GeoArch

Report 2021/11

Analysis of archaeometallurgical residues from Lydney B North, Phase II

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24th July 2021

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Abstract

The site produced a large assemblage (almost 190kg) of archaeometallurgical residues. The assemblage was present largely within makeup and levelling deposits, occurring mostly in contexts of Periods 3 (63%), 4 (19%) and 5 (12%). There was no evidence for metallurgical activities having been undertaken within the excavated area.

Most of the residues (85%) were from iron smelting and formed elements of a characteristic assemblage that typifies the waste from a particular type of iron smelting furnace. This assemblage was first recognised from Roman deposits at Cardiff Castle, but is known from across the region. The present material is the largest collection of the 'Cardiff-type' assemblage yet described in detail.

Slags with a conventional tapslag morphology comprise only 33% of the smelting slag assemblage. 40% of the assemblage is formed by apparently massive slags, 22% by slags in large channels and 5% by internal furnace slags. Although 9% of the overall assemblage were indeterminate iron slags and 2% hearth or furnace ceramic (or slag formed from that ceramic), just 4% were certainly identifiable as smithing slags including smithing hearth cakes from both blacksmithing and bloomsmithing.

The cut surfaces through the massive slags revealed traces of internal flow lobes not visible on the external surfaces; similar observations have recently been made equivalent material from Cardiff Castle. These apparently 'massive' slags contained mould of fragments of roundwood and partly-reacted pieces of iron ore. The poor visibility of the flow lobes has been attributed at Cardiff to either limited oxidation of the cooling slag surfaces and a slow cooling rate (and probably both).

Detailed provenancing of the iron ore was not possible because the trace element chemistry of the ore had a rather broad compatibility with sources in the Forest of Dean. Since the ore lacked the characteristics typical of particular known localities in the area, the probability of the ore being relatively local to the southern part of Dean is high, but this origin is not certain.

Modelling of the mass balance of the analysed material has been undertaken on the basis that the overall assemblage preserves the approximate bulk waste from operation. On that basis, if the iron mineral in the ore in its original state was goethite, 1 kg of ore would generate approximately 390g each of slag and raw bloom; an extractive efficiency of 64%. This is higher than for the medieval iron smelting on the same site, for which an extractive efficiency of 54% was proposed (possibly hampered by an unusually siliceous ore for the area).

Other metallurgical activities were indicated by six crucible sherds (probably from two small vessels) indicating the casting of copper alloys. The copper alloy compositions could not be determined with certainty, but contamination of the sherds tentatively suggests one vessel may have held gunmetal (a ternary alloy of copper, zinc and tin), the other a leaded brass, both common Roman casting metals.

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Methods

Project rationale and history

The material described here derives from Phase II of the excavations at Lydney B North, conducted by Cotswold Archaeology (CA project LYF17). This project was commissioned by Jacky Sommerville, of Cotswold Archaeology. The analysis was undertaken in summer 2021.

The material was assessed and catalogued (the catalogue is reproduced in the Appendix A to this report as Table A1), following visual inspection. An assessment report was produced in June 2019 (Young 2019b).

The assessment recommended:

> *'This assemblage includes one of the most comprehensive residue suites from a distinct regional (at very least) style of Roman iron smelting so far recognised. Further characterisation of the residues from this would be highly desirable to clarify the technology, which is so far very poorly understood.*
>
> *One facet of the assemblage that adds extra interest to further analysis would be the direct comparison of the Roman smelting from Phase II of this project, with the medieval smelting from Phase I (Young 2017b, 2019a). It is likely that many aspects of the smelting system would be the same (or similar), such as the furnace clays and perhaps the ore. Comparison may be made through the mass-balance modelling approaches of Thomas & Young (1999a,1999b).*
>
> *The ore is of particular interest, because on the adjacent medieval site there were reasonable grounds for suspecting a very local origin of the ore. It would be useful to know whether such sources were being exploited in the Roman period (when apparent trials for iron ore, if not productive sources, were opened in the Lydney area; Wheeler & Wheeler 1932). Provenancing of ore within the orefield may be attempted through the elemental discriminants of Young & Thomas (1998, 1999) and developed by Young (2000).*
>
> *The value of additional investigation is reduced, however, because the residue assemblage was derived from secondary contexts; there was no structural evidence for smelting within the site and the smelting had presumably taken place outside the excavated area.*
>
> *Accordingly, only a limited campaign of analysis of the iron slags and iron ores is recommended. This should take the form of suite of elemental analyses covering the major facies of smelting slags, smithing slags, furnace ceramic and iron ore.*
>
> *The small crucible from (3092) requires further investigation and non-destructive analysis by pXRF to determine, if possible, its use. If a substantial part of the profile of the vessel can be reconstructed than it may be worth illustration.'*

The commissioned analytical programme addressed these questions through bulk elemental analysis of six pieces of smelting slag, plus three bulk elemental analyses of iron ore and one of furnace ceramic.

Analytical methods

The selected samples (Table 2) were slabbed on a diamond saw and subsamples crushed for preparation of a whole-sample chemical analysis. The GeoArch site code used for the samples is LYDII.

Bulk chemical analysis was undertaken using two techniques. The major and minor elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, P and S) were determined on a fused bead using wavelength-dispersive X-Ray fluorescence (WD-XRF). Whole-specimen chemical analysis for thirty-six trace elements (Be, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Sn, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Th, and U) were undertaken using a sample in solution by Inductively-coupled Plasma Mass Spectrometry (ICP-MS). Both XRF and ICP-MS analyses were commissioned from ChemoStrat Ltd (Welshpool, UK).

For XRF analysis, samples were ground using a tungsten carbide shatter mill, dried at 105 C overnight and then 0.5 g was mixed with 6.5g of 50:50 LiT/LiM

flux and fused to produce a glass disk using a Claisse M4 Fluxy automatic fused disk maker. The samples were analysed using a Bruker S4 WDXRF using the default wavelengths for the elements identified. Calibration was via a selection of iron slag reference materials and geological reference materials.

Samples for ICPMS analysis were drawn from a second aliquot of the powdered material to establish trace element using the alkali fusion method (Jarvis & Jarvis 1992a and 1992b; Pearce *et al.* 1999). Once prepared, the samples were then all subjected to ICPMS analysis using a Thermo Scientific XSERIES 2. Data quality was strictly monitored in terms of precision and accuracy by five international rock standards of known concentration and varying compositions which are run after every 20 unknown samples. In addition, external monitoring of data quality is carried out four times a year via the GeoPt round robin proficiency testing program (http://www.geoanalyst.org/overview.html).

The results of the chemical analyses are presented in Tables 3 and 4 of this report.

The pXRF analyses of the crucible sherds were undertaken with a Bruker Tracer IIISD portable X-Ray fluorescence spectrometer (instrument belonging to the Department of Archaeology, Cardiff University, and the National Museum Wales). The instrument was operated with the Bruker 'yellow' filter (300µm Al + 25µm Ti), at 40kV and 9.60 µA, with a filament current of 189 µA, for 100s. The instrument was controlled by a PC running Bruker's S1PXRF software. Data were exported as text files for further imaging and processing in Bruker's Artax software. Data are presented here (Table 5) as the net peak area for the principal peaks as reported by Artax.

Archaeometallurgical background

Evidence for early iron smelting is widespread in and around the Forest of Dean. Iron ores are hosted by the Carboniferous limestones on both east and west crops of the synclinal structure as well as occasionally with the later sandstones in the Coal Measures in its core. The aera forms one of the most important expressions of the Bristol Channel orefield *sensu* Young & Thomas (1998 and 1999). The composition of the iron ores of the Bristol Channel Orefield has been investigated reasonably thoroughly and some understanding of regional variation established (Thomas 2000; Young & Thomas 1998, 1999; Young 2000) enabling a moderate precision in provenancing.

The Lydney North site has provided evidence for iron smelting in two distinct periods – Roman and medieval. In Phase 1 of the project medieval furnaces were discovered close to the manorial complex of Archer's Hall. These furnaces probably closely preceded development of the manorial complex and are similar to 11th-13th century examples elsewhere, being constructed over one end of a narrow trench. The residues associated with the furnaces (directly, as slag dumps and as build up for the later manorial buildings) were the subject of detailed analytical investigation (Young 2019a).

During Phase II of the project large quantities of residue (180kg) from ironmaking in the Roman period were discovered, together with just a small quantity of additional medieval material (7kg) (Young 2019b). This assemblage was almost entirely from smelting and comprised residues characteristic of the use of a furnace type common across the region that produced thick dense slag blocks, commonly containing moulds of roundwood and fragments of partly reduced iron ore, often in association with complex slag runners and channels. This assemblage was first recognised by Young & Kearns (2011) during assessment of an collection from Cardiff Castle; this assemblage has recently been analysed (Young 2021), but like Lydney North Phase II the site lacks evidence for furnaces.

The iron smelting residues

General description of the smelting residues

The assemblage includes 3.9kg of smithing hearth cakes (SHCs) and 2.9kg of possible SHCs. The remaining 180kg of the assemblage was of smelting slags (including 15.6kg of indeterminate slags, probably also smelting slags; Table 1).

The certain smelting slags included 7.7kg of internal furnace slag, 33.2kg of channel slags, 0.2kg of slag rod and 60.3kg of more massive slags (a total of 101.4kg), compared with just 58.7kg of tapslags.

The tapslags mostly comprised fragments of amalgamated rather stout flows, commonly forming rather narrow slag cakes, often with indications of lateral constructions (preserved as non-wetted surfaces). The tapslags were commonly up to approximately 50mm in thickness. A few examples were found in which the base of tapslag was strongly secondarily reddened, suggesting inversion of slag masses during clearance after tapping onto the margin of the tapping area, with the hot gasses from the furnace arch playing over the surface of the cleared material. The tapslags commonly showed small inclusions of iron ore, particularly on their lower surfaces. Two examples of tapslags were analysed as samples LYDII 4 and LYDII 5.

The apparently more massive slags were typically 50-100mm in thickness. The bases often showed lobation, although examples with slightly prilly bases suggesting flows subsiding into an underlying fuel bed were also produced. The tops of the massive slags commonly showed flow lobes, although possibly with lobes of convexity than in the conventional tapped slags. The massive body of the slags was commonly interrupted by one or more surfaces of flow lobing, commonly with no significant reddening. It was unclear prior to cutting the samples to what extent the massive nature of the slags is attributable to a genuine lack of flow lobing within them, and to what extent the relative invisibility of flow lobes which had formed with significant surface oxidation. Two examples of the massive slags were analysed as samples LYDII 7 and LYDII 8.

The dense slags frequently carried inclusions of partly- or un-reacted iron ore up to 25mm across within the body of the slag. They also commonly had moulds after pieces of round- and split-wood. The round-wood ranged up to approximately 20mm in diameter, with larger diameters apparently split. The largest split wood showed an external radius of curvature of up to 50mm. An example of the massive slags bearing roundwood was analysed as LYDII 6.

The channels and related materials formed a complex set of residues with channels formed from slag moulding a hollow below the cake, with rods forming where the slag-filled entity became separated from the main mass. The feeders were deeper channel-like

masses, sometimes with flow-lobed or corrugated tops. The feeders were commonly multiple – either side-by-side or stacked vertically. Individual channels ranged from 35mm to 70mm in width. The slag rods were narrower, ranging between 15 and 30mm in diameter. The fills of the rods, channels and feeders graded from dense slag (similar to that of the massive cakes) though to charcoal-rich materials. The most common microstructure was probably a porous slag containing rounded but irregular vesicles. An example of the stacked channels was analysed as sample LYDII 9.

Approximately 2% of the assemblage was provided by pieces of hearth or furnace ceramic, the majority of which was in the form of complex mases of sloughed partially melted pale grey slag from lower parts of smelting furnaces. One fragment of this grey ceramic showed stalactitic slag grows descending from the wall, suggesting the wall was fragment was from an overhanging section at 65°-70°. The smaller quantity of more classic oxidised-fired vitrified lining might have derived from either smelting furnaces or smithing hearths, in either case from near the air blast. An example of relatively unaltered lining was analysed as sample LYDII 10.

Two contexts of period 4 yielded assemblages almost solely with tapslags which were slightly more vesicular than was typical. This tentatively suggests that these contexts contained slags associated with the medieval iron smelting on the Phase I site immediately to the west. The smelting slags from this site were typically more vesicular than those from the Roman activity on the Phase II site. No examples of these materials was submitted for laboratory analysis.

Details of analysed smelting slags

LYDII 4 (510g, context (3314))
A 45mm-thick tap slag flow. The upper row of flow lobes is well formed, with a dark, very slightly maroon, surface. Below the upper layer of flow lobes the slag is more vesicular and is of chaotic appearance. The base is rather variable, with areas of probable sediment contact and other areas that are lobed and non-wetted. The base locally includes small, rounded grains of grey fired clay.

LYDII 5 (652g, context (3595))
A 45mm thick very dense tap slag flow. The centres of the flow lobes are large open voids. The flow lobe boundaries are also marked by lines of very small vesicles. The flow lobes on the upper surface are well formed. The base of the piece is a fracture into material rich in vesicles.

LYDII 6 (596g, context (3314))
An accumulation of slag with poorly-developed flow lobes bearing abundant voids after roundwood. One fracture surface provides a hint of tubular vesicles above a contact surface. Another surface appears to be a contact with fuel-rich material at a high angle to plane of the flow lobes – a geometry not easily explicable.

LYDII 7 (502g, context (3314))
A 60mm thick accumulation showing some traces of poor flow lobes, with a horizon of abundant examples of part reacted ore fragments. These are continuous with particularly dark zones of slag which surround adjacent paler, more vesicle-rich, zones. Some of the part-reacted ore particles show rusty external surfaces, suggesting considerable metallic iron had been present in/around them.

LYDII 8 (680g, context (3022))
A 70mm thick accumulation of flow lobes (though neither base nor top is original), demarked by slightly darker boundaries. One side of the block shows a non-wetted contact with a piece of red sandstone, now largely missing.

LYDII 9 (786g, context (3595))
Complex amalgamated slag channel fragment. The surface is very variable, locally with a surface suggestive of very viscous flow deformation, other areas are dimpled. Internally, the slag is very vesicular, with very irregular vesicles, but with local dense zones along some margins/

LYDII 10 (138g, context (3314))
Grey fired clay with numerous small voids. The piece is very slightly brecciated.

General description of the iron ores

Twleve pieces of ore (total 394g) were present in the collection, most of which were broken to the size probably employed in the smelting (to judge by the abundant part-reacted ore clasts in the massive slags of 5-15mm). The most common ore type had a layered microstructure with alternating bands of fine-grained massive ore and bands of fibrous-textured, probably botryoidal material.

One large fragment (102g) had a possibly brecciated texture and an overall morphology suggestive of a boxstone-like morphology. This was sampled as LYDII 1. The cut surface showed a slight suggestion of a layered structure, with abundant voids.

Although the ore is common slightly red in colour, it is believed to be mainly goethite, although the cracking in a few pieces suggest it may have in those cases have been roasted (and the samples analysed all had a ow loss on ignition, LOI, indicating they were of a haematite or maghemite). Ruddle was present in the porosity of the more stalactitic-textured pieces; this texture was sampled as LYDII 2. Two pieces were particularly fine-grained, one of which was sampled as LYDII 3. This piece showed small areas of a very fine texture, with associated zones of very fine scale stalactitic microstructure.

Bulk elemental compositions of samples

Iron ore
The major element analyses of the iron samples (LYDII 1-3) are shown in Table 3. Two of the analyses (LYDII 1 and 2) are of ores of very high grade, despite their very different textures. All major elements are at very low concentration in these ores except for silicon, present at levels equivalent to 2.0 and 3.9% silica. Trace elements too were at very low levels. The LOI was close to zero.

The third sample (LYDII 3) had a more significant level of gangue, with silica at 9.4% and similarly elevated levels of most trace elements.

The Upper Crust-normalised REE profiles (Figure 2; normalisation factors after Taylor & McLenan 1981) of the first two ore samples are humped, with the light REE markedly lower than the middle REE, and the heavy REE only very slightly lower than the middle REE. The third ore sample has a similar humped profile, but somewhat flatter – probably reflecting the influence of the 13% of gangue. On a plot of Eu_N/Lu_N v

Eu_N/La_N (Figure 3, upper), which provides a means of describing the profile shape, the analyses plot further from the origin (i.e. are more humped) than almost all analyses from the western crop, overlap with the shape of analysed examples from the east crop and ere less humped than examples from the central area.

The uranium contents of all the ore samples are low. A plot of U v SiO_2 (Figure 3 lower) shows that although the uranium contents overlap with low-uranium examples from all areas of the Forest of Dean, they show elevated levels of silica. Although some examples from each area show high silica, this distribution is closest to analyses of the sandstone-hosted ores of the central area.

Smelting slags
The major element analyses show a relatively small range of composition of the slags (though not as tightly-clustered as the medieval smelting slags from Phase 1). The range of iron oxide (expressed as FeO) is from 65.7% to 77.0%, with the analyses plotting in both the wustite and fayalite fields on the SiO_2-Al_2O_3-FeO ternary diagram (Figure 1).

The major element analyses are characterised by low concentrations of the alkalis and alkaline earths, of which magnesium is the most abundant (but still at levels of 1.4wt% MgO or less). This relatively magnesian composition discriminates these analyses from all other recent analyses from the area (see Figure 4a b, and c for different representations of these data). Although an input of some magnesium from the fuel ash is possible, the much high concentrations of magnesium compared to calcium in the furnace clay analysis (LYD II 10; see below) probably indicate the most likely source.

Older data from Fulford & Allen's (1992) analyses of materials from Woolaston are also somewhat magnesian, but only 5 out of 15 slag analyses show MgO < CaO.

The slags show an average uranium content of 5.75ppm (range 3.74 to 7.20ppm). Figure 4d illustrates the uranium content (normalised on an iron-free basis) plotted against the SiO_2:Al_2O_3 ratio. The uranium content normalised in this manner overlaps that of the uranium-poor examples from the west crop and is only slightly more elevated than typical east crop ores. An elevated concentration of uranium is found in Roman slags from Usk, as well as in medieval slags from St Briavels and Trellech (Thomas 2000), all examples believed to have been from west crop ores. Similar levels are also known from Roman smelting slags from Kingswood to the east of the Severn (Young 2017a). Levels of uranium are lower in Roman slags from localities believed to have sourced ore from eastern or central Dean, including *Ariconium* (Thomas 2000; Jackson 2012), Cannop (Young 2013) and Frocester (Thomas 2000).

In general, the form of the Upper Crust normalised REE profiles for the slags (Figure 2, upper) closely resembles that of the ore samples (although flattened through reaction with the furnace ceramic). Figure 4e illustrates the profile shape (using Gd_N/Lu_N v Gd_N/La_N). On this measure the slope of the HREE is minimal and lies outside the fields of other analyses from Dean, whereas as the LREE slope is typical of Dean in general.

The phosphate content of the slags is rather low (Figure 4f). It is possible this is related to the particularly low calcium content of the slags (calcium phosphates are the most common carrier of phosphate slags). It is possible that this might have resulted in a small amount of phosphorus being transferred to the iron metal, which only occurs at exceptionally low levels elsewhere in Dean.

Furnace ceramic
A single fragment of probable furnace clay was analysed. The composition is moderately aluminous, but typical of clays chosen for furnace construction. The composition matches closely with the value (derived as an average of the ceramic analyses from Woolaston; Fulford & Allen, 1992) chosen for a clay with which to model the mass balance for Phase 1 of the project (Young 2019). This close similarity validates the use of this clay to model the smelting on the Phase 1 site.

Interpretation

Technology
Although the Forest of Dean was one of the great centres of iron production in Roman Britain, very few even moderately well-preserved furnaces have been excavated and described adequately. Furnaces of Roman age have been published recently by Jackson (2012; although largely based on the work of Bridgewater, 1965) from *Ariconium* and by Fulford & Allen (1992) from Woolaston (associated with The Chesters Roman villa, 7km SW of the present site).

The latter site produced slags the description of which (Fulford & Allen 1992, 193-194) resembles closely the 'Cardiff-type' assemblage The site produced evidence for many furnaces, but the best evidence for the relationship between the 'massive' slags and tapslags appears to have been derived from blocks present on the dumps, rather than in-situ. The furnaces were located within an open-sided padstone structure, which was not closely dateable but apparently post-dated c.250 (making the Woolaston assemblage rather younger than the likely date of the material from Cardiff itself). The furnaces were mostly very poorly preserved, and little can be gleaned from their descriptions. There appear to have been two geometries of slag present, one in which the tapslag accumulation was connected with the interior of the furnace by a very narrow, often of considerable length channel (in one example 580mm long), whereas other accumulations were interpreted as tapslag and massive slag being divided solely by the overlying clay of a wide furnace arch. The 'massive' slags at Woolaston were described as containing much partly reacted ore and charcoal. Although this sounds very similar to the present material, the photographs appear to show some of the 'massive' slag as having a rough surface, unlike the rather smooth appearance of the present 'massive slags. Fulford & Allen interpreted the massive slags as having formed inside the furnace structure from a melt of high viscosity and they claimed, probably erroneously, that 'some may never have been more than moderately plastic'.

The examination of the 'massive' slags in the present assemblage, as well as of those recently investigated from Cardiff Castle (Young 2021), has shown that although apparently massive, these slags have well-developed, if somewhat cryptic, internal flow lobing. The present project was restricted solely to elemental analyses, but the microstructural studies undertaken of the Cardiff material show the crusts of the flow lobes to be discontinuous and formed typically of a sparse

distribution of magnetite, rather than a dense crust as commonly seen in tapslags.

The interpretation by Fulford & Allen of the 'massive' slags as having cooled with the furnace is supported by the poorly-developed lobe margins. There are two potential mechanisms - firstly a lack of oxygen in the environment means that the development of a strongly oxidised crust may not have been possible (those at Cardiff were found to be formed largely of aluminous magnetite, Young 2021) and secondly in a rapidly formed, thick accumulation of slag the effects of chilling on the lobe boundaries will be much reduced by the high ambient temperature and the low cooling rate. This means that lobe boundaries will be defined neither by marked mineralogical changes nor by large changes in crystal size, thus rendering them more cryptic, as observed here.

If the muted expression of the internal lobes can be explained by the location of cooling of the slag, the other facets of the 'massive' slags, the presence of roundwood moulds and of ore particles, requires further explanation.

The descent of partly reacted ore into the region of slag accumulation is indicative of the lack of an iron bloom acting as a barrier. This could be either because the ore has descended before the bloom has formed, or because the ore descended laterally to the bloom (as perhaps might happen more readily on a large furnace). The presence of partly reacted ore in the base of non-slag tapping furnaces (slag pit furnaces in the broad sense) has been documented for a variety of furnace types, mostly in examples where accumulation of a small quantity of partly-reacted ore sinter appears to have been a normal part of the a smelt (e.g. Young 2007, Plate 2) , but in one instance (Folly Court, Wokingham, Young 2018b, Young & Anelay in prep.) where large quantities of sinter were produced in a large dome furnace and it appeared quite likely that this was not the intended outcome. Although a comparison may be made with these occurrences in non-tapping furnaces, it appears that passage of ore through these furnace (at least in the recognised examples) does not result in mixing of ore and slag, perhaps because the ore descended into a relatively cold basal pit.

The roundwood moulds present in the massive slags are unusual, for unlike normal charcoal moulds they show no signs of combustion, but appear as moulds of perfectly regular pieces of wood or charcoal. Again, a parallel might be sought in non-slag tapping furnaces that employed a wood pit packing. In these the wood, whether as roundwood or split, may show superficial cracking from charring but is often very well preserved (e.g. Hardy & Young 2017).

These observations provide the suggestion that the method of operation of a 'Cardiff-type' furnace may have incorporated elements of non-tapping technology, including the use of a pit packing, but within the context of a furnace from which much, though not all, of the slag was tapped. Full understanding of the type will, however, only come from discovery and careful of a much better preserved example of the furnace than any investigated to date.

Mass balance

A graphical approach (after Young 2016b) has been used to constrain the likely nature of the mass balance of the smelting reaction. Bivariate plots of various elemental components (as in Figure 5, where the plots are all against wt% SiO_2) shows a mixing curve between the furnace ceramic and the ore (brown dashed lines on Figure 5). The concentrations of the elements present in the slag samples has been increased (i.e moved away from the origin) through the removal of iron from the mixture as bloom. The degree of enrichment indicates the amount of iron removal from the slag system. This figure is likely to slightly over-estimate the amount of iron present in the extractable bloom (which will itself be much more than the refined iron that can be produced from the bloom).

For some elements (e.g. sodium and potassium), the loss of material to the furnace gasses renders the mass balance incalculable, but in practice these elements are small components of the overall system and so, to a first approximation, they can be disregarded. Much of the potassium, together with much calcium, will be present in the fuel ash. This rarely influences the bulk slag composition by more than 2%, so it too is ignored for the present calculations.

If the average composition of the whole waste from a single smelt was known, then the amount of iron extracted could be calculated. In practice in this case, the composition of the waste has to be estimated from a weighted mean of the slag analyses, since there are no furnaces with the waste from last smelt left in-situ. The weighted mean of the slag compositions has been based on the proportion of the main facies recorded in the overall catalogue. The composition is represented by the tip of the red arrows on Figure 5.

An appropriate description of the mass balance can be obtained because for most elements the proportions of the ceramic-ore mixture must be a constant (i.e. the crossing point on the red arrows and brown dashed lines on Figure 5 must be at, in this case, a fixed silica content for all elements). The location of the crossing point, thus constrained, is very close to a mixture of 90% ore and 10% ceramic (a value well within the range of mixtures suggested by Thomas 2000).

Detailed modelling, based on that figure and employing compositions based on recasting all compositions to have all iron included as FeII and with the major element oxides normalised to 100%, shows that the enrichment factor of the oxides in the slag compared to the theoretical starting mixture is approximately 2.3.

Thus, 900g of ore reacted with 100g of lining to form 1kg of theoretical mixture. The enrichment factor of 2.258 means that FeO would be raised to 198%, whereas it is actually 70.47% in the weighted average slag. Therefore 127.56% must correspond to the FeO lost in the reduction, which would be equivalent to 99% Fe metal. Thus, for every 1kg of slag, 990g of iron has been removed as metal.

Viewed from the perspective of the input then 1kg of the model ore is equivalent to 1.10kg of ore (if the iron mineral was haematite) or to 1.23kg of ore if the iron mineral was goethite. That 1kg of goethitic ore would generate 393g of slag and 389g of iron.

The proportion of iron produced in the model compared with the iron in the ore (i.e. the extractive efficiency) is 64%.

Because the slag from the site was ex-situ, reworked and fragmented, it is not possible to estimate the original size of the slag output per smelt and thus to estimate the iron production per smelt.

Provenance

The analyses described above indicate that a common origin for the Roman smelting slags and the ore fragments from the site is likely based on both major and trace (particularly REE) element evidence. The analyses of both ores and slags are sufficiently different from those analysed in Phase 1 of the project to indicate that the source of the ore for the Roman smelting operation whose reworked slags were found in Phase 2 was different from the source of the ore for the medieval iron smelting investigated in Phase 1.

Attempts to provenance ores to particular localities within the Forest of Dean is limited by the extent and nature of comparative analyses. In practice, these mainly comprise samples collected from surface localities; it is not possible to know precisely how the composition of these might relate to mined ores in the past. Some information may also be gleaned from analyses of ex-situ ores (e.g. from smelting sites) and of slags.

For the medieval smelting activity excavated in Phase 1, the report concluded that a relatively local origin was possible, with a combination of the historical and geological evidence suggesting that a source in the Red Hill area was likely, although not entirely certain.

The present material shows some slightly different characteristics (the uranium content is lower than in the ores from Phase 1, the analyses have CaO>MgO), whereas there is similarity in others (the slightly elevated silica content overlaps, the REE profile shapes overlap).

Supplemental evidence may be derived from comparison of the slag assemblages from the two areas. When plotted on the FeO-SiO_2-Al_2O_3 ternary, the slags from two sites show a very similar distribution, although the Phase 1 slags have a slightly higher Si:Al ratio (compare Figure 1 with Young 2019a figures 5-7).

The uranium content of the Phase 1 slags is typically higher than for those of Phase 2.

The shapes of the REE profiles for the two groups of slags fall into discrete clusters, with those from Phase 2 being flatter than those from Phase 1. This compares with the rather scattered nature of the REE analyses from ores recovered on both sites, suggesting a high degree of bulk homogeneity in the orestock despite the variability of the ores in detail.

The shape of the mixing curve between the ore and the ceramic may be modelled, although there is inherent uncertainty in this because only one ceramic sample was analyses from Phase 2 and none from Phase 1. This modelling suggests that the REE contents of the Phase 1 slags represent a mix of the measured Phase 2 furnace ceramic with an ore of a composition close to a simple average of the two analysed pieces. For the Phase 2 slags, the REE content of the bulk ore must have been close to that of sample LYDII 2 (a sample with a rather simple stalactitic morphology with interstitial ruddle and the highest iron content of the three analysed samples).

When the composition of the Phase 2 ore samples is compared with samples from known localities in the Forest of Dean, several factors characterise the Phase 2 ores: an almost complete lack of calcium, a low uranium content (exceptionally so in 2 out of the 3 samples) and a relatively flat REE profile. The composition most closely matches (apart from the REE profiles) that of samples, from Minetrain Quarry in Bixslade, 7.5km NW of the site. Minetrain is one of the few known ore sources in Dean where the ore is hosted in the Pennant Sandstone (most ore sources are within the Carboniferous limestones, particularly the Crease Limestone (the local development of the Gully Oolite Formation). The REE profiles from the present site, however, show shapes that overlap with the flattest of those found both on eastern and western limbs of the syncline and are much less humped that those from Minetrain quarry.

In summary therefore, the composition is not strongly diagnostic; it differs from other analysed collections, but those collections do not include material from the Lydney area. It would appear likely, therefore, that the source of the ore, although not specifically identifiable was within the poorly sampled southern part of the ore outcrops, rather the northern parts of either the east or west limbs, which are rather better known.

Iron smithing residues

Description of the smithing residues

The assemblage included a very small proportion (2%) of slags identified as certainly or probably deriving from smithing. These pieces were essentially recognisable fragments of smithing hearth cakes or complete examples. All of the SHCs occurred in assemblages likely to be of Roman age.

The complete examples ranged from 169g to 1655g in weight. The smallest was a coal-fuelled blacksmithing SHC (from context (3535)). A second small crescentic slag mass (172g; context (3288)) resembled one of the forms of small coal-fuelled SHC-equivalents from Cleevelands (Young 2016a, 2018a).

Five SHCs (or almost certain SHCs) lay in the weight range of 316g to 466g, a range of weights towards the heavy end of the spectrum of Roman blacksmithing SHCs. The largest SHC (from context (3704) closely resembled the plano-convex charcoal-fuelled bloomsmithing slags from other sites (particularly those from School Road, Miskin; Young & Macdonald 1998; Thomas 2000).

Interpretation

The combination of small SHCs, fuelled by coal and deriving from blacksmithing, with large SHCs, fuelled by charcoal and produced during bloomsmithing has been encountered at a number of Roman sites around the region (e.g Kingswood, Young 2017a; Lockleaze, Young 2020; Cardiff, Young 2021). The use of coal for blacksmithing purposes is almost ubiquitous in the region, but charcoal was required for bloomsmithing to avoid incorporation of sulphur and other impurities into the iron.

The assemblage is too small for detailed comparison with those from other sites.

The non-ferrous residues

Description of the crucible sherds

This small collection of six crucible sherds may be from a single vessel but are not certainly so; they form fragments of three larger pieces. Five sherds are from

one or two thumb-pots. Their fabric shows protruding quartz grains on the inner surface of the vessel, locally overlain by a slight concretionary material that may be residual dross or slag (but which has the reddish colour of the local soil). The fragments show an upward absence (probably spalling) of the outer vitrified face, but an upwards continuation of the thinning inner clay. At this point the internal surface appear to be vertical but the outer vitrified surface is inclined markedly outwards. One potential interpretation of this geometry is that a luted lid has been removed. The sixth sherd is from the wall of a slightly larger crucible with a finer fabric and a deeply vitrified exterior.

Apart from the slightly concretionary red soil (some adhering and an isolated spalled single fragment), there were no indications of internal dross or slag and no colouration of the external vitrification suggesting spilled metal.

Analysis of the crucible sherds

Two determinations (Table 5, #1 and #2) were made on the interior surface of the largest sherd (that with the finer fabric). The surface of the sherd was clean of any residue (and appeared to have been thoroughly washed). The analyses showed elevated levels of zinc alone.

One determination (Table 5, #3) was made on the external vitrified surface of this sherd. This showed elevated strontium (from the fuel ash) and possibly very slightly elevated copper, zinc and tin, but these were barely above background.

A determination (Table 5, #4) was made on a small fragment of brownish concretionary material that had spalled from interior of a thumb-pot sherd. This showed strongly elevated levels of iron, copper, zinc and lead.

One determination was made on the reddish accretionary material attached to the inside of one of the larger thumb-pot sherds (Table 5, #5). This showed strongly elevated levels of iron, copper and lead.

Interpretation

These results conform closely with the typical pattern of metal contamination in crucibles used for handling molten copper alloys. The different metallic elements involved in copper alloys behave differently during heating in crucible. Lead is very reactive with silica to form a slag, zinc may become concentrated because of its high volatility within the ceramic body (Kearns *et al*. 2010), copper may be retained either as a dross or as a contaminant of a slaggy glaze whereas tin tends to be concentrated as an oxide in the dross or separately on the internal wall.

In this case, the fine textured crucible showed zinc within its fabric, with probable traces of copper, zinc and tin externally. The coarser-textured thumb-pot(s) showed evidence for copper, zinc and lead internally. The metals being handled were thus potentially a gunmetal (a ternary alloy of copper, zinc and tin) and a leaded brass respectively, but the evidence is inconclusive. Both metal types were widely used during the Roman period, when recycling commonly led to complex copper-zinc-tin-lead alloys (Dungworth 1997).

Discussion

The metallurgical evidence from the site conforms with that of other iron production sites around the Severn Estuary. The original location of the source of this assemblage is however unknown. The analysis of an example of furnace ceramic showed a composition close to that of the clays at Woolaston (Fulford & Allen 1992, 192-193 and tables 8, 9), which were attributed to a probable origin in exposures of Triassic strata of the Mercia Mudstone Group around the mouth of Ley Pill. Further consideration of the origin of the clays may be necessary, for the Triassic strata do not extend as far north as Lydney. So, an alternative origin for those of the Lydney North site may perhaps be needed to be sought either in the Devonian St Maughan's Group bedrock, or more likely, within the overlying alluvial deposits and the provenance of the Woolaston clays may also need to be reconsidered.

The Woolaston site also appears to provide a very good analogue for the slag assemblage. Although the material from Lydney North is derived, it is unlikely to have brought from so far away and the Woolaston slags also show elevated calcium contents compared with those from Lydney North. A nearby origin is much more likely.

Despite the derived nature of the slag, the collection represents the largest assemblage of 'Cardiff-type' slags yet described in detail. It provides valuable information on the range and proportions of the different slag facies, which can contribute to understanding of this assemblage type elsewhere.

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Figure Captions

Figure 1. elemental analyses by XRF of the bulk samples of smelting residues, illustrated within the ternary system SiO_2-Al_2O_3-FeO (fields after Schairer and Yagi 1952, fig 6). Black = ore (LYDII 1-3), green = slag (LYDII 4-9), orange = furnace cermaic (LYDII 10).

Figure 2: upper crust-normalised rare earth element (REE) profiles (normalisation after Taylor & McLennan 1981) for ICP-MS analyses of (upper) slag samples (LYDII 4-9) and (lower) iron ore samples. (LYDII 1-3) and furnace cermaic (LYDII 10).

Figure 3: discrimination diagrams for employed for provenancing the iron ores. Samples of iron fromboth Phases 1 and 2 of the Lydney North development are shown, together with comparative analyses of ores from the west crop of the Forest of Dean (W), the east crop € and the central area of Bixslade (C). The comparative ore analyses are divided into those from primary sites (i.e. geological samples and casual finds close to outcrops) and secondary (ores recovered from smelting sites for which ore provenance is reasonably firmly established).

Upper: Eu_N/Lu_N v Eu_N/La_N, where X_N is the Upper Crust-normalised concentration of element X (following the normalisation factors of Taylor & McLennan 1981). Eu_N/Lu_N is a measure of the slope of the heavy REE (HREE) and Eu_N/La_N, a measure of slope of the light REE (LREE). Where both values are elevated, the profile is therefore more strongly 'humped'.

Lower: the concentration of uranium (in ppm) against the concentration of silica (in wt%).

Figure 4: discrimination diagrams for employed for provenancing iron smelting slags.
The iron slags recovered during both Phase 1 and Phase 2 of this project are indicated. The slags from St Briavels and Trellech were probably produced during the smelting of ores from the western side of the Forest of Dean, whereas those from Frocester Court and *Ariconium* are probably from east crop ores. The slags from Miskin and Cardiff result from the smelting of very high- and moderately high-silica ores from Glamorgan respectively.

Figure 5: variation diagrams, showing mass balance model. See text for full details.

Dashed line: tie line linking ore with composition of furnace lining. Model 'smelting mixtures' lie on this line. Red arrow: the trend away from the origin from enrichment following extraction of metallic iron from the 'smelting mixture'.

Table 1: Summary of materials in archaeometallurgy collection by period and context (after Young 2019b, Table 3).

Context	Sample weight (g)	SHC	SHC?	Furnace slag	Channel slag	Slag rod	Massive slag	Tap slag	Lining slag	lining	Indet. slag	Iron ore	Scale	Crucible	*residue total*	Coal/ coke	Rock	Iron	Conc.
Period 2																			
3092	425		186				94	56		23	42			12	*413*				12
3111	66									66					*66*				
3126	58							18	34		6				*58*				
3194	48								26		22				*48*				
3204	156							120	18		18				*156*				
3332	135							56			78				*134*	1			
3439	56														*0*				
3661	26							26							*26*				
3666	116							108							*108*				8
3685	<1										<1		x		*<1*				
3687	33								14						*14*			2	17
3668	58							52				6			*58*				
3671	670							670							*670*				
3708	1152						542	120		10	480				*1152*				
3710	116									22	94				*116*				
3721	424							340							*340*				84
Period 2/3																			
3013	370							370							*370*				
3042	1280						830	236	18	6	190				*1280*				
3046	388						116	232			40				*388*				
3047	316							242		2	72				*316*				
Period 3																			
3008	106							58			48				*106*				
3010	338							338							*338*				
3017	110							96			14				*110*				
3018	566						228	230		108					*566*	<1			
3020	2706			670			1794	136	52		46				*2698*				
3022	2774						2022	344		264	62				*2692*			82	
3051	16							16							*16*				
3053	378			102			142	114			20				*378*				
3055	380						290	14			76				*380*				
3065	4302						3234	572		296	90	48			*4240*				62
3073	344						124	202			18				*344*				
3083	62								62						*62*				
3100	863				214			474			73	102			*863*				
3101	292						34	114	16			122			*286*				
3102	490							140	188		38	124			*366*				
3104	252							224			28				*252*				
3117	78							78							*78*				
3119	808							808							*808*				
3123	158							158							*158*				
3138	54									34	20				*54*				
3146	22							18			4				*22*				

Context	Sample weight (g)	SHC	SHC?	Furnace slag	Channel slag	Slag rod	Massive slag	Tap slag	Lining slag	lining	Indet. slag	Iron ore	Scale	Crucible	*residue total*	Coal/ coke	Rock	Iron	Conc.
3159	72							20		4		48			*72*				
3161	284							284							*284*				
3165	30										30				*30*				
3167	176						168				8				*176*				
3178	64							24				40			*64*				
3180	54				54										*54*				
3182	236							120	26		90				*236*				
3188	220							220							*220*				
3189	412							154	258						*412*				
3202	6														*0*				
3207	1352				58			984			310				*1352*				
3210	908			126			736	46							*908*				
3222	48														*0*				
3224	1589			166	635		106	522			160				*1589*				
3228	154							154							*154*				
3253	916				816			38			62				*916*				
3254	940							940							*940*				
3261	738						500	238							*738*				
3263	596				428			74			94				*596*				
3269	318						106	212							*318*				
3272	486				46			402							*448*		38		
3283	900						534	366							*900*				
3303	1308							972	54	4	278				*1308*				
3313	4117			416			2021	1526	8						*3971*		146		
3314	7948						4812	2920		154	62				*7948*				
3315	1348	182					818	216		28	26				*1270*		78		
3316	2784						794	1424	86		480				*2784*				
3317	1788			512			1062	134							*1108*			80	
3323	6										6				*6*				
3325	876							678		2	196				*876*				
3328	258							100							*100*				158
3364	1724				312				304		1100				*1716*	8			
3366	12									12					*12*				
3367	68							54			14				*68*				
3371	1126			358				28	144		596				*1126*				
3424	550				270			280							*550*				
3427	120										120				*120*				
3445	1230						890		170		170				*1230*				
3446	576	456					120								*576*				
3455	634						518	116							*634*				
3457	126								4	36	86				*126*				
3458	5012				1470		948	1584	178	646	186				*5012*				
3480	440						440								*440*				
3490	196						92	52			52				*196*				
3516	6897				2975		2704	1218							*6897*				
3521	414							372		42					*414*				

Context	Sample weight (g)	SHC	SHC?	Furnace slag	Channel slag	Slag rod	Massive slag	Tap slag	Lining slag	lining	Indet. slag	Iron ore	Scale	Crucible	*residue total*	Coal/ coke	Rock	Iron	Conc.
3527	<1										<1				*<1*				
3534	186							154			32				*186*				
3542	348						326	22							*348*				
3543	2959			970	1315			674							*2959*				
3545	540							540							*540*				
3555	56							56							*56*				
3579	3378						3378								*3378*				
3580	82							72							*72*				10
3582	642														*0*				368
3586	16							16							*16*				
3587	68										68		x						
3588	2037				1265		630				124				*2019*				18
3595	14331		316	434	7018	22	3458	2663			420				*14331*				
3597	1682						1650				32				*1682*				
3607	210				210						0				*210*				
3609	64							64			0				*64*				
3611	338							338			0	12			*338*				
3619	134							22			112				*134*				
3621	2037				1335		536	56	70		40				*2037*				
3650	38						32				0				*32*				
3677	1606						1606				0				*1606*				
3682	6847				1410		4040	1115			224				*6789*				48
3689	126						0	126			0				*126*				
3703	7986			280	3941		166	2052	162	102	1182				*7919*	1			100
3704	9092	1655	410		1739		590	2038	468		2116				*9016*			76	
3713	500						298	170			32				*500*				
3716	46										46				*46*				
Period 3/4																			
3361	704							704							*704*				
3375	588							452	44		92				*588*				
Period 4																			
3225	306							306							*306*				
3234	22							8	14						*22*				
3236	376							376							*376*				
3258	720			236	146			338							*720*				
3288	20198	1196		184	1322	68	3777	8541	54	158	4898				*20198*				
3347	1601				1235		202	164							*1601*				
3350	28											28			*28*				
3356	94					94									*94*				
3378	34							34							*34*				
3395	248							232			16				*248*				
3399	26							26							*26*				
3415	4390							3978			412				*4390*				
3453	416						130	216	30		32				*408*				
3473	3886							3886							*3886*				
3496	260							260							*260*				

Context	Sample weight (g)	SHC	SHC?	Furnace slag	Channel slag	Slag rod	Massive slag	Tap slag	Lining slag	lining	Indet. slag	Iron ore	Scale	Crucible	*residue total*	Coal/ coke	Rock	Iron	Conc.
3503	762	266	298					68	130						*762*				
3506	20										20				*20*				
3507	770						770								*770*				
3508	226							226							*226*				
3547	646							646							*646*				
3622	94							94							*94*				
3640	1030						796	184			50				*1030*				
Period 4/5																			
3004	7817			2569	2146		1050	1468							*7233*			6	578
3005	16531		1667	718	2614		6590	2736			576				*14901*				1630
Period 5																			
3034	24							24							*24*				
Period 6																			
3035	192						156	36							*192*				
3037	20									1	19				*20*				
No period given																			
3296	206						110	96							*206*				
3321	306						306	0							*306*				
3349	398				250			148							*398*				
3493	68							68							*68*				
3535	948	168					644	102			34				*948*				
Unstratified																			
3673	264						76	188							*264*				
3674	1052						652	110	30						*792*				260
u/s	1939						1609	284							*1893*		46		
	totals	*3923*	*2877*	*7741*	*33224*	*184*	*60397*	*59429*	*2662*	*2020*	*16282*	*530*		*12*	*188579*	*10*	*308*	*246*	*3353*

Table 2: summary of sampled materials.

Sample	Context	Elemental analysis	Specimen weight	Specimen notes
Smelting residues				
LYDII 1	3100	X	102	? brecciated box stone
LYDII 2	3101	X	40	brush with ruddle
LYDII 3	3101	X	52	fine
Iron ore				
LYDII 4	3314	X	510	tap slag
LYDII 5	3595	X	652	tap slag
LYDII 6	3314	X	596	slags with roundwood
LYDII 7	3314	X	502	massive slag
LYDII 8	3022	X	680	massive slag
LYDII 9	3595	X	786	channelled furnace slag
LYDII 10	3314	X	138	lining

Table 3: Major elements as determined by XRF. < = below detection. All elements presented as wt% oxide. LOI = loss on ignition. FeO column represents the iron analyses as FeO rather than Fe_2O_3.

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	SO_3	LOI	Oxide total
Iron ore														
LYDII 1	3.90	0.22	95.11	85.60	0.016	0.61	<	0.063	0.142	0.013	0.066	<	0.92	101.1
LYDII 2	2.00	0.08	97.38	87.64	0.018	0.71	0.09	0.040	<	0.015	0.049	<	0.83	101.2
LYDII 3	9.39	1.52	86.75	78.08	0.040	0.52	<	0.091	0.523	0.119	0.096	<	1.48	100.5
Smelting residues														
LYDII 4	25.78	4.05	73.01	65.71	0.284	1.41	0.73	0.048	0.337	0.208	0.230	0.029	-6.09	100.0
LYDII 5	15.51	3.02	85.53	76.98	0.143	0.90	<	0.026	0.628	0.137	0.209	0.118	-6.31	99.9
LYDII 6	23.05	3.92	75.31	67.78	0.245	1.09	0.39	0.322	0.456	0.211	0.230	0.158	-5.32	100.1
LYDII 7	23.36	3.73	74.31	66.88	0.232	1.11	0.11	0.093	0.635	0.219	0.231	0.275	-4.68	99.6
LYDII 8	23.42	4.24	74.54	67.09	0.201	1.39	1.13	0.051	<	0.186	0.198	<	-6.45	98.9
LYDII 9	17.08	3.10	82.23	74.01	0.210	1.41	<	0.111	0.607	0.166	0.278	0.013	-4.24	101.0
LYDII 10	69.39	13.91	7.30	6.57	0.043	2.00	0.21	0.758	2.543	0.872	0.210	<	1.17	98.4

Table 4a: Trace elements as determined by ICP-MS. < = below detection. All elements presented as ppb.

Sample	Be	V	Cr	Co	Ni	Ga	Rb	Sr	Y	Zr	Nb	Mo	Cs	Ba
Iron ore														
LYDII 1	10.99	12.26	2.64	12.13	34.36	2.82	3.15	21.73	2.65	12.46	0.66	16.35	<	37.12
LYDII 2	8.04	12.07	1.69	28.50	51.64	3.07	1.54	13.51	3.17	3.65	0.27	19.65	<	11.86
LYDII 3	11.88	27.88	15.28	7.44	23.15	5.02	13.56	31.84	3.95	36.26	1.60	20.14	0.41	101.06
Smelting residues														
LYDII 4	16.43	50.17	57.75	1.75	9.43	6.24	22.08	55.46	29.98	127.20	4.35	4.95	0.14	261.75
LYDII 5	7.59	40.91	40.26	1.13	9.28	5.66	14.03	22.50	11.68	59.01	2.65	5.36	<	166.45
LYDII 6	15.53	45.28	47.92	0.89	7.77	6.35	19.24	54.13	19.82	112.40	4.07	3.13	0.06	235.95
LYDII 7	14.01	63.45	59.09	1.72	11.95	6.74	17.12	45.62	24.22	119.80	4.24	5.39	0.05	219.55
LYDII 8	15.00	48.79	54.67	0.97	7.00	6.82	29.48	62.03	19.44	113.50	4.47	3.73	0.68	247.35
LYDII 9	8.57	50.60	48.56	0.86	4.44	4.73	12.61	17.10	9.67	57.81	2.45	6.54	<	161.65
LYDII 10	2.33	89.69	154.60	13.42	51.15	17.93	81.30	66.53	21.80	437.40	14.41	0.51	3.38	304.05

Table 4b: Trace elements as determined by ICP-MS. < = below detection. All elements presented as ppb.

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Pb	Th	U
Iron ore																				
LYDII 1	2.99	6.86	0.93	4.02	1.05	0.28	1.07	0.14	1.18	0.22	0.56	0.07	0.49	0.07	0.27	0.08	42.84	32.06	0.46	1.54
LYDII 2	3.39	7.94	1.04	4.56	1.14	0.29	1.14	0.15	1.18	0.23	0.62	0.09	0.61	0.09	0.05	0.05	44.90	18.59	0.31	1.48
LYDII 3	5.77	13.96	1.58	6.43	1.46	0.37	1.33	0.19	1.53	0.28	0.76	0.11	0.73	0.10	1.42	0.15	2.34	31.22	1.74	3.29
Smelting residues																				
LYDII 4	20.76	30.68	5.03	20.99	4.68	1.05	4.67	0.71	4.70	0.98	2.88	0.40	2.67	0.40	3.22	0.32	10.98	1.32	3.60	7.20
LYDII 5	9.77	18.71	2.62	10.96	2.44	0.55	2.19	0.31	2.27	0.48	1.39	0.20	1.33	0.20	1.49	0.21	47.60	2.62	2.17	3.74
LYDII 6	13.94	27.94	3.70	15.72	3.62	0.79	3.40	0.50	3.44	0.71	2.08	0.30	1.99	0.30	2.82	0.30	2.01	13.65	3.39	6.59
LYDII 7	16.64	33.04	4.80	20.18	4.72	1.07	4.48	0.68	4.41	0.88	2.52	0.35	2.33	0.35	2.96	0.30	0.74	4.31	3.83	6.19
LYDII 8	14.40	26.72	3.38	14.01	3.11	0.71	2.99	0.44	3.07	0.66	1.91	0.27	1.83	0.29	2.92	0.33	44.00	0.88	3.97	6.52
LYDII 9	8.08	16.15	2.15	8.76	1.95	0.46	1.93	0.25	1.93	0.40	1.14	0.17	1.11	0.17	1.45	0.19	<	0.08	1.92	4.28
LYDII 10	33.78	68.23	7.77	28.83	5.20	0.97	4.21	0.66	4.50	0.94	2.83	0.43	2.93	0.46	10.74	0.97	0.67	14.15	11.76	2.29

Table 5: net peak areas for selected elements from pXRF analyses of crucible sherds. Shaded values indicate metals at level of interest.

Element	**Fe**	**Cu**	**Zn**	**Rb**	**Sr**	**Y**	**Sn**	**Sn**	**Pb**	**Spot location**
Line	**K12**	**K12**	**K12**	**K12**	**K12**	**K12**	**K12**	**L1**	**L1**	
Energy/keV	**6.405**	**8.046**	**8.637**	**13.396**	**14.165**	**14.958**	**25.271**	**3.444**	**10.551**	
#1	167060	2868	339363	11295	8412	3752	1261	1976	2748	large fine sherd, internal, lower part
#2	172170	2671	321829	11158	7554	3918	1765	1955	2611	large fine sherd, internal, lower part
#3	143966	4818	6230	8840	13953	2977	1075	3483	1680	large fine sherd, external
#4	341586	17431	4396	6045	7112	3301	1814	1826	45805	spall of soil from interior of thumb-pot
#5	356392	17119	43145	4812	4177	3407	2165	1756	31955	thumb-pot sherd with possible internal dross

Figure 1

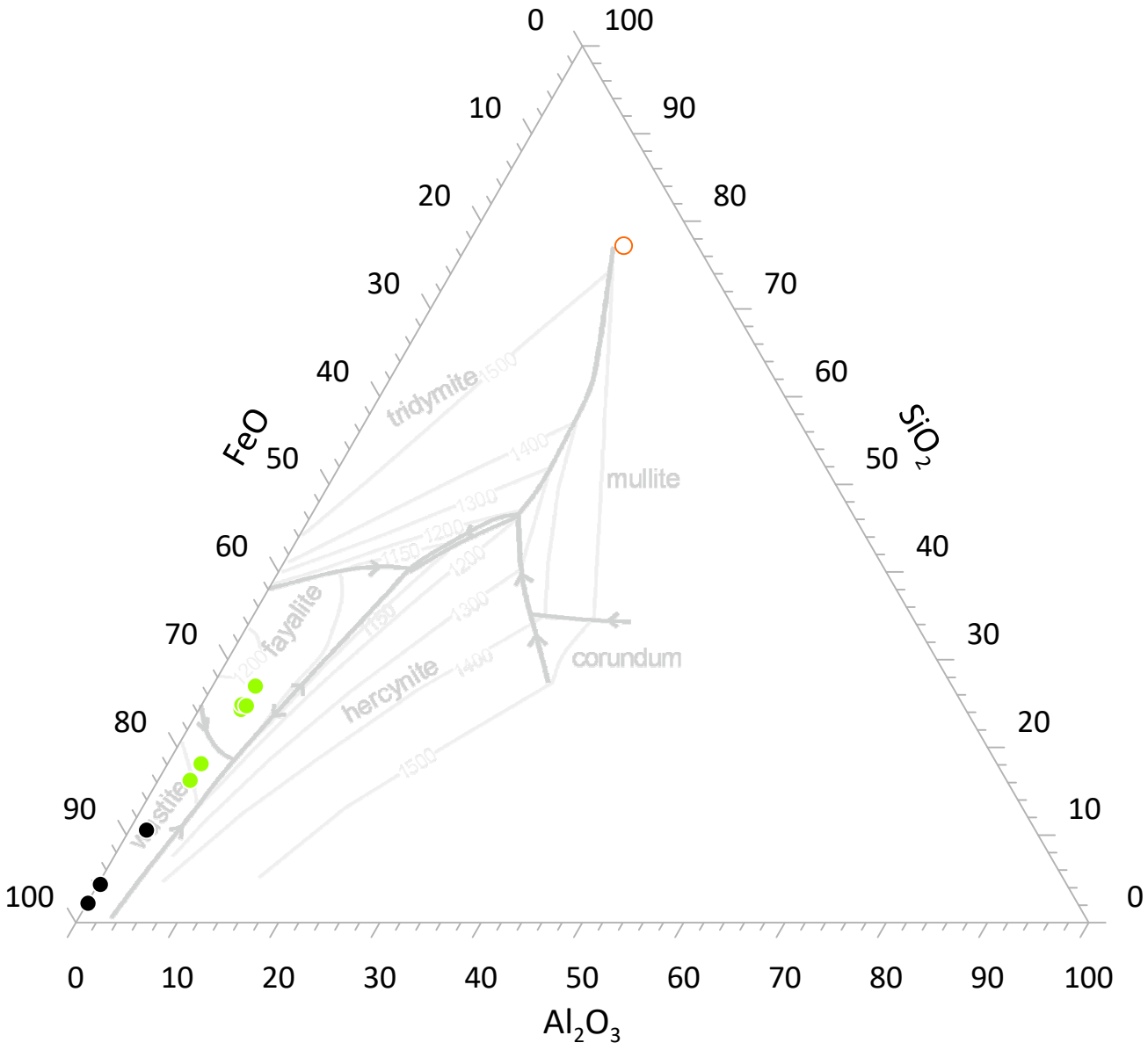

FeO
SiO2
Al2O3
tridymite
mullite
corundum
fayalite
hercynite
wüstite
1500
1400
1300
1200
1150
1100

Figure 2

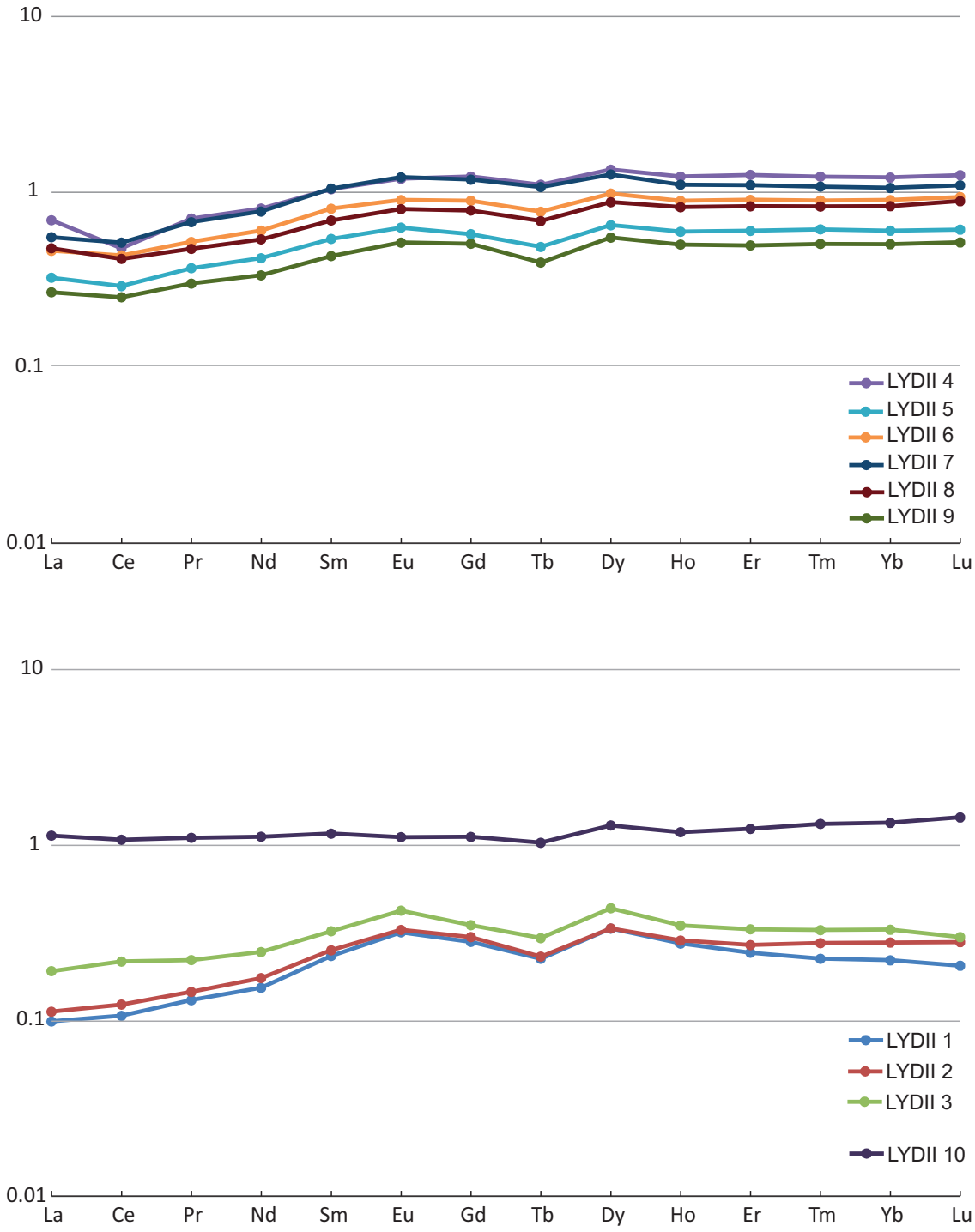

10
1
0.1
0.01
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
LYDII 4
LYDII 5
LYDII 6
LYDII 7
LYDII 8
LYDII 9
10
1
0.1
0.01
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
LYDII 1
LYDII 2
LYDII 3
LYDII 10

Figure 3

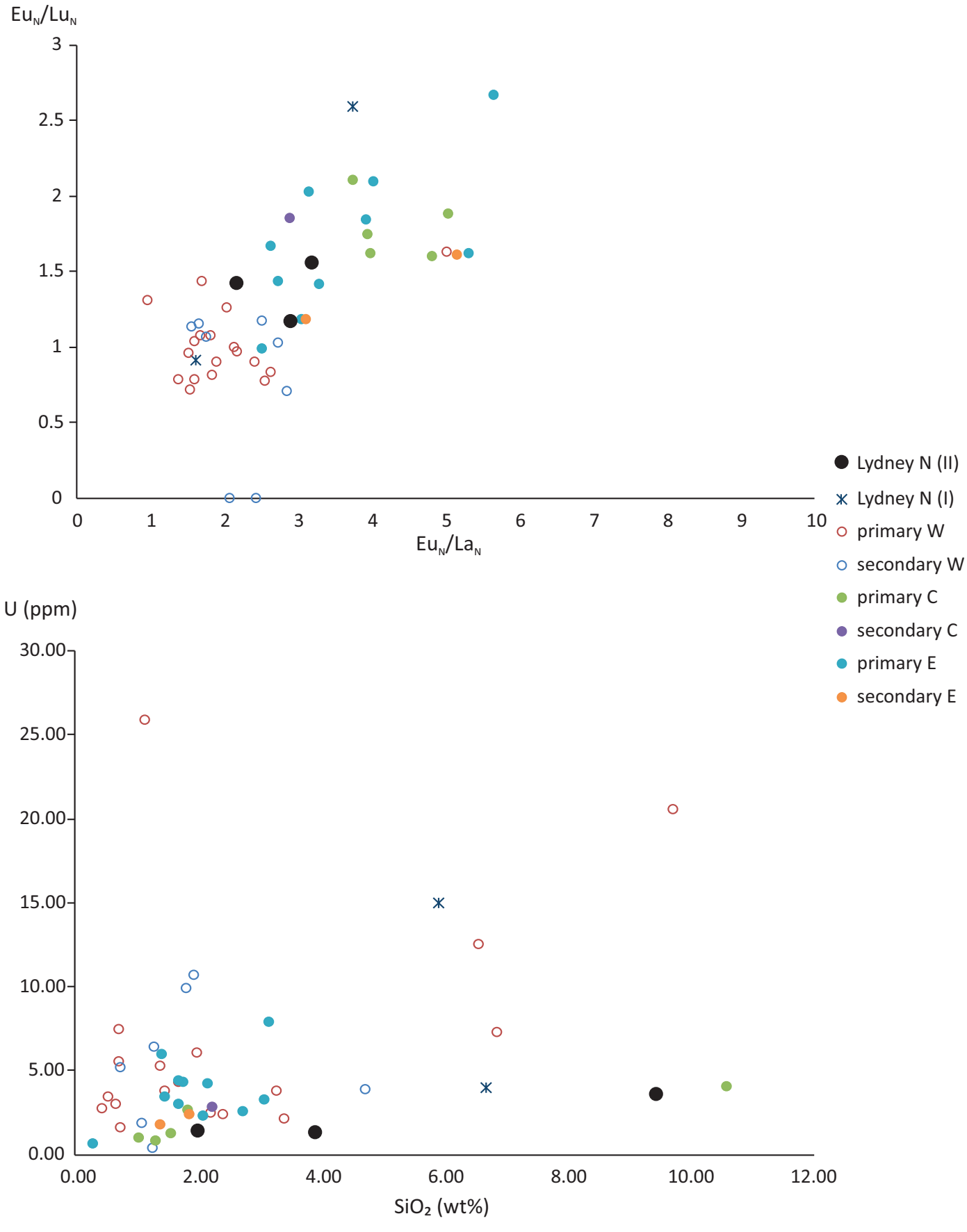

Eu$_N$/Lu$_N$
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8
9
10
Eu$_N$/La$_N$
Lydney N (II)
Lydney N (I)
primary W
secondary W
primary C
secondary C
primary E
secondary E
U (ppm)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
SiO$_2$ (wt%)

Figure 4

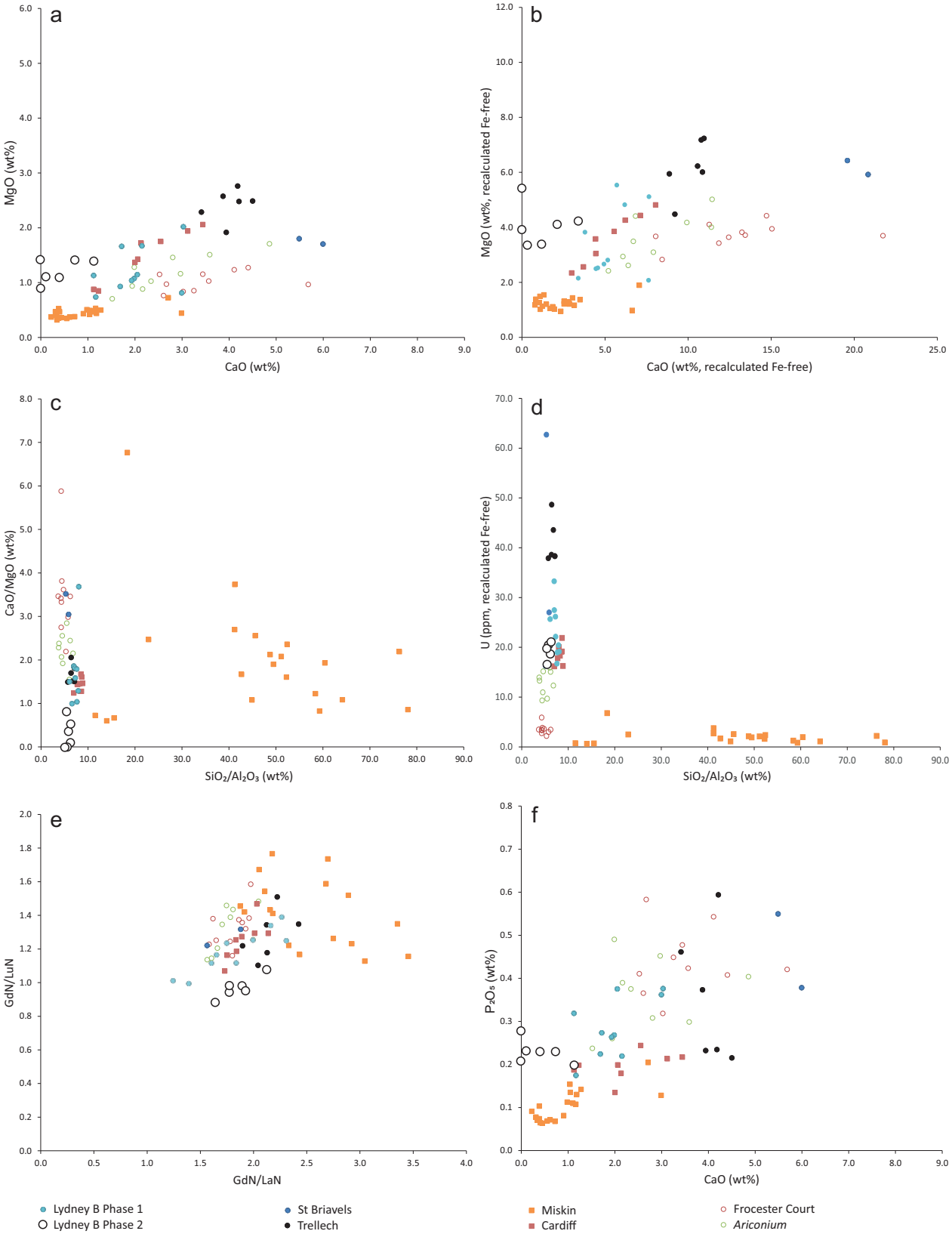
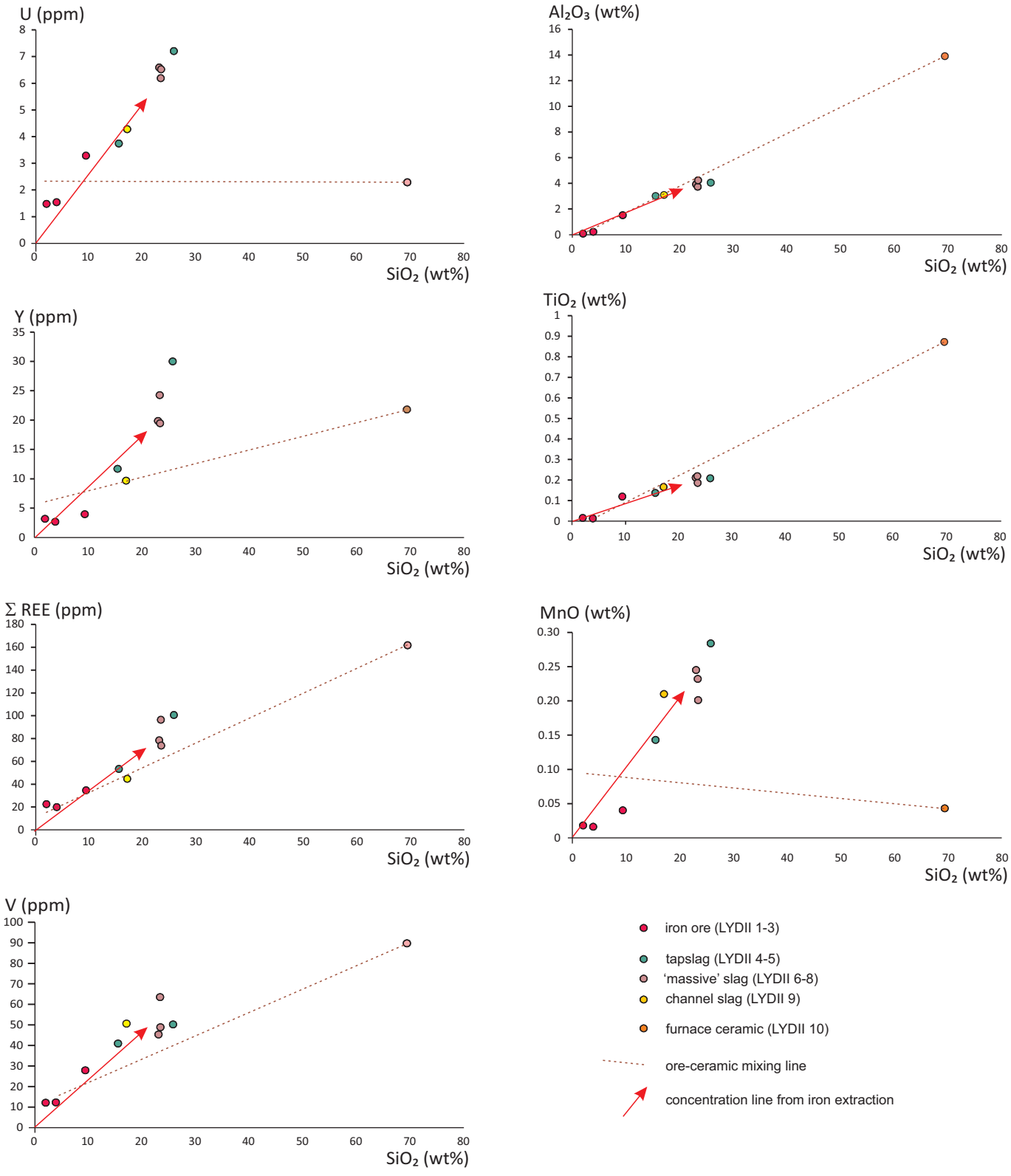

a
MgO (wt%)
CaO (wt%)
b
MgO (wt%, recalculated Fe-free)
CaO (wt%, recalculated Fe-free)
c
CaO/MgO (wt%)
SiO2/Al2O3 (wt%)
d
U (ppm, recalculated Fe-free)
SiO2/Al2O3 (wt%)
e
GdN/LuN
GdN/LaN
f
P2O5 (wt%)
CaO (wt%)
Lydney B Phase 1
Lydney B Phase 2
St Briavels
Trellech
Miskin
Cardiff
Frocester Court
Ariconium

Figure 5


U (ppm)
SiO₂ (wt%)
Al₂O₃ (wt%)
SiO₂ (wt%)
Y (ppm)
SiO₂ (wt%)
TiO₂ (wt%)
SiO₂ (wt%)
Σ REE (ppm)
SiO₂ (wt%)
MnO (wt%)
SiO₂ (wt%)
V (ppm)
SiO₂ (wt%)
iron ore (LYDII 1-3)
tapslag (LYDII 4-5)
'massive' slag (LYDII 6-8)
channel slag (LYDII 9)
furnace ceramic (LYDII 10)
ore-ceramic mixing line
concentration line from iron extraction

Appendix A:

Catalogue

Table A1: summary catalogue, listed by bag and context (after Young 2019b, Table 1). Weights in g.

context	weight (g)	number	notes
box 2			
3020	648	1	angular fragment of thick massive slag, no surfaces, multiple roundwood moulds
	466	1	complex piece with charcoal locally dense slag, one non-wetted contact and one ceramic contact
	232	1	dense slag with multiple half roundwood pieces
	360	1	rusty slag with multiple pieces of wood, some with charcoal preservation, no surfaces
	52	1	deep vesicular lining slag on pale ceramic
	120	1	angular fragment of dense fine slag with tapslag surface protruding in mid-section
3020	286	1	thick massive fine slag with tapslag top, (non-reddened), one internal non-wetted surface could be wood margin
	136	1	tapslag
	46	2	fragments of thin indeterminate slag sheet
	24	1	rounded nub of dense slag apparently a wall intrusion
	142	1	angular fragment of charcoal debris rich slag with large fuel and wood moulds and slightly prilly base
	148	3	angular fragments of indeterminate fine massive slag
	38	1	small piece of reddish slag (cf. 142 piece above) with wood/charcoal mould margins
3053	142	1	dense slag with multiple roundwood moulds
	102	1	slag with charcoal debris in massive slag
	20	1	indeterminate slag fragment
	114	2	tapslag
3042	830	1	large block of dense slag, impressions of wood moulds form base, many pale grey ceramic inclusions in one half of block then rather cryptic level of lobes, then other half of block shows faint hints of internal lobing, with large wood mould.
	236	9	slightly worn fragments of tapslag
	6	1	fragment of pale grey furnace ceramic
	18	1	lining slag
	190	8	worn fragments of varied indeterminate dense slag
3055	76	1	base of slightly lobate slag, with striated ridge on base - probably a tool mark/rod
	66	1	small worn slag fragment with prilly base and parts of roundwood moulds

context	weight (g)	number	notes
	224	1	dense fine slag irregular fractured edges except for one re-entrant face with a non-wetted lobate contact
3005	88	1	unusual slag with dimpled base, slightly concavo-convex, upper face has intense metallic lustre, with suppressed lobes, similar to those of a non-wetted surface, no reddening
	62	1	tapslag
	104	1	dense angular slag fragment, fine grained massive
	8	1	small chip of weathered vesicular material - probably a vesicular tapslag
3008	58	1	tapslag
	48	1	sheet of vesicular lag, one side sandy, the other side has fuel dimples, unclear if from a floor or wall
3013	370	3	tapslag
3018	20	1	small fragment of slag with abundant ore fragments
	>1	1	coal
	74	4	tapslag fragments
	82	1	internally lobate slags forming moulds of large flat surfaces, probably wood
	156	2	complex slags, probably tapslags, but containing round moulds
	126	2	fragments of indeterminate dense massive lags
	108	3	vitrified and slagged slightly oxidised furnace wall
3020	8	1	rusty accretion on pot sherd
3017	96	4	tapslag fragments
	14	1	indeterminate rusty slag fragment
3035	156	1	angular fragment of dense fine slag, possible ore debris in one vuggy area
	36	2	lobate flowed slag with ore clasts, probably tapped flowing around fuel clasts
3055	14	1	worn tapslag fragment
3010	338	2	dense tapslag, one forming edge of channelled flow
3117	78	1	tapslag

context	weight (g)	number	notes
3034	24	2	tapslag
3051	16	1	tapslag
box 12			
3022	82	1	iron
	680	1	massive flow up to 70mm thick with lobate top and impression of earlier lobate surface on base, one face is non-wetted contact with red ceramic - probably a carried clast rather than a margin
	740	1	massive flow with lobate top and with lobes visible on one later non-wetted surface full height of 80mm thickness, internally appears massive, but has some cryptic lobed horizons
	264	2	large blocks of vitrified pale grey ceramic
	432	1	appears to be from margin of a slag bowl with a large piece of roundwood, and with a lobate top
	344	6	fragments of tapped slag with rather chaotic lobed texture to varying degrees
	170	1	angular fragment of dense massive slag
	62	1	sandy contact spalled from base of slag piece
3065	974	1	mostly massive dark slag, one maroon surface exposed just below top and base appears a little prilly, 100mm thick
	1020	1	massive appearing slag with prilly base and ceramic clasts, but flow lobes visible on one face that is lightly more weathered
3207	984	15	very heavily worn fragments of tapslag
	28	2	vesicular iron slag
	58	1	curved eroded piece of granular slag, could be lower part of SHC, but more likely from a runner
	282	1	dense rounded cobble of massive slag
3188	220	5	fresh fragments of tapslag
3083	62	1	slagged and vitrified lump of complex dark grey indurated wall ceramic
box 13			
3065	296	1	large thick block of grey reduced vitrified and slagged wall, front face has numerous stalactites suggesting wall at about 65-70 degree overhang

context	weight (g)	number	notes
	48	1	iron ore, dense angular fragment, alternating fibrous and fine massive layers, red on one end surface, slightly cracked in places
	572	10	tapslag
	1240	7	fine massive slags, just locally with hints of lobing, no clear tops or bases
	62	1	concretion on dense slag
	90	3	irregular indeterminate slag fragments
3263	428	1	very irregular slag mass, slightly dimpled base, appear massive but has 'randomly' located lobes, possibly FB but might be a fragment from a complex multiple runner
3261	238	2	tapslag
	500	1	highly worn and weathered rounded lump of extremely dense slag containing a partially melted sandstone clast 25mm across
3092	94	2	worn small fragments of very dense massive slag
	186	1	slag fragment with dense sheet 20mm thick attached on one side to indeterminate lumps, with some possible wood/charcoal impressions - could possibly be an SHC fragment but not certainly
	42	1	small bleb of slag, protrusions and hollows on one side, other side smooth and fragmented - possibly deformed by impact (of hammer?)
	12	1	small concretion with slag debris
3458	60	2	lobate slags, possibly tapslags, dark fresh
	442	1	very fresh dark fragment of very dense slag, non-wetted base, tapslag like top, hints of internal lobing, so thick tapslag flow, up to 60mm thick
	362	1	dark fresh, very dense slag, one face has lobate surface fused to wall, opposite face shows slightly lobed surface with fine lobes
	444	1	channel, 40mm wide and 30mm deep, top covered with finely brecciated slag
3210	434	1	massive slag with lower? face of small prills, has quarter round mould of 50mm radius, plus flat surface of split wood on opposite side.
	160	1	rounded worn dense slag lump
	46	1	tapslag fragment
	30	1	small slag fragment with flat faced wood impression
	80	2	dense slags with internal prilly structure
	32	1	dense slag fragment
	126	2	lower density iron slags with charcoal?, both with hints of lobing

context	weight (g)	number	notes
3100	102	1	iron ore - complex internal structure, possibly brecciated box-stone
	102	2	tapslag
	166	1	dense vesicular slag with curved lower crust - probably a channel fragment
	20	2	small indeterminate fragments
	53	1	fragment with well-developed double fibrous microstructures, uncertain origin
	48	1	small channel/rod fragment
	372	1	very dense slag, has curved lower face showing lobes on contact, upper face has poorly developed lobes, dense tapslag
3047	76	2	lobed slags with roundwood cavity
	2	1	fragment of vitrified and bloated pale grey lining
	166	7	tapslag
	28	1	base of slag with small dimpled probable tool mark
	44	3	fragments of indeterminate thin slag sheets
3102	188	3	deeply vitrified grey sandy lining/lining slag
	38	1	indeterminate worn rusty slag nub
	140	1	tapslag
3101	40	1	brush ore with crusts and ruddle filled cavities (might be similar to problematic texture in 3100)
	16	1	even fine grained ore
	16	1	even fine ore divided by curvilinear (botryoidal?) fibrous crusts
	50	1	fibrous brush ore divided by stringer vein/box margin
	6	1	pot sherd
	114	5	worn tapslag fragments
	16	3	small lining slag fragments
	34	1	angular fragment of dense fine slag
3092	12	6	sherds from a very small crucible - possibly with luted lid
3458	6	1	fragment of vitrified oxidised fired lining, very sandy, leading to glaze of granular appearance
3189	258	1	large block of vitrified, and flowed pale grey wall, apparently slightly convex in horizontal plane (to judge from the orientation of glaze runnels)
	154	1	tapslag with strongly reddened base - secondary heating

context	weight (g)	number	notes
3073	202	3	tapslag
	18	1	fuel dimpled small prills
	124	1	angular fragment of dense fine slag, massive
box 14			
3119	808	1	fragment of tapslag cake, base shows flow over lobes so not original base, internally rather massive in appearance with better defined lobes on upper surface
3224	562	1	90x40mm cross section rounded base flat topped (fracture) porous slag, probably a large channel/runner, shows crescentic concentric ridges from flow on upper surface, broken in two, ceramic clast
	522	11	tapslag, several in unusual bloated, vesicular, viscous morphologies
	106	1	quarter round mould (?wood, ?tuyère) approximately 65mm diameter equivalent), on outside is parallel tool mark/rod 20-25mm diameter
	73	1	dimpled slag forming over cross sectioned runner/tool mark
	166	1	curved slag crust with overlying slag (obscured by accretion), base partly spalled off, but shows crust is finely vesicular. Probably furnace slag but uncertain
	126	1	dense vesicular slag fused to fine grey hearth wall, one large piece, one small piece showing angle between two ceramic-covered edges, and two ceramic pieces spalled from such a surface
	34	2	small scraps of rusty porous (charcoal-bearing?) slag
3159	48	3	ore, two angular fragments of fine even ore, and one thin sliver of a porous, possibly brecciated material
	4	1	grey vitrified furnace ceramic
	20	1	tapslag
3182	120	1	tapslag, one with a strong lateral non-wetted surface
	90	3	indeterminate worn iron slags
	26	1	pale grey vitrified furnace wall ceramic, vesicular
3046	116	1	dense slag fragment, bears ore fragments, massive, fine
	232	7	tapslag
	18	1	8mm thick basal crust, overlain by highly vesicular iron slag, base smooth planar shiny
	22	1	small fragment of dense fine slag

context	weight (g)	number	notes
3439	56	7	highly porous fragments from large storage jar
3111	56	2	slagged vitrified oxidised lining, probably from near b/h
	10	1	vitrified pale grey lining material
3332	1	2	coal
	78	1	worn and accreted indeterminate dense slag fragment
	56	2	tapslag
3194	22	1	thin indeterminate slag sheet
	26	1	lining slag
3138	34	1	angular fragment of pale grey vitrified lining
	20	1	indeterminate slag sheet fragment
3225	306	1	worn tapslag
3222	48	1	dense slag with marginal dense crust 12mm thick (probably base but not certain) passing into highly vesicular slag, culminating in exposed large rounded vesicle on fracture
3234	14	1	vitrified and vesicular pale grey lining
	8	1	dense slag fragment, probably a flow lobe
3161	284	6	worn dense slags, potentially all tapslags
3178	40	1	unusual very fine ore with localised conchoidal fracture, probably roasted, with cracking more intense in one area
	24	1	tapslag
3104	224	2	very dense tapslag fragments, worn, one with lateral contact with (or clast of) grey ceramic
	28	2	indeterminate iron slag scraps
3236	376	3	worn fragments of tapslag
u/s	46	1	possibly burnt red limestone

context	weight (g)	number	notes
	284	3	worn tapslag fragments
3146	18	1	tapslag
	4	2	prilly slag scraps
3123	158	2	worn tapslag
3126	18	1	tapslag
	34	1	lining slag
	6	1	small scrap of thin slag sheet
3165	30	2	highly worn dense slag scraps
3167	168	1	angular block of very dense fine slag, hint of lobing suggests a tap slag possibly
	8	1	small scrap of slag
box 16			
3316	512	6	dark tapslag, only one shows good reddening
	520	1	dark dense slag, red top showing in one area through accretion, one large probably charcoal clast, probably a tapslag
	542	1	angular block, upper parts show narrow flow rivulets, lower parts have large probable wood mould and other wood/charcoal moulds, lobes at odd angles, suggesting this might be from outflow from massive cake into lower-lying flow
	392	1	dark tapslag forming part of bowl, contains large charcoal piece
	86	1	highly vesicular clinkery altered furnace wall
	420	1	angular fragment of dense highly accreted slag, some areas show small prills, probably a furnace slag
3316	252	1	irregular fragment of dense fine massive slag with multiple roundwood 15mm diameter
3313	22	1	tapslag attached to (flowed over) pot sherd
	236	4	tapslag
	212	2	dense fine lags with hints of internal lobes
	262	1	dense irregular slag fragment surfaces largely obscured by accretion
	124	1	mass of coalesced prills, no sense of flow, one surface has possible wood impression

context	weight (g)	number	notes
3313	218	1	dense slag with much accretion, multiple moulds of both split and roundwood. Some may be charcoal but others probably wood
	138	1	accreted slag, probably tapslag
3317	134	1	very dense tapslag flow, internally rather massive, base has fine lobes and abundant very fine ore
3328	114	1	accretion on iron
	44	1	elongate, rod like piece, showing sign of explosion, iron bar
	100	1	dense internally lobate slag fragment, no original surfaces
3325	678	13	tapslag
	2	1	small chip of pale vitrified and vesicular lining overlain by dark glass
	196	1	rounded worn lump of slightly rusty slag with chaotic probably slightly lobate form. Indeterminate origin
box 23			
3458	262	1	deeply slagged strongly oxidised fired lining with thin reduced surface below slag
	52	1	vitrified and slightly bloated reduced lining, slightly convex surface
	598	6	tapslag fragments
	286	1	accreted lump of slag, shows two large wood/charcoal moulds, slightly dimpled base and top with ore in accretion (and possibly in slag)
	146	2	irregular lumps of porous slag - possibly furnace slag or runner fragments
	40	2	worn dense slag scraps possibly tapslag
	182	2	angular fragments of very dense, but slightly vesicular slag
3473	584	5	dense, moderately fresh pieces of tapslag
	488	8	worn and in some cases weathered rounded fragments of dense slag, all probably from tapslags
3473	2500	7	tapslag, in all but one cases more vesicular in upper most layers and with slightly wrinkled lobe surfaces, than is typical for this assemblage
3283	366	1	tapslag fragment
	534	1	very dense slag lump, probably from a flow, basal layer is vesicular, just 2mm thick, then c40mm of very dense fine slag, a few large rounded voids, then top shows some granular areas some with smooth lobes, but partially obscured by accretion

context	weight (g)	number	notes
3415	1838	18	tapslag fragments, largest is part of bowl 50mm thick, at 65mm from probable margin
	20	1	worn slag scrap
	160	1	slab of lower density slag with tapslag like lobes preserved on margin only, interior porous, could be margin of low-density flow (as seen in some of the runners)
3254	698	1	fan of tapslag flows, maximum thickness 30mm, maximum width 160mm on break about 100mm from likely apex position
	64	1	tapslag
3204	22	2	tapslag
	18	1	narrow slag prill with fuel/wood impressions along sides
	18	1	low density residue; fired hearth ceramic
3493	68	1	tapslag
3202	6	1	concretion on slag?
3490	92	1	dense irregular massive slag fragment
	48	1	worn dense slag, probably tapslag
	4	1	tapslag fragment
	52	1	shiny fuel-dimpled base of slag of uncertain nature
3272	38	1	stone with Mn staining
	402	4	very worn tapslag fragments
	46	1	porous slag fragment, probably from a runner
3204	98	4	tapslag fragments
3375	452	9	tapslag fragments
	24	1	slagged and vitrified lining with pale buff/grey colours
	20	1	bloated slagged lining, possibly a sandstone fragment rather than clay
	92	1	rounded lump of charcoal-bearing slag
3457	36	1	vitrified oxidised lining
	4	1	shard/flap of bright blue glassy slag

context	weight (g)	number	notes
	86	1	slightly dimpled probably non-wetted base from slag of uncertain nature
3496	260	1	dark tapslag fragment
3453	8	1	charcoal
	30	1	deeply vitrified pale grey furnace lining with dark glass
	216	1	fragment of tapslag
	130	1	angular block of massive slag with inclusion of iron ore
	32	1	worn dense slag fragment
box 24			
3253	760	1	double runner/channel; 120mm long, 40mm deep and 80mm wide overall, with some additional slag on top
	38	1	very worn tapslag
	62	2	fragments of neat 10mm thick curved vesicular slag sheet
	56	1	worn fragment of porous slag, probably a channel fragment
3317	80	1	concretion on iron
	134	1	slag with numerous wood/charcoal and some roundwood moulds
	396	1	very dense slag with lobate top, although with no clear flow, and with abundant roundwood moulds
	512	1	angular slag lump, porous with charcoal and vesicles, dense, has protrusion on one side contain lobate material, possibly furnace material from head of runner?
	436	1	dense angular slag fragment with moulds of roundwood pieces
3415	1980	6	tapslag blocks
	84	1	neat margin of slag cake, acute angle, slag vesicular but surfaces weathered so lacking detail
	308	1	slag block with prilly base, upper part fractured off across large moulds, probably of charcoal
3424	280	1	fragment from thick tapslag mass, has ore particles between flows
	270	1	complex slag lump in vesicular slag with charcoal - protrusion suggests a runner/rod extending from below, but piece is torn and twisted so uncertain
3507	350	1	angular fragment of extremely dense slag, locally finely vesicular

context	weight (g)	number	notes
3371	28	1	recently broken fragment from base of lobate dense slag, presumably a rather massive tapslag
	596	1	angular large fragment of dense slag, partly accreted so interpretation difficult, appears slag is granular and porous
	144	1	slightly flowed thick lining slag, up to 50mm of slightly foliated vesicular pale lining slag, possibly grading into bloated pale lining
	358	1	block from base of probable porous furnace slag, has small probable toolmark on base in form of what appears to be a small diameter rod
3258	296	5	very worn tapslag fragments
	146	3	worn fragments of channels/rods; 15mm diameter small frag, 15x10mm rod as part of 15mm radius semi-circular cross section piece; 35x20mm dense semi-circular channel
	42	1	dense slag with smooth concave areas on top, possibly deeply worn tapslag
	236	1	concavo-convex piece of dimpled, porous slag, base of FB or SHC, probably FB
3269	212	3	worn tapslag
	106	1	worn angular fragment of dense fine slag
3455	116	4	worn tapslag fragments
	272	2	worn angular blocks of fine slag with some suggestion of lobing, presumably thick tapslag blocks
	220	1	angular fragment of fine dense slag, no indication of lobing
	26	1	small scrap of slag with small roundwood impression
3303	956	30	tapslag fragments, dark fresh
	54	3	lining slag on pale grey ceramic
	4	1	pale grey furnace ceramic
	130	3	charcoal-bearing slags, two with dimpled bases
	44	1	dimpled dense slag, possibly a lobe cooled within the fuel bed
	104	2	rusty dense slags of irregular form and possible granular appearance
	16	1	dense slag with numerous small ceramic fragments, probably a worn tapslag fragment
3254	92	2	tapslag
	86	1	dense fine tapslag with non-wetted ?base with contact with thin roundwood, other surfaces fractures
3263	74	4	worn and weathered tapslag
	80	1	dimpled base of slag with crude rounded protuberances, porous interior with some large rounded cavities,

context	weight (g)	number	notes
	14	1	indeterminate slag scrap
3356	94	1	crude rod swelling at one end, rod section 25x27mm, slag porous
3427	120	1	margin of highly vesicular slag cake, surfaces not lobed
3315	16	1	small fragment of slag sheet, fused to sand on one side, large rounded vesicles contained within the sheet
3399	26	1	tapslag
3323	6	1	indeterminate dense slag with large vesicles
3350	28	1	fragment of iron ore, has some dense zones suggestive of marcasite type ore
box 25			
3458	106	1	thin tapslag flow with fine part reacted ore incorporated
	178	1	deeply vitrified and altered grey lining - almost all slag
	178	1	dense fresh slag from base of a mass, base is 10mm or so crust, fracture above shows hint of flow outline, so mass is probably tapslag flow
	140	1	basal crust with abundant part reacted ore, appears brecciated above with possible rod base
	186	1	fragment of rather low-density iron slag, well formed microdimpled base, vertical edge formed by two layers of lobe margins, could be fragment of SHC but not certain - could be furnace slag?
	264	1	angular block of dense fine massive slag
	430	1	block of porous iron slag forming sheet with stout tool mark/channel below, slightly double profile 55mm wide, 30mm deep, slightly curved in plan view
	450	1	complex block, at first sight two large channels intersecting at 60 degrees, but might be disrupted basal crust
3315	182	1	crescentic fragment, vesicular iron slag over fused, burr-like contact with grey ceramic, probably edge from large SHC
	328	1	irregular fragment of probably lobed slag containing angular and roundwood moulds, unclear if charcoal or wood
	490	1	angular block of slag, generally fine and massive, with at least one line of maroon-surfaced lobes, one large wood mould
	196	1	irregular fragment of probable tapslag
	20	1	weathered tapslag

context	weight (g)	number	notes
	10	1	rusty slag nub
	28	1	pale grey ceramic intruded by slag vein
	78	1	polished pebble of rhyolitic (welded?) tuff
3313	202	1	dense tapslag, margin of flow
	206	1	dense tap in what appears to be a narrow, tall, flow of thin rivulets, bordered by vertical contact with ceramic/stone, small veneer of which adheres
	690	2	dense angular slag bocks in fine dense material, both with slightly lobed surfaces so probably tapslag
	1205	3	angular blocks of dense massive slag, one has ceramic clasts and maroon surface with tubular vesicles in lower part, other two less well-developed surfaces, some large vesicles some ceramic clasts
	146	1	natural conglomerate
	416	1	irregular concretionary mass, probably a porous furnace slag
box 33			
3314	510	1	tapslag, good conventional flow up to a maximum of 50mm thick
	40	1	tapslag
	310	1	indeterminate light rusty massive slag bock, one small area of face shows smooth, possibly blown surface
	596	1	massive pale slag with multiple round wood moulds and one slightly prilly (basal?) surface
	954	2	massive fine slags with some rounded voids and occasional hints of lobing
3314	138	1	lightly vitrified block of pale grey furnace wall
	966	6	tapslag
	552	3	dense fine massive slags, with just localised surfaces with lobing
	554	4	blocks of tapslag like material with abundant roundwood moulds
	16	1	vitrified pale grey hearth wall
	476	3	dense massive fine slags with rare roundwood moulds
	62	1	rounded small fragment of dense indeterminate slag
3446	234	1	broken in two fragment of probable SHC, shows flat topped bowl up to 30m thick, overlain by cauliflower like growths to 15mm with voids between
	222	1	curious ‘U’-shaped slag block, rough base, dense slag, smooth grey top with upturned edges, suggests SHC fragment
	120	1	pale grey slag forming a mass of roundwood moulds

context	weight (g)	number	notes
3394	16	1	indeterminate slag fragment
	232	1	weathered and etched rather coarse-grained slag, completely lobed internally, but on surfaces preserved
3349	250	1	worn slag block, wedge shaped, top covered in fragmented slag, rusty, worn
	58	1	tapslag
	90	1	very worn lump of probable tapslag
3296	96	2	very worn tapslag lumps
	110	1	worn lump of very dense slag without certain lobes
3506	20	1	worn indeterminate slag lump
3366	12	1	slagged vitrified strongly oxidised fine-grained lining
box 34			
3004	1965	1	200x160x40mm slab of slag, one side is rough, with brecciated slag and lining, but approximately planar, the other side shows a ridge parallel to one side and a rounded trough (i.e. a high ridge on the supporting surface), appears to be a form of FB
	136	1	fragment of rounded tool mark or runner
	64	1	slag fragment with rounded margin - from a runner or perhaps the edge of an FB of the type of the 1965g piece
	138	1	dense runner/tool mark fragment
	58	1	flat topped runner fragment, 55mm long, 30mm wide, 17mm deep
	22	1	tapslag
3004	6	1	corroded iron
	64	2	tapslag
	224	1	asymmetric channel fragment in dense slag, tool mark sheared from base of large block? Broken in 2
	86	1	small twisted runner fragment in fresh dark porous slag
	268	1	sub-conical runner fragment, with a couple of lobes on narrow end
	84	1	tapslag in narrow flow, or channel slag with tapslag like texture
	196	1	probable FB fragment has lenticular basal crust thickening into gentle basal ridge, body of more porous but obscured by accretion
	820	1	bundle of channels/feeders, double probably on base, 65 x30mm section irregular slag on top total thickness of 75mm, probably a deformed third runner, denser edge is truncated oblique

context	weight (g)	number	notes
3004	1000	1	angular block of very dense slag, 80mm thick, lower part with inclined wood contact surfaces, suggestive of wide split wood. Slag is dense and fine and contains some very fine enclaves
	352	1	highly accreted block, elongate, U shaped with one lobate margin, probably an open trough shaped runner
	408	1	angular lump of dense massive slag with low profile lobate-topped runner extending from one side
	578	1	irregular block of slag, possibly more than one held together by ferruginous accretion
	452	1	very dense dark tapslag
	90	1	thin tapslag sheet
box 35			
3288	446	1	SHC with well-formed bowl with dimpled base and with upper lining slag slab, 90x90x55(50) mm
	1075	1	fragment of bowl of very dense FB, base (or is it side) of very dense flow lobed material, body of slag contains multiple pieces of mainly round wood, 90mm thick from non-wetted edge
	460	1	irregular lump of charcoal bearing slag
	354	1	55mm wide x 45 deep piece with 10mm protruding round ridge as wide as the block
	116	1	dense slag with wood moulds, similar to structure of margin of large block in this bag
3314	344	1	tapslag flow with almost vertical non-wetted side 60mm high, granular/fragmental base, very dense
	600	1	tapslag block with 45mm thickness, planar base with non-wetted lobes and ore inclusions
	460	1	tapslag block 50mm thick, base probably missing
	648	1	slab of dense slag, 35mm thick, one face is somewhat finely fragmental
	40	1	fine slag with pore spaces and a wood contact surface
	682	1	angular block of dense slag with flow lobed top almost cherry red, roundwood mould, in lower part, 90m thick
3361	704	9	tapslag
3458	72	2	tapslag
	72	1	tapslag in narrow runner, 70mm wide, 30mm deep, good conventional dense tapslag
	56	2	worn slag pieces probable tapslags
3508	226	3	tapslag
3378	34	1	probable tapslag fragment

context	weight (g)	number	notes
box 36			
3288	972	10	tapslag
	100	1	pale grey ceramic veined with apparent slag intrusions
	118	1	rounded worn slag lump with dimpled surface, suggestive of a tool mark from the base of a block
	170	3	fragments of basal crust from slag - in each case around 20mm thick with a slightly columnar microstructure
	324	1	worn block of very dense slag, has pale (ceramic?) inclusion
	184	1	small fragment of porous slag bearing a length of small round wood mould
	108	2	broken fragments from the dimpled base of slag
	140	1	irregular slag fragment with rather chaotic appearance of small lobes
3288	770	10	10-15mm rod embedded within irregular slag fragment, probably passing from rod to tool mark
	96	1	very worn lump of slag with lobes visible in weathered cross section; tapslag
	88	2	dimpled slag bases
	172	1	crescentic slag, rather granular, with pale vesicular lining slag spread across inside of curve - probably a Cleevelands-style crescentic SHC
	174	3	irregular fragments of slightly vesicular slag
	106	1	fragment of dense slag with isolated lobe hanging below base, probably from the margin of a steep-sided tapslag
3288	582	15	tapslag
	650	1	dense bowl shaped slag, lower part is 25mm dense slag with slightly dimpled or smooth base with slightly undulating surface, upper part of block is 30mm of vesicular iron slag, with remnants of a slightly lobate top. Could be homogenised tapslag or FB type material
	420	12	worn lumps of dense slag, some show dimpled bases, but most devoid of features
	20	1	vitrified pale grey lining
3288	396	1	neat dense almost circular SHC, planar top with some ceramic clasts, base rough, half covered in altered ceramic forming burr-like layer, 90x90x40mm, small piece missing from distal side
	428	19	tapslag, mostly rather worn
	152	4	rounded worn lumps of dense massive slag
	92	5	indeterminate slag fragments
	404	1	rounded worn dense slag, indeterminate

context	weight (g)	number	notes
box 38			
3005	1635	1	large block of dense slag with irregular form, 90mm is lower part with chaotic assemblage of roundwood moulds, upper 30mm is more simply flow lobed, as is upper surface, imprints of possible roundwood also impressed into upper surface
	1210	12	tapslag, one of largest pieces shows exceptionally wide flat flow lobes, other more normal,
3547	646	1	tapslag, up to 45mm dense flow with lobed top, shows basal contact on margins, but inside margin shows fracture
3288	792	4	tapslag
	362	1	irregular slag lump with basal dense crust overlain with planar contact by more porous material, all bears charcoal
	322	1	irregular lump of charcoal-bearing slag
	432	3	worn lumps of dense indeterminate slag
	182	1	fragment of very dense crust with columnar structure (tubular vesicles and microstructure), has curved smooth embayment in upper surface. Probable but no certainly a fragment from a very large SHC
u/s	130	1	flow lobed upper surface of fractured block with large piece of roundwood below
3288	608	8	tapslag, all worn
	38	1	grey slightly vesicular vitrified lining
	228	3	worn rounded lumps of fine massive very dense slag
	68	1	40mm length of 27x30mm slag rod
	134	1	irregular subcircular pad of dense vesicular slag with grey ceramic adhering to lower face, probably from base of FB rather than SHC
	234	1	basal crust, lower 20mm dense above irregular base, and the overlain by up to 30mm of more porous slags
	360	5	worn lumps of slightly vesicular iron slag
box 39			
3347	1235	1	150mm long tall runner, 50mm wide, 115mm tall, basal section in U is vesicular, upper parts more lobate
	164	1	worn dense tapslag lump
	202	1	worn slag nub with multiple ore clasts
3364	312	1	runner 30mm wide x 15mm deep, with up to 50mm of slag of granular appearance stacked on top
	8	1	coke

context	weight (g)	number	notes
	1100	4	irregular blocks of granular slag bearing some dense lobed components. None easily interpretable
	254	1	irregular slag flow showing hot deformation (twisting and cracking on upper surface), probably a deformed thin flow, sandy base
	50	1	highly weathered tapslag fragment
3288	1055	13	tapslag pieces, mostly heavily worn
	396	6	irregular worn rounded slag fragments, one with roundwood mould
	54	1	vitrified grey sandy failed ceramic
3445	170	1	vitrified and slagged oxidised fired ceramic, large almost planar slab,
	890	4	irregular slag lumps, with some lobate surfaces, externally and internally, but of slightly chaotic appearance.
	170	1	rounded worn dense slag lump
3611	194	1	very dense tapslag block with overhanging non-wetted contact to one side
3321	306	1	very dense slag lump, with multiple roundwood moulds to 80mm long and 20mm diameter
3180	54	1	small slag piece, probably a runner fragment
3288	1620	14	tapslag bocks, the two largest both showing later constriction by non-wetted surfaces (? stones)
	486	2	large round slag nubs, slightly granular in texture, smooth curves on the surface of each may suggest gentle tool marks
	286	3	worn slag lumps, possibly slightly poorly lobed tapslags
	92	1	angular dense slag fragment, massive
3288	898	13	worn tapslag lumps
	344	3	Worn, but originally angular dense massive slag lumps
	198	1	slag with strong tool mark or narrow runner, possibly above or beside another narrow tool mark or runner, worn
3288	684	11	worn tapslag lumps
	108	2	fragments of slag sheet, origin uncertain, c15mm crust, with one piece showing more porous material above
	200	1	large rounded mass of porous slag, probably an exceptionally large flow lobe
	426	4	worn rounded irregular slag fragments, no real features
	214	1	possible block of tapped material over fuel - has small lobes in a rather chaotic pattern
	260	1	block of somewhat laminated slag carrying a piece of low-grade ore, very dense

context	weight (g)	number	notes
3535	168	1	plano-convex block, probably an SHC, has peripheral lobes, irregular top and rough base, 70x75x30mm, deeper dimples on base appear to trap coal and coke
	34	1	irregular basal part spalled from slag block
	102	2	tapslag blocks
	644	5	tapslag textured tops to massive, dense slags
box 40			
3503	266	1	crudely plano-convex mass of finely prilly slag, possibly most of an SHC, 55x90x45mm, lobes on base may be toolmarks
	298	1	thin bowl, overlain by maroon -topped slag, all dense; could be SHC fragment or remnant of drained smelting bowl, 100x(60)x45mm
	130	1	dense indurated reduced ceramic, just possibly partially stone
	68	1	slightly worn margin of very dense tapslag flow, with narrow low lobes on surface and internally
3661	4	1	small chip of tapslag
3586	16	1	probable tapslag
3580	70	5	worn tapslag fragments
	2	1	maroon surfaced slag prill, probably tapslag
	10	1	concretion on iron
3689	126	1	margin of tapslag flow, possible wood impression on base, has soft pale clast - unclear if ochre or ceramic
3716	46	1	slag sheet with columnar structure, up to 8mm thick; shows large smooth surfaced vesicle on upper surface, unclear if fractured from tapslag flow, but probably so; base smooth and very subtly dimpled
3543	110	1	tapslag flow, from near margin with tall divergent flows, so possibly part of a birds-foot structure; base includes reworked slag clasts
	24	1	small piece with thin tapslag flows passing over a probable fuel contact
box 64			
3005	32	2	small tapslag fragments
	180	1	dense tapslag

context	weight (g)	number	notes
	972	1	dense massive slag fragments, probably two separate items attached via corroded iron, one shows large open cavities, probably fuel moulds rather than vesicles
	42	1	massive dense slag with base showing possible toolmarks or lobes
	404	1	dense, rather featureless lightly accreted slag fragment
	226	1	rounded mass of finely prilly dense slag - could be a furnace slag or possibly a partly deformed SHC
	132	1	unusual channel slag, top not preserved, two sides show mostly non-wetted contacts, one with a little attached sandy ceramic; probably an asymmetric tap channel
3621	1335	1	slag channel, 70mm wide, U shaped, rough contact to 50mm above base, total thickness 70mm, 200mm long, slightly twisted so probably deformed slightly on extraction (unless original curved sideways and down)
	536	1	angular dark dense slag block with prilly base, 65mm thick, abundant moulds of cut, spilt and round wood, to 30mm diameter and >100mm long
	56	1	angular dense slag fragment with maroon top and scatter of dark sand glaze, possible SHC fragment, but base has iron ore inclusion, so probably a tapslag
	70	5	various fragments and prilly lumps of low density 'lining' slag, mostly dark in colour
	40	3	fragments of dense slag
3704	422	15	small tapslag fragments and prills
	70	3	lower density iron slag fragments, porous, slightly granular in appearance
	50	1	slag fragment with dished profile, base non-wetted dimples, top shiny, non-wetted appearance, with several grey ceramic clasts, unclear if deflated tapslag flow or SHC
	58	1	dense slag fragment with curved features on base, possibly tool marks
	40	1	elongate slag fragment
3480	440	1	massive slag block, rather lobate base, with fine slag suggestive of flow slag just above, remainder coarser with larger void - probably mainly large vesicles but one might be a wood mould, 75mm thick
3661	22	1	worn tapslag fragment
3650	32	1	small slag fragment with intersecting curved surfaces - unclear if flow lobe contacts or wood moulds
3671	248	4	very worn tapslag fragments
	422	1	worn tapslag fragment with very broad flat-topped flow lobes, base prilly suggestive of flow over charcoal, very dense
3555	56	1	worn tapslag fragment, rather vesicular

context	weight (g)	number	notes
3704	80	1	tapslag fragment, dimpled base, somewhat vesicular lobes
	406	1	large block of contorted vitrified and glazed failed wall
	668	1	block of somewhat accreted apparently granular dense massive slag
	334	1	irregular mass of porous iron slag with surfaces with layered botryoidal coatings, could be channel fill or margin of SHC
	188	1	dense mass of small prills, probably margin of tapslag block,
	46	1	tapslag fragment with multiple rounded fired ceramic clasts
	76	1	weathered iron
	62	1	glazed and crudely lobed grey sandy ceramic
	102	1	crust-like fragment with dense slag on margin passing into more coarsely open slag, one small smooth lobe hints this has fractured from the base of flow rather than being internal
box 65			
3704	1655	1	well-formed large SHC, 155x125x70mm, base mainly microdimpled with rare smooth non-wetted lobes, top flat with slightly raised edges, slightly dimpled, but details unclear
	682	1	large block of slightly porous slag, appears to be a deformed channel fragment, but not without problems because of twisting
	410	1	block with indurated curved contact surface suggesting burr, coarse crude lobes to one side - quite possibly a worn fragment of a large SHC, but furnace slag cannot be excluded
3004	756	8	somewhat worn tapslag fragments
	50	1	iron slag bearing numerous lengths of c10mm diameter roundwood moulds
3005	592	1	margin of deep eroded slag bowl, accreted surface, no lobes so either furnace slag or more likely fragment of a large SHC, bowl 55mm deep, top slightly raised in centre by 10mm
	896	1	tapering channel, probably from c100mm to 60mm, also changing from massive to flow lobed lags along this 140mm length, proximal section of channel
	660	1	porous slag with one rounded face and a top of large porous flow lobes, probably a channel slag, but might be the margin of a bowl of some sort
	734	1	extremely dense angular bock of slag with no preserved surfaces
3005	426	1	large fragment of bowl, with a rather irregular profile up to 30mm, probably a residual furnace slag rather than an SHC
	170	1	rusty appearing concretion on iron/slag
	736	3	blocks of rather variable tapslag, one well formed, others more porous and massive internally
	60	1	dense slag with slightly dimpled shiny base and large internal void

context		weight (g)	number	notes
		84	1	dense slag fragment - possibly SHC fragment, but could be deflated tapslag
		134	1	fragment from base of channel - almost V profile
		212	1	unusual plano-convex slag fragment, planar surface has fine dimples, convex surface has inflation around large fine lobe inside mass, section moderately vesicular, probably an odd tapslag, but SHC not quite certainly excluded
box 66				
3005	2 of 2	1460	1	various pieces of slag bound by concretion, apparently around iron
		792	1	double channel slag, main section 70mm wide, 50mm deep, but with various protrusions, slag porous but dense
		766	1	very dense angular block of fine slag, obscured by accretion on surface
3543		540	2	tapslag
		970	1	mass with rounded base and dense, possibly fragmented 20mm thick dense upper sheet, probably a rounded and accreted piece of FB but might just be an SHC of odd form
		1315	1	interesting large block with apparently sloping top with tapslag like reddened flows with ore debris, rear? face has several wood impressions - but these are on a steep alignment compared with the flowed surface, remainder of block is massive, fine and dense, clear base not seen, several bits of corrosion suggest former iron inclusions
3005	1 of 2	1655	1	large block of dense slag, bearing reddened lobes on /near upper surface, heterogeneous internal structure with wood contacts, occasional lobes and a non-wetted steep surface, suggests original slag cake >100mm thick
		496	1	rounded biconvex mass, densest in upper part - a possible SHC, but other interpretations are possible, but not determinable because of accretion, 80x80x50mm
		353	1	slightly biconvex lump with dimpled top, 70x90x40, possible SHC, but could be pall from FB base
		292	1	rounded accreted lump, partly dimpled base, could be FB fragment or rolled fragment of FB base?
		202	1	tapslag flow, dark with vertical non-wetted surface appearing more likely to be a wood contact than a margin
		622	1	block of slightly brecciated? dense fine FB type slag, with bowl shape contact partly preserved on one side
3677		804	1	unusually weathering (forming gey powdery surface) dense slag block showing roundwood on base, then dense slag, then flowed slag with rounded voids and ore debris, 90mm thick
		274	1	unusually weathering grey slag preserving charcoal, massive with ceramic clast, charcoal clasts and voids after roundwood
		528	1	plano-convex block of FB material, dense slag with some roundwood, odd weathering leaving yellow accretion with red clay in moulds on top

context	weight (g)	number	notes
3005	94	2	worn and corroded tapslags
3582	274	1	dark fresh tapslag
	368	1	large rounded concretion of various materials around iron
3708	42	3	tapslag
	60	1	irregular angular fragment of slag with charcoal and rounded vesicles
box 67			
3682	1115	2	tapslag, one almost birds-foot of very narrow prills and descending prills not flows in its lower part
	1180	2	large angular blocks of fine massive slags, largely without other features
	498	1	angular block of fine-grained massive slag bearing a probable wood contact, in its upper part it is cut by a smoothly contoured void - probably a feeder tube, above which is a lobed flow surface
	688	1	large angular block of mostly fine-grained massive slag, one side is a large c80-100mm diameter equivalent roundwood surface
	252	1	flat topped wide runner/channel, 60mm wide 20mm deep, base is marked by cavities (charcoal debris?), top is accreted sand
	652	1	160mm length of 60mm wide 50mm deep complex channel, appears curved, probably from amalgamation
3674	260	1	concretion on iron starting to explode
	30	1	slightly bent sheet of low-density slag - flap of lining lag?
	110	1	tapslag
	652	1	mostly dense fine slag with lobate top, appears slightly chaotic with lower part with rounded voids, at least some of which are small roundwood
u/s	460	1	dense fine slag with abundant charcoal moulds plus some roundwood ones
	566	1	dense fine slag with spit roundwood moulds, one suggesting a 80-100 mm diameter, well over the right angle probably represented, some dark-surfaced cryptic lobes in piece
	453	1	dense fine slag with prilly base(?) and some roundwood moulds
3708	542	1	unusually weathered dark fine slag blocks - polished almost black where dense, turning yellow-brown on porous sections
	50	1	tapslag
	26	1	prilly slag, probably base of tapslag flow

context	weight (g)	number	notes
3507	420	1	deeply weathered slag turned greenish, fine grain massive facies with just a hint of internal lobes. Worn cavities suggestive of fuel moulds on base
3607	210	1	fragment from two (probably) vertically-stacked runners, lower 25x15mm, upper 40mm diameter
3516	416	1	equant block of extremely dense fine slag, upper face shows low profile dark (not red lobes), a few cryptic lobes visible internally, associated with ore fragments, base shows small area of wood mould
3619	22	1	tapslag
	112	1	curved microprilly sheet, uncertain origin
3713	170	6	tapslag
	298	1	block of grey slag with lobate base, but apparently massive body (though with elongate vesicles) and top fractured away
	32	1	small fragment of indeterminate fine slag
3666	32	3	tapslag
	76	2	fine dense slag with some lobing, unclear if true tapslags
	8	1	small concretion on iron
3587	24	1	weathered low density slag, porous
3587	44	1	low density porous charcoal rich slag
3542	22	2	tapslag
	224	1	dense massive homogenous slag with maroon surfaced flow lobes on top
	102	1	irregular slag fragment with dark surfaced cryptic lobes and possible wood mould
box 68			
3516	88	1	fragment from thin tapslag sheet with planar base
	1170	1	complex block with uncertain attitude, probably c100mm thick, some impersistent lobate surfaces, very rich in roundwood moulds up to 40mm long
	680	1	dense slag block of uncertain attitude, full of moulds of roundwood to 20mm, some with bright maroon surfaces

context	weight (g)	number	notes
3640	184	2	worn fragments of tapslag with sandy bases and large rounded (viscous?) lobes
	796	1	worn large block of dense slag with some large rounded vesicles but no clear flow lobation. Contains several large blocks of part-reacted ore
	36	1	small fragment of dense slag with dimpled base
	14	1	fragment of dimpled sheet of lining slag
3545	206	1	block of tapslag, locally massive, but locally with tiny rivulets of c5mm diameter
	182	5	variable lumps of tapslag, some worn
	56	1	dense slag with prilly base - probably a tapped slag over a fuel bed
	96	1	a worn fragment, probably tapslag with a sandstone clast
3597	590	1	angular large bock of massive slag, way up uncertain, no original surfaces, multiple contact surfaces with flat surfaces apparently of large split wood
	174	1	dense slag, poorly developed lobes at top and downward prills at base, has ore inclusions
	32	1	small fuel dimpled dense slag fragment
	408	1	dense angular slag fragment with lobate upper surface of low amplitude broad lobes with clear flow sense, various lobe surfaces visible within other massive slag
	478	1	dense angular slag fragment, several prilly surfaces suggesting downward movement into fuel, has at least one large iron clast
3721	340	8	dense tapslag fragments
	84	1	ferruginous concretion
box 69			
3703	572	26	small fragments of dense tapslag
	24	1	oxidised fired vitrified lining
	310	3	fragments of probable channel slags, none with good profile
	102	1	glazed contorted grey ceramic
	38	1	ferruginous concretion
	742	10	slightly granular porous slags with occasional maroon lobe surfaces, probably disrupted taps slags but might be furnace slags
	166	1	dense slag, massive with large internal rounded vesicles
	78	1	complex slag - probably interaction of flow lobed material and reduced fired ceramic

context		weight (g)	number	notes
3579		1220	1	complex block of very dense slag, main part is massive, with lobate base and occasional lobe surfaces, pus ceramic clast, but inserted into this is a block of similar material with slightly lobate top rotated through 90 degrees. Tapped bowl must have been at least 70mm deep and completely fluid to accept rotated block
		1100	1	dense massive slag with some lobed surfaces close to ?top, but with two major steep? non-wetted surfaces, suggesting flowage into gaps between stones
		540	1	rather massive dense slag fragments with some moulds of wood fragments
		518	1	massive angular slag fragment with one surface suggestive of prills descending into charcoal bed - if so probably >70mm flow, but orientation uncertain
3588		1265	1	complex block 180mm long, 100mm tall and 65mm wide, may be two channel slags stacked above one the other - or a deep channel with the upper part not so constrained as the earlier - probably two distinct phases, vesicular
		630	1	very dense thick fragment from lenticular flow, traces of lobing top and bottom with possible non-wetting lobes (or include pre-existing lobes) on one side
		124	1	contorted crude flap or sheet of rather low-density vesicular slag
		18	1	ferruginous concretion
3673		188	5	slightly worn dense tapslag fragments
		76	1	worn dense slag fragment
3516		426	2	tapslag fragments, one missing base, the other fairly thin with a sandy base
3534		88	3	tapslag fragments
		32	2	vesicular iron slag fragments
		66	1	angular fragment of very dense slag, probably a tapslag
3473		314	6	rather varied fragments, al worn and all probable tapslags
3367		54	1	tapslag fragment
		14	1	vesicular sand-bearing iron slag
box 70				
3704	1 of 2	288	2	fresh tapslag pieces with some accretion, extremely dense
		430	1	tapslag fragment, base shows dimpling from fuel contact, but also abundant altered ceramic clasts and several large ore pieces

context		weight (g)	number	notes
		498	2	granular slags with some lobes, both of complex morphology, possibly deformed, both show hint of microprilly basal convex surface, so probably either from SHCs or furnace
		196	1	vesicular dense slag with hints of surviving maroon smooth surface area, base fractured, unclear if from a tapslag or possibly an SHC??
		354	1	extremely dense angular block, has rounded large internal voids, a vug with coarse olivine, a surface with hints of lobes and abundant ore fragments, probably a massive facies 'furnace' slag
		434	1	crudely plano-convex mass of porous dense slag, with some ceramic clasts on upper surface and rough lower surface. Probably a basal furnace slag not an SHC, but this is not certain
3703		1565	1	complex stacked multiple runner, 220mm long, at least two surfaces with large viscous lobes, but was up uncertain 110x60mm section
		1650	1	complex stacked runners, 160mm long, 130mm (wide?) x 70mm section, largest component is 70x40mm section double runner, others (progressively smaller) may have formed laterally to this
		78	5	scraps of probable tapslag
		46	2	dense featureless slag scraps
3704	2 of 2	584	8	dense tapslags
		236	1	block of tapslag, lobed top and base, massive internally, lateral surface formed by contact with furnace ceramic, which is orange until grey just mm from slag contact, could be in-situ but not certain
		126	1	dense slag, massive with irregular fracture and elongate voids, possibly from runner
		303	1	fragment of double runner
		294	1	runner fragment showing slightly brecciated nature - cracked when still hot?
3703		968	17	tapslag fragments, dense, mostly fresh (if slightly accreted)
		208	1	angular fragment of dense but vesicular iron slag of uncertain origin
		62	1	concretion on iron
		416	3	fragments of ‘U’-shaped runners with open trough like tops in porous slag
		434	1	large slag flow lobe with top cracked in raised concentric ridges
		60	1	thin flowed slag, twisted, maroon surface, dimpled fuel contacts on base (more lining than conventional tapslag?)
		70	1	complex slag fragment with granular texture and some protruding lobe margins
		280	1	dense burr-like area with attached indurated buff lining, probably from burr in furnace, but origin in a SHC not entirely to be excluded
3668		6	1	cracked (roasted?) ore fragment
		36	1	probable tapslag containing large part-reacted ore piece
		16	2	tapslag fragments

context		weight (g)	number	notes
3609		64	2	tapslag, larger piece a bundle of very fine lobes
3622		94	6	tapslag fragments
3650		6	1	Mn crusts on stone
box 71				
3595	1 of 2	22	1	tapering dimpled slag rod 50mm long 10-20mm diameter
		260	1	double or triple channel in dense slag with fragmental top, overlain by a small area of tapslag like material
		492	1	porous slag in FB like lump, but internally in the form of two adjacent channels
		442	1	dense large channel with dimpled surface 50mmx40mm overlain by somewhat lobate material
		644	1	triple channel block in rather porous slag, 30-40mm diameter components
		210	1	irregular block of slight rusty dense slag
3595	2 of 2	578	3	fragments of porous channels similar to material in bag 1
		548	1	shows shiny base suggestive of channel material, very dense, forms block of two layers, probably FB/channel
		358	1	irregularly fractured massive fine slag, hints of roundwood inclusions
		100	1	fragment of porous channels
		404	1	rusty worn fragment across lenticular material similar to 548g piece above, probably from a FB/channel, but might also be a section through the centre of an SHC
		224	1	dense plano-convex slag with attached ceramic over lower face, unclear if FB, SHC or Burr, probably latter, but uncertain
		170	1	irregular rusty worn slag lump indeterminate
3595	2 of 2	786	1	agglomeration of three channels stacked sub-vertically, lowest lobe has reddened flow lobe extending from its tip
		450	1	divergent channels/rods, 35mm in diameter
		496	2	tapslag
		726	1	irregularly fractured massive lump of fine slag, no original surfaces
3595	1 of 2	1645	6	tapslag
		220	1	rounded base of slag mass in very vesicular slag, passing up into dense slag with large elongate voids, presumably part of a channel
		256	1	dense vesicular massive slag with local hints of cryptic flow lobed surfaces

context		weight (g)	number	notes
3595		450	4	fragments of porous channels - several of these may fit onto blocks in the bags above
		206	1	irregular fragment of base of slag mass, dimpled base, overlain by porous slag with some very large rounded voids (suggesting viscous flow?)
		44	1	small fragment of porous slag with some roughly lobate surfaces
		316	1	biconvex block suggestive of small SHC, rough base with hint of burr on one side, top is irregularly and smoothly raised and strongly reddened
box 72				
3516	1 of 2	1775	1	large runner, 230mm long, lower element is tapering, 80mm wide x 30mm deep at wide end, 50x20mm at narrow end, upper element slightly oblique to lower, whole is 85mm tall
3516	2 of 2	1200	1	large block with FB like material rich in charcoal and some roundwood, apparently passing forward into dense channels
		438	1	rather massive slag, internal detail not visible but carries several small ceramic and sandstone clasts
		704	4	tapslag, dark
3682		650	4	tapslag
		468	1	tapslag block with poorly visible internal lobes, a clast of red fired clay and on top a substantial clast of fresh ore
		490	1	dense slag, has rather fragmental top, but internally has numerous dark lobate surfaces (not reddened) possible base is slightly prilly, but may not be true base
		506	1	very dense fine slag in irregularly fractured piece, carried impression of end of 40mm diameter round-wood
		224	1	dished rusty slag with fragmental upper surface, has rounded vesicles, probably from furnace floor
		48	1	concretion on iron
		76	1	coarse slag fragment with impression of very large rounded wood exterior as well as other wood contacts
3595		234	1	30mm wide runner in dense dark slag, at one end topped by poor tapslag like lobes, the other the rod widens and becomes rough and obscure
		824	1	80mm wide channel half full of porous slag with some charcoal and some ceramic fragments
		142	1	tapslag
		318	1	massive grey slag with some cryptic dark (not red) lobe surfaces
		688	1	block of massive fine slag, has reddened lobe surfaces on top, carries one large inclusion of ore
		238	1	plano-convex section, probable runner fragment, 70mm wide, filled with porous slag with abundant fine charcoal moulds
3595	2 of 2	380	1	dense dark tapslag flow, carries some ore
		568	2	dense angular fragments of fine slag, slightly accreted so internal detail not visible

context		weight (g)	number	notes
		348	1	80mm wide runner (possibly double) in porous slag, fresh break so may join with another fragment
		544	1	dense massive fine slag with multiple slightly reddened lobe surfaces, but orientation suggests a degree of chaotic organisation
box 91				
3037	5	20	8	6 worn slag pieces and 2 small fragments of fired clay
3092	9	56	19	iron smelting slag debris
		22	8	vitrified furnace lining
		1	1	curved piece of reduced fired fine ceramic with organic temper with vitrified exterior, probably lining
3102	16	124	9	iron ore in various lithologies from massive with botryoidal cavities, to brush, to individual stalactites, with abundant charcaol debris
3228	21	154	10	iron smelting slags
3313	27	32	1	tapslag
		8	1	lining slag
3316	30	60	4	Iron slag, indeterminate
3317	31	96	12	slag, including one fragment with large wood moulds
3374	34	2.9	16	coke
3521	37	372	26	tapslag
		42	3	lining
3527	36	<1	assm	tiny assemblage of slag debris
3587	50	<1	assm	tiny assemblage containing some slag debris and a few pieces of flake hammerscale

context		weight (g)	number	notes
3611	38	144	45	small fragments of iron smelting slag
		12	1	complex brush type finely stalactitic ore
3685	46	<1	assm	assemblage of 5 fragments, one of which may be FHS,
3687	47	10	2	ochreous concretions with iron; one elongate, one disc-like
		2	2	mineralised iron
		14	1	lining slag bleb
		7	1	concretion, probably ferruginous, rich in coal dust
3703	53	116	12	indeterminate iron slag
		1	15	coal
3708	54	420	103	small fragments of iron smelting slag
		10	1	vitrified and bloated wall
3710	55	94	7	indeterminate slag
		22	3	grey fired clay
		8	1	stone

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