

The site shows an unusually good level of preservation of the slag dump and, despite lacking a furnace site, does possess a very good suite of residues (furnace materials, smelting slags, smithing residues).

No ore was recognised in the assemblage, but on some sites there is evidence for the use of a powder ore, which is a significant component of furnace floor concretions (e.g. Young 2008b).

Such an assemblage would therefore normally be recommended for additional analysis. Such a programme of analysis would involve investigation of all the materials in an attempt to create a mass-balance description of the reaction (following the methodology of Thomas & Young 1999a and b) – which in turn may be used to calculate yield.

In this instance, however, there are some short comings, which might argue against further detailed work. In particular the lack of the furnace itself, whilst not preventing the mass balance analysis, does not permit reconstruction of how much slag was produced by a single smelt – and hence the yield of iron per smelt, an important economic parameter, could not be calculated. In addition, any analytical programme would need to be undertaken with great care with regards to the high degree of weathering of some of the materials.

Whether or not further analysis is commissioned at this time, the site is of significance and full retention of the assemblage is recommended. Further analysis of the assemblage would be highly desirable and the materials should remain available to future scholars.

## Glossary

*Birds-foot slag:* a form of flow slag in which persistent flow from close to the bloom leads to development of a stalactitic morphology, with multiple coalesced vertical prills which may fan-out on reaching the slagpit floor. These structures usually form close the blowing wall of the furnace.

*Blacksmithing*: the working of iron and steel. Often restricted to the secondary smithing – i.e. the smithing of iron to produce or repair artefacts.

*Bloom:* the crude iron block formed by iron smelting in a bloomery. It may contain voids and inclusions of slag and charcoal. It will require some degree of reworking (bloomsmithing) and/or refining before the iron can be used by a blacksmith.

*Bloom refining*: the conversion of a raw bloom to useable metal. Often accomplished by bloom smithing, but other techniques, such as remelting, may sometimes have been employed.

*Bloom smithing*: the smithing of a bloom – often by folding and welding, to convert it into usable iron. Sometimes called primary smithing.

*Burr:* the zone of interaction between slag and the hearth or furnace wall just below the tuyère/blowhole. Typically seen as a dense lunate slag, with attached highly indurated ceramic, forming a protuberance on the margin of an SHC or FB.

*Flake hammerscale (FHS):* flake-like particles formed by the surficial oxidation of hot iron in air (Young 2011c). The iron oxide layer will detach from the workpiece because of differential thermal contraction or during deformation of the workpiece when hot-worked at the anvil. The thin scales fall from the workpiece and will accumulate mainly close to the anvil (although some will be lost elsewhere in the forge and even in the hearth). Flake hammerscale has planar surfaces, one of which is typically very smooth and reflective, the other only slightly less so.

*Flow slag:* smelting slags that have flowed within the smelting furnace, typically into the basal pit of a slagpit furnace, but have not flowed out of the furnace. Flow slags may include various morphologies: individual slag spheroids, isolated vertical prills, horizontal flows/prills, birds-foot structures.

*Furnace bottom (FB)*: a rather poorly-defined term for the main slag mass formed during iron smelting in a non slag-tapping furnace. If the basal part of the furnace is shallow this may be dense, but if the bottom is deep then a rather low density FB, formed of coalesced prills, is more common. Slag escaping incorporation into the main FB forms flow slag lower in the pit.

*Primary smithing*: see bloom smithing

*Secondary smithing*: see blacksmithing.

*Shaft furnace*: a furnace in which the charge descends under gravity as the fuel burns and the reducing gasses rise. The blast furnace, the bloomery and the early tin smelting furnaces are all shaft furnaces.

*Slagpit furnace*: a variety of non slag-tapping smelting furnace in which a pit for slag collection lies below the base of the shaft. Slag pits are commonly packed with organic material prior to smelting – which is typically split wood in NW Europe, but may be of cereals or grass (particularly in eastern Europe). Flow slags form where slag descends into the pit and a furnace bottom may form across the top of the pit. This is the dominant form of early iron smelting furnace in Ireland.

*Slag flats*: formed from an accumulation of slag on the surface of the workpiece (or sometimes on the surface of the smith's tools). This accumulation may be formed from slag escaping from the inclusions in the workpiece, formed from melting of the surface oxide layer, or formed from contact with slag drips in the hearth. Slag flats are thicker than flake hammerscale, have one planar but rough surface and one irregular surface.

*Slag spheroids*: sub-spheroidal particles, often dimpled (coffee bean spheroids), dull in lustre, and less perfectly spherical the spheroidal hammerscale. These spheroids are typically up to about 10mm in diameter. These are mainly slag droplets formed by the dripping of slag within the fuel bed of the hearth. Isolated spheroids may form in non slag-tapping smelting furnaces as a variety of sparse flow slag, but are more common in smithing hearths.

*Smithing hearth cake* (SHC): the slag cake formed in a smithing hearth by reaction of iron oxides lost from the workpiece with silicate material from hearth ceramic and/or fuel, below and in front of the tuyère/blowhole. They are very variable in form, but are typically plano-convex in shape (although concavo-convex and biconvex forms are common), frequently with a dense lower crust and a less well consolidated upper part. In some cases the top is formed of glassy slag.

*Spheroidal hammerscale (SHS*): spheroidal particles of typically less than 2mm. Often these are vesicular or hollow. Mainly formed (Dungworth & Wilkes 2009; Young *2011c*) when, mainly during forge welding, the iron is heated sufficiently for the surficial oxide layer to melt; when the two sides of the weld are closed, the molten oxide is expelled. This process is often enhanced by the addition of a welding flux – particularly where quartz sand is used. The melt coalesces into droplets and chills in flight to form spheroidal hammerscale. Typically they have a shiny surface with a metallic lustre and a close to perfectly spherical shape (unless deformed by impact).

*Tapping*: allowing slag (in the context of a bloomery) or metal (in the context of some other furnace

types) to flow from the furnace to cool and solidify outside the furnace. Slag tapping bloomeries have an advantage in being easier to clean and refurbish between smelts compared with no-tapping varieties. They may also (depending on slag viscosity and quantity) assist with a high degree of bloom-slag separation.

*Tapslag*: smelting slags which have been tapped – i.e. permitted to flow out of the furnace.

*Tuyère*: a tube, frequently ceramic in Ireland, through which air was blown into a smith's hearth. The tuyère allows separation of the bellows from the fire and protects the nose of the bellows (which were probably formed of organic materials). Ceramic tuyères were progressively consumed during use and would have formed one of the inputs for slag formation in the hearth.

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*Table 1: summary catalogue of submitted material from Cloonnafinneela 1*

| C# | S# | label | weight | no. | notes |
|---|---|---|---|---|---|
| 8 | 1002 | 1 of 4 | 184 | 1 | **Deformed vitrified furnace lining**:. strongly striated dark glass on orange oxidised clay. Strongly concave suggests pulled when plastic - somewhat resembles 818 g piece in tub 4. |
| | | | 216 | 1 | **Vitrified furnace lining**: gently curved block of lining slag – front with fissured/granular pale grey-buff vitrified ceramic with dark glass film. Rear mainly is base of detached glassy layer, but has horizontal band of orange oxidised clay across centre of piece - not clear what structural position this is - towards base of shaft? |
| | | | 150 | 1 | **Vitrified furnace lining**: slab of vitrified lining with dark almost purple opaque glass with vertical striations (from slight down flow?) on oxidised fired clay, slightly concave - close to blowhole? |
| | | | 534 | 1 | **Modified flow slag**: very dense block of slag - has concave smooth top (blown after bloom removal) over dense descending prills mixed with some gravelly grey clay |
| | | | 656 | 18 | **Concretion?**: friable granular material with slag, charcoal, green glass and lots of rust - not clear if this is a decomposed slag or a cemented detrital deposit (much of the small pieces in this tub are probably this friable material too) |
| | | | 138 | 1 | **Flow slag:** dense multi-lobed tapslag-like piece. Striations on base suggest a wood contact. Surfaces dark not maroon, flow slag from pit base, upper surface covered in fragmented red/orange fired clay |
| | | | 332 | 5 | **Flow slag:** birds-foot fragments |
| | | | 386 | 1 (2) | **Modified flow slag**: smooth but irregular topped birds-foot root. Lots of adhering, buff, orange and grey gravelly clay - hard to work out geometry - but broadly similar to other flat topped pieces |
| | | | 406 | 8 | **Vitrified furnace lining**: oxidised-fired furnace wall with deep vitrification. One piece shows a good relining section |
| | | | 216 | 5 | **Furnace wall**: oxidised-fired clay, low fired, no vitrification - outer/upper parts of furnace? |
| | | | 510 | 8 | **Vitrified furnace lining**: vitrified reduced- fired clay. Vitrification often thick, very porous and very irregular |
| | | | 274 | 4 | **Flow slag:** rusty lobed slags - probably poor furnace bottom flow slags but only one shows very high density |
| | | | 122 | 1 | **Lining slag**: irregular mass of black glassy slag in convoluted forms |
| | | | 404 | 1 | **Flow slag:** dense slightly curved slag sheet, prilly against gravelly clay to rear, smooth to front - possibly lower part of burr area, but could be foot of wall |
| | | | 230 | 1 | **Flow slag?:** rounded lump of slag , very rusty, with very large internal cavities |
| | | | 166 | 1 | **Furnace** slag: vaguely plano-convex shaped mass of dark rusty slag in irregular shape, probably a charcoal rich slag coated in dark secondary oxides |
| | | | 194 | 2 | **Concretion?**: 2 more pieces of the granular material |
| | | | 172 | 1 | **Modified flow slag?**: weathered sheet of slag with smooth top/front and prilly rear/base on to grey gravelly clay, contains lots of charcoal despite high density |
| 8 | 1002 | 2 of 4 | 764 | 48 | **Flow slag:** dense flow slags, vary from individual prills to fragments of birds-foots |
| | | | 238 | 20 | **Furnace wall**: low-fired gravelly clay, mainly slightly oxidised (buff colour), but some more dominantly reduced (pale grey colour) |
| | | | 494 | 12 | **Vitrified furnace lining**: reduced-fired vitrified lining, often has glass penetrating down minor fissures, less glassy pieces are more bloated, surface tends to be iron oxide coated, brown, and rusty. |
| | | | 1195 | 28 | **Vitrified furnace lining**: oxidised-fired vitrified lining, black surficial glassy slag often very irregular, sometime dimpled, some pieces how the fissured glass filled texture seen on the more purely reduced fired pieces, but within a 10-15mm reduced zone between glass and oxidised rear |
| | | | 168 | 1 | **Burr:** well formed concavo-convex burr, large charcoal fragments on front, gravelly pale grey wall to rear, burr crust layer thins from 5-15mm down wards |
| | | | 194 | 1 | **Flow slag:** interaction of dense slag and wall - variably grey and ornate, probably a rather poor upper section from birds-foot |
| | | | 484 | 11 | **Concretion?**: friable material - either very weathered slag or concretionary material |
| | | | 1075 | 39 | **Furnace slags**: mainly rather low density porous furnace slags, rich in moulds/mineralised charcoal, occasional flow lobes visible within |

| C# | S# | label | weight | no. | notes |
|---|---|---|---|---|---|
| | | | 322 | 7 | **Indeterminate slags**: fragments of dense slags too small for firm identification - some rather SHC like, but probably all dense FB material |
| | | | 154 | 2 | **Slagged furnace lining**: granular sheets of slag or sintered ore? In thin curved sheets , in one attached to reduced fired grey gravelly wall |
| | | | 46 | 1 | **Slagged furnace lining**: grey gravelly wall attachment with pendent flap of dark, low density slag |
| | | | 950 | | (*plus substantial quantity of small detritus and stones*) |
| 8 | 1002 | slag | 572 | bag | **Fines:** includes lots of fired clay, flow slag debris and possible ore dust - but are also rich in flake- and spheroidal hammerscale |
| 8 | 1002 | 3 of 4 | 688 | 1 | **Vitrified furnace lining**: large block of reduced-fired furnace wall, 130x140x 50mm, 30mm thickness of well fired grey/lilac, 20mm of yellowish softer material. Face dark vitrified and weathered with rusty coating |
| | | | 1930 | 1 | **Flow slag**: dense birds foot structure onto orange clay. 160x160x80mm. dense slag of slate grey or darker, somewhat metallic lustre |
| | | | 1250 | 1 | **Flow slag**: small dense birds foot structure. Narrow flows build up into narrow ridges on top - between wood? 110x100x80mm, orange clay on vertical wall, foot rests on charcoal |
| | | | 864 | 1 | **Flow slag**: small dense birds-foot structure, 100x140x60mm |
| | | | 802 | 1 | **Flow slag**: strange block, probably a poorly developed birds-foot; has elliptical basal block of finely prilly slag with almost central possible feeder. Top of pad covered with orange clay, base rusty and charcoal rich - could just be other way up and rusty ellipse is the end of FB with a down-going feeder? |
| | | | 396 | 1 | **Smithing hearth cake (SHC)?:** rounded mass of slag, at least partially charcoal-bearing, probably a small SHC with charcoal slag mounded on top. All rather rusty and unclear 90x70x70mm of which dense bowl 40mm |
| | | | 306 | 1 | **Vitrified furnace lining**: block of reduced fired furnace wall, possibly relined - surficial slag layer is flaking away, but a bit weathered to be sure. Lots rounded gravel in wall, reduced layer thinner than in other block, 100x110x50mm. |
| | | | 396 | 1 | **Vitrified furnace lining**: curved block of oxidised fired clay with attached lining slag. Very odd piece - curve is wrong way for a tuyère – so possibly from a shaft base? |
| | | | 1600 | 1 | **Flow slag?**: friable mass of prilly slag that appears to have had quartzite slab impressed into top. 160x160x80mm. *(plus broken detritus)* |
| 8 | 1002 | 4 of 4 | 476 | 1 | **Vitrified furnace lining**: dished slab of furnace lining, crudely semi-circular dark area, but mainly grey porous vitrified material with hint of included charcoal debris - probably a scar from above the blowhole, rear includes both reduced and oxidised zones. |
| | | | 270 | 1 | **Vitrified furnace lining**: piece of vitrified furnace, thick glassy slag over reduced fabric on oxidised base. One edge looks original - in which case is it a shaft bottom – or a 'brick' construction join? This edge is almost planar but not quite, well cracked, but not curved enough for typical tuyère base. |
| | | | 818 | 1 | **Vitrified furnace lining**: oxidised vitrified lining, dark slag on thin grey layer on bright orange rear, strongly curved with an iron rich adhesion - the nature of which is not entirely clear, probably a weathered charcoal-rich slag. Where the vitrification is thinnest the orange comes almost to the inner surface |
| | | | 666 | 1 | **Burr?**: concavo-convex burr like mass, gravelly reduced lining to rear, hollow presumably faces upwards and inwards, below is slag ledge with charcoal-rich slags and hints of flowage |
| | | | 584 | 1 | **Modified flow slag**: mass with smooth slightly concave top, rear shows prills descending through bright orange ceramic, base appears to be root of a birds-foot with some significant iron inclusions - presumably therefore also close to a burr region |
| | | | 458 | 1 | **Vitrified furnace lining**: large block of strongly vitrified furnace wall - almost lilac below glass, some oxidation, but well below surface. Shows superficial glass penetrating into network of small fissures within the lilac layer |
| | | | 404 | 1 | **Smithing hearth cake (SHC)?:** thin plano-convex vesicular slag block, 100x(100)x30mm, charcoal-rich, thin crust to about 7mm below vesicles. Not certainly a SHC but resembles one - probably c 85% if SHC |
| | | | 306 | 1 | **Vitrified furnace lining**: block of furnace wall, thick chaotic glassy layer directly onto not very well-fired buff gravelly material. Grey layer shows strong thickness change across specimen 20-50mm, presumably surface material is mainly sloughed |

| C# | S# | label | weight | no. | notes |
|---|---|---|---|---|---|
| | | | 250 | 1 | **Modified low slag?**: small birds foot (or just possibly flat-topped root of birds-foot with lots of grey gravelly and red clay around prills). |
| | | | 326 | 1 | **Flow slag/burr**: very dense agglomeration of prills - probably the burr region with a concave puddle and clay/gravel on hearth wall side |
| | | | 304 | 1 | **Furnace wall**: gravelly reduced fired clay attached to friable iron rich material - could be on the wall or even the base of pit |
| | | | 422 | 1 | **Concretion:** rubbly/granular looking lump with variable slags in a charcoal rich mixture - with some bright green glasses. Contains iron - probably a sub-bloom slag, but might be a concreted mixture from bloom cleaning. Rather too weathered to be sure without cutting |
| | | | 148 | 1 | **Burr?**: smoothly concave topped slag with fresh break, internally vesicular and with oxidised clay on base - probably another piece from burr area |
| | | | 324 | 1 | **Flow slag**: worn block of very dense slag, top irregular but smooth, base is prilly into grey gravelly clay. Probably, but not certainly, a 'foot of wall' slag. |
| | | | 172 | 1 | **Flow slag?**: rather irregular curved slag sheet with fired clay backing, rather similar to item above - either foot of wall of just possibly a SHC fragment |
| | | | 20 | 2 | **Furnace wall:** fired clay fragments (oxidised, probably broken from one of the larger pieces) (*plus some detritus*) |
| 8 | <3> | slag & mag res | 598 | bag | **Slag fines:** plenty of dense flow slag fragments, much of the more sintery material is overgrown by black botryoidal secondary minerals - so details obscure - one particle shows pale green glass extending out from coatings |
| 8 | <3> | slag & mag res | 2685 | bag | **Slag fines:** 1795g flow slags (many hundreds of pieces); 280g (24 pieces) of lining and slagged associated material; 634g rough slags and bits |
| 9 | <4> | slag & mag res | 212 | bag | **Slag fines:** mainly slag in small fragments and stone, rare FHS |
| 9 | <4> | slag & mag res | 342 | bag | **Slag fines:** 224g (38 pieces), flow slag, dense neat lobes, 22g (6 pieces) soft grey fired lining; 76g (8 pieces) other slags - lining and/or charcoal rich - most both; 18g (4 pieces) gravelly concretion (or weathered lining?) |
| 9 | <4> | fired clay | 128 | bag | **Furnace wall:** c25 pieces of buff/grey fired clay, one small fragment of flow slag coated in red clay |
| 10 | <5> | burnt clay | 58 | 4 | **Furnace wall:** low fired buff clay |
| | | | 28 | 2 | **Vitrified furnace lining:** fired clay with a vitrified surface. Oxidised rear, one shows the glassy network seen in other material |
| 10 | <5> | slag & mag res | 1085 | bag | **Slag fines:** mixed dark assemblage of mainly dense flow slag fragments, fired clay and concretionary materials, but also has good amount of FHS |
| 10 | <5> | slag & mag res | 1005 | c.207 | **Slag fines:** 212g (53 pieces) of rough, sintery or charcoal-rich slag fragments; 692g (148 pieces) of dense flow slag; 70g (5 pieces) slagged vitrified wall - one with oxidised rear is lenticular and may be a burr fragment; 4g (1 piece) concretion |
| 14 | 1001 | | 338 | 30 | **Concretions :** yellow brown concretions rich in straw and some in charcoal, about half show some hammerscale, one sample is very rich in FHS with some SHS |
| | | | 28 | 1 | **Furnace/hearth ceramic:** vitrified and glazed ceramic - sinusoidal profile, mainly reduced to rear become oxidised to one end. Gravelly fabric. Neat glaze perhaps more resembles tuyère front than the smelting furnace fragments from elsewhere on this site |
| | | | 552 | 18 | **Flow slags:** weathered flowed slags, mainly with charcoal associated (i.e. not tapslag like), dense, some well amalgamated into larger masses |
| | | | 144 | 2 | **Vitrified furnace lining:** pieces of vitrified wall, oxidised buff/orange to rear, passes through thin grey in mash of pale bloated clots in darker glass |
| | | | 32 | 4 | **Vitrified furnace lining:** bloated grey vitrified ceramic |
| | | | 42 | 4 | **Indeterminate slag**: scraps of slag rich in very fine charcoal debris |
| 14 | 1001 | | 40 | bag | **Fines**: very rich in FHS, rare SHS |

| C# | S# | label | weight | no. | notes |
|---|---|---|---|---|---|
| 14 | <6> | slag & mag res | 516 | c130 | **Slag fines:** 156g (45 pieces) are dense flow slags; most of rest is concretion with straw and rare FHS; 2 fragments of oxidised-fired vitrified lining and a couple of pieces of grey bloated lining. Straw moulds are excellent. |
| 14 | <6> | slag & mag res | 700 | bag | **Slag fines:** mainly flow and amorphous slags, but plenty of FHS (some quite thick) and rare SHS |
| 16 | <7> | slag & mag res | 147 | bag | **Fines**: dominated by 'ashy' concretions, but abundant FHS and slag spheroids, moderate SHS |
| 16 | <7> | slag & mag res | 110 | 54 | **Slag fines:** 42g (18 pieces) small fragments of neat dense flow slags; 40g (37 pieces) of concretions with charcoal and some FHS; 10g (5 pieces) vitrified lining debris; 10g (2 pieces) dull matt slags |

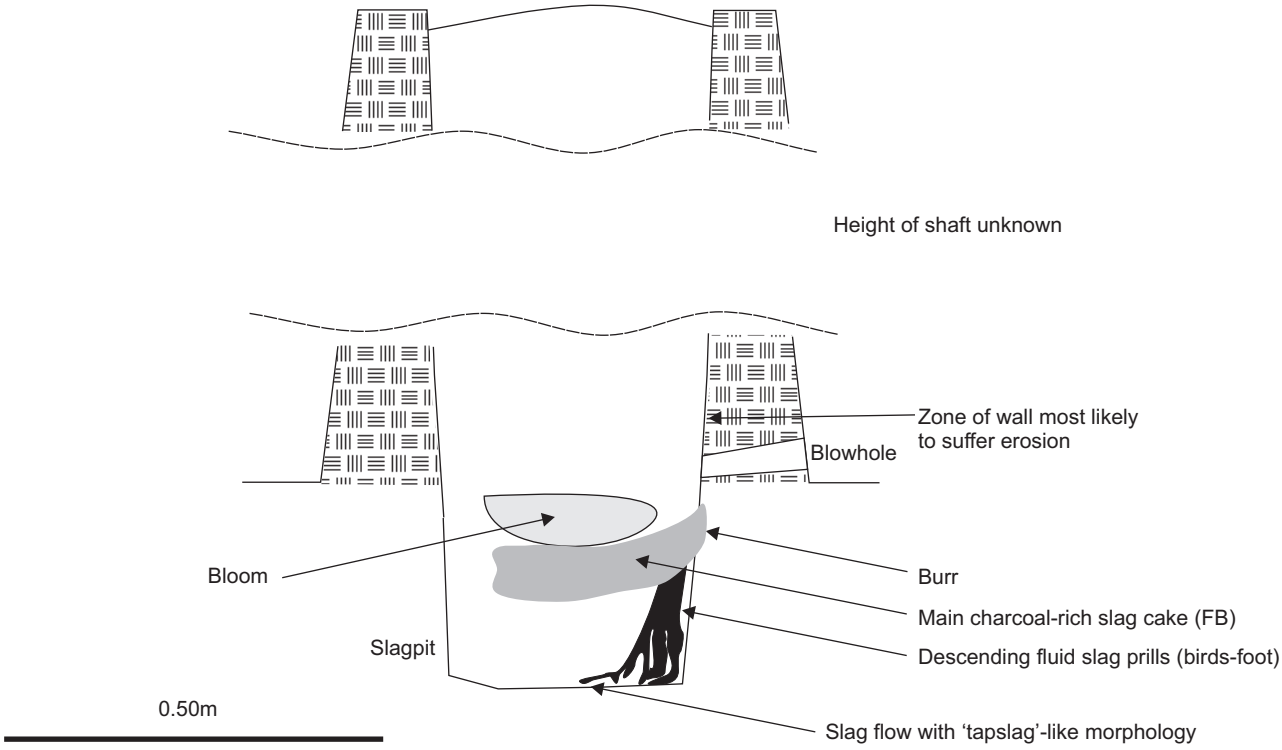


*Figure 1. Sketch of cross-section of a slagpit furnace showing the relationship of the features mentioned in the text.*

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