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Assessment of archaeometallurgical residues from Lockleaze (Ding Crusaders)

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Dr T.P. Young

Abstract

The submitted materials from the site (total 32kg from 93 contexts, of which metallurgical residues comprised 28kg, the difference being mainly fuel materials) included several distinct groups of material: from iron smelting in a cereal-packed non-tapping (slagpit) furnace, from iron-working (smithing) with charcoal fuel and from iron-working with coal fuel.

The iron smelting evidence was extremely unusual, for apart from one single small fragment of probable tapslag of more typically Roman aspect, the evidence (6.4kg of slag from 15 contexts) indicates the use of a non-tapping furnace of slagpit type, of which the basal pit had been packed with cereals/grass. This technology is known rarely in Britain from the Iron Age and also slightly more widely from the early medieval period, but only one example has been recorded from Roman period (Leda Cottages, Kent). The evidence at Lockleaze is dominantly from earlier contexts, but the furnace has not yet been identified and it is unclear whether the activity was Iron Age or Roman in date.

Smithing employing charcoal fuel is indicated by 2.6kg of slag from 8 contexts. At least a proportion of this material is from 'early' contexts, with a particularly significant collection being of fragments from large smithing hearth cakes (SHCs) that would most likely have been produced during bloomsmithing, from a posthole spot dated as being from the 1st century.

In contrast, most examples of residues from coal-fuelled smithing are of mid- to late Roman age. Although blacksmithing employing coal as fuel is typical on Roman rural sites in the region, the material from Lockleaze is unusual for the presence of examples of particularly large SHCs ,more similar to those from urban assemblages.

In addition to the macroresidue assemblages there were sieved samples containing microresidues from many areas, seven of which were particularly rich (and four of these were also rich in coal residues). Some of these collections derived from, and close to, the hearth in the N range of the villa. This hearth may indicate the location of a smithy (not necessarily the only smithy present on the site).

The site thus possesses some significant metallurgical evidence – an early (Iron Age or early Roman) phase of iron smelting in an unusual furnace type, possibly accompanied by charcoal -fuelled bloomsmithing and blacksmithing, followed by later coal-fuelled blacksmithing, including a period contemporary with the villa with a possible smithing hearth and smithing floor microresidues. These share aspects in common with other sites in the area, but also differ in important details.

Contents

Methods

All materials were examined visually, using a low-powered binocular microscope where required. As an assessment, the materials were not subjected to any high-magnification optical inspection, not to any form of instrumental analysis.

The identifications of materials in this report are therefore necessarily limited and must be regarded as provisional.

This assessment was conducted in November 2018 and was commissioned by Ed McSloy of Cotswold Archaeology.

Results

General description of the assemblage

The archaeometallurgical residues from the site (total 31kg from 93 contexts) included several distinct groups of material: from iron smelting in a cereal-packed non-tapping (slagpit) furnace, from iron-working (smithing) with charcoal fuel and from iron-working with coal fuel.

Iron smelting residues

Iron smelting residues were represented by 6.4kg of iron slags, some flow lobed, bearing localised areas of imprints of narrow, cylindrical organic matter, presumably the stems of cereals or grass.

These materials are indicative of formation within the basal pit of a non-tapping furnace. Non-slag-tapping furnaces typically possess a basal pit or chamber below the level at which the bloom is formed to contain the slag generated. This pit or chamber was usually packed with an organic combustible material. Usually either wood or cereals/grass.

The cereal-packed slags are accompanied by blocks of charcoal-rich slag from the 'furnace bottom' slag that forms below the bloom. These fragments ranged up to 1780g (context (904)), with other large fragments showing wall and floor contacts, but none provides any evidence for the overall size or form of the furnace bottom. These and other charcoal-rich slags have been grouped in Tables 2 and 3 as 'indeterminate charcoal-bearing slags' because some of the material may be from charcoal-rich SHCs rather than furnace bottoms.

A further 848g of the assemblage comprised dense flow slags. Flow slags in the form of elongate prills of formerly fluid, flowed slag are commonly formed by the passage of slag from the hot-zone of the furnace into the lower, cooler parts of the furnace, most especially in non-tapping furnaces, but also sometime in tapping furnaces. A 406g block of slag from (12922) showed reddening, possibly suggestive of flow over ore fines, a feature most commonly seen in Roman slag tapping furnaces. A very small (36g) fragment of flow slag from (10679) with narrow amalgamated flows with a reddened upper surface was a typical residue from slag-tapping. Thus, although approximately half of the dense flow slag collection is possibly also associated with the same source as the cereal-marked slags, some 442g may derive from a quite separate slag-tapping smelting process. Flow slags may also be formed, albeit usually in smaller pieces, by a similar low of fluid slags within a smithing hearth and some small fragments may have this origin.

Iron ore

Fragments of high-grade iron oxide (haematite/ goethite) ore were recovered from five contexts:
(10799), 9g
(10854), 10g
(11632), 24g
(12095), 66g
(121036), 244g

All collections were of broadly similar material, compatible with an origin in one of the ore bodies of Bristol Channel Orefield (*sensu* Thomas & Young 1999a, 1999b; Young 2000).

Ironworking residues

The ironworking residues fall into three groups:
- 2558g of smithing hearth cakes (SHCs) with evidence for the use of charcoal fuel
-6624g of fragments of SHCs with evidence for the use of coal a fuel.
- microresidues from smithing

Charcoal-fuelled SHCs:

Smithing employing charcoal fuel is indicated by 2.6kg of slag from 8 contexts. At least a proportion of this material is from 'early' contexts, with a particularly significant collection of fragments from large smithing hearth cakes (SHCs) that would most likely have been produced during bloomsmithing, from the fill (12701) of a posthole spot dated as being from the 1st century.

In addition to those pieces identifiable as SHC fragments, it is likely that some of the material grouped

as 'indeterminate charcoal-bearing slag' derives from SHCs.

Coal-fuelled SHCs:
The assemblage included 4466g of slag derived from coal-fuelled SHCs. As with other classes of residues, a high degree of fragmentation means there is little evidence for overall size and form. A single almost intact SHC (774g, from context (10259)) was probably coal-fuelled, with a 280g example from (10885), a 420g example from (10945) and a 672g fragmented example from (11148) more certainly so.

Micro-residues:
Microresidue assemblages (mostly collected on a 1mm mesh) were retrieved from a wide variety of contexts, commonly in association with either raw or burnt coal. In very small quantities these occurrences are not especially significant, but several assemblages were rather larger. In addition to the individual particles, microresidues were also recovered in concretionary masses of the type commonly known as smithing floor (for their common, but not obligatory, occurrence within the deposits formed on smithy floors). Such concretions commonly form around small particles of corroded iron metal.

The microresidues from the hearth fill (11801) from the northern range of the villa, were very sparse, but the small assemblage included both hammerscale and droplets. If in-situ, this would be a significant assemblage, but it in such small quantities it might equally be intrusive.

The assemblage from (11258) is modest in size but includes both microresidues and coal (and coal residue).

The assemblage from (11277), also from the villa's northern range (probably the fill of pit [11276]), was rather larger, with microresidues, fuel residues and small concretions based around iron.

The fill of pit [11470], context (11471) contained a similar, but modest, assemblage of metallurgical microresidues and fuel materials.

Context (11622), the fill of pit [11621), also from the N range area, produce a further example of a similar assemblage with both isolated microresidues and 'smithing floor' concretions.

Context (12563), a fill of pit [12562] was particularly rich, with 2.7kg of sieved residues, mostly from fuel (coal and coke), but also with a rich assemblage of hammerscale, slag droplets, iron debris and other residues.

All of these materials would be typical of the fine-grained detritus that accumulates on smithy floors, but their occurrence within the fills of pits may suggest that the pits were places for disposal of smithy floor sweepings, rather than a primary accumulation. It must also be borne in mind that such assemblages commonly occur within the post settings (both structural and for internal features such as anvils or bellows supports) for smithy structures, presumably infiltrating as the timber rotted.

Non-ferrous metalworking residues

Non-ferrous materials examined in the project comprise a single body sherd from a small crucible. This is likely to have been employed in the casting of copper alloys, but there is no direct evidence (without further analysis).

The initial site reporting suggests that there may have been an area of lead working in the northwest of the site.

Clinker

Context (12168), a fill of pit [12170], produced an assemblage of 3kg of clinker from the burning of coal. This context produced no residues to indicate a metallurgical purpose for the activity and so it is likely that the clinker was produced in a domestic hearth or one involved in a non-metallurgical craft activity.

Distribution of the assemblage

The residue assemblage of 28kg from 76 contexts, with only 8 contexts producing more than 1000g, was rather sparse. The residues were widely distributed across the site. Apart from the association of good microresidue assemblages with the northern wing of the villa, the provisional (and partial) distribution maps kindly supplied by Tom Brindle show little evidence for geographical foci.

The investigation of the stratigraphic distribution of productive contexts is similarly uninformative at this stage (see Table 3 for the key productive contexts and their spot dates), although there is a general bias towards 'early' contexts for the iron smelting and charcoal-fuelled smithing and later ones for the coal-fuelled blacksmithing. This clearly requires further investigation at the analysis stage.

This evidence suggests that as well as a dispersed style of disposal, it is likely that there is a high degree of residuality in the occurrence of the residues.

Interpretation

The diversity of residues from Lockleaze, and to some extent their widespread, sparse distribution, may be paralleled at other sites in the region. In particular, recent excavations at Kingswood by AC Archaeology (Young 2017c), but also the less well-documented residues from Frocester Court villa (Price 2000; Thomas 2000) provide local examples with similar ranges of processes.

The presence of low levels of iron smelting residues on Roman rural sites across the Bristol Channel area (e.g. Allen & Fulford 1987, Thomas 2000, Young 2014c) is indicative of widespread, but sporadic iron smelting outside the major production centres. It is likely that this reflects the use of the region's woodlands resources through movement of iron ore from the Forest of Dean, South Gloucestershire and the Bristol area. What is less certain is whether this intermittent activity (presumably undertaken by itinerant, or at least mobile, iron smelters) was simply maximising the productivity of rural estates with a woodland component, or was intended to provide materials for particular campaigns of construction.

The iron ore recovered at Lockleaze indicates smelting of a rich oxide ore from the Bristol Channel Orefield, which includes numerous small ore bodies in the Bristol area as well some larger ones in South Gloucestershire. Ores of this general type were smelted at the early medieval smelting site at Emersons Green (6 kms east of Lockleaze; Young & Young 2013). No orebodies have been recorded in the area of Lockleaze, which does not lie along faulted margins of the Coalpit Heath coal basin which contains the ores of Iron Acton, Frampton Cotterell and Yate – perhaps too with ores near Emersons Green. Nor does Lockleaze share a geological context with the Carboniferous limestone-hosted ores of the Clifton area. Instead, the Lockleaze site has a solid geology of Lower Jurassic rocks, too young to host such ores. Further analytical work would be required to determine more closely the provenance of the ore smelted here.

The technology of iron-production at Lockleaze is markedly different from that of the other sites investigated in the region. Although a very small quantity of residues from iron smelting in a slag-tapping furnace (as seen on other Roman sites in the region) is present, the majority of iron smelting residues are from a non-tapping furnace.

In contrast to most British examples, the combustible material of the pit-packing was not wood, but cereals or grass. The use of cereals or grass occurs sporadically in the British Iron Age and is known more widely in the early medieval period, but only one example is currently known from the Roman period.

The Iron Age examples include Furnace 4 at Folly Court, Wokingham (approximately 2nd century BC) and probably sites in E Yorkshire (pers. obs.). Evidence for this technology is similarly sparse, with only the material from Leda Cottages, Kent, currently recognised (Keys 2006; Paynter 2007, Fig 4).

Early medieval parallels are provided by a site at Eckington (Derbyshire; Young 2017e) with a 14C date of Cal AD 650-770 (SUERC-75177 (GU45045)), two sites in the Forest of Dean (Yorkley and Clearwell Quarry; Young 2015a; Paynter 2002) that have produced 14C dates of the 8th to 9th centuries AD and a site at Hemyock, Devon (Smart *et al* .2018; Young 2016b), that gave 14C dates of the late 9th to early 10th centuries AD. In Ireland the situation is similar, with pit-packings almost entirely of wood, but cereal/grass packing is known from sites at Camlin (Co. Tipperary; Young 2011b) and Clonfad (Co Westmeath; Young 2012a), probably both of the 6th to 7th centuries AD.

The significance of the furnace type is unclear. At Folly Court, the small slagpit furnace sits alongside much larger dome furnaces and it is uncertain whether they represent successive technologies or two the parts of a two-stage process. Somewhat similarly, although a millennium younger, the Churchills Farm Hemyock examples are accompanied by slag tapping furnaces and extensive campaigns of 14C dating have failed to reveal any major difference in age. In both these examples a high phosphorus content to the ore provides a context within which a two-stage process might be employed. In contrast, the Lockleaze example and those from the Forest of Dean are in areas with extremely low phosphorus ores, making a two-stage process rather unlikely.

Whatever the explanation for the unusual smelting technology employed, the onward working of the iron blooms would seem to be indicated by the charcoal-fuelled smithing. The evidence for this (2.6kg of slag from 8 contexts) shows, like the smelting, a bias towards earlier contexts, including the fill (12701) of a posthole spot dated as being from the 1st century. Charcoal is typically employed in the early reworking and refining of iron blooms to avoid the incorporation of sulphur into the finished iron. The SHC fragments are insufficiently complete to provide evidence for their overall size or morphology. The largest fragment is a 956g piece from context (11426). SHCs of such a size are indicative of residues from bloom smithing (the processing of raw iron, rather than the working of finished iron), as seen in assemblages from Miskin (Thomas 2000), Kingstone (Young 2012b), Cardiff Castle (Young & Kearns 2011) and Dymock (Young & Kearns 2010). The smaller fragments may, of course, derive from smaller SHCs, and thus it is possible that blacksmithing is also represented by the charcoal-bearing SHCs.

In contrast to these early activities, the coal-fuelled blacksmithing is an activity that can be paralleled on a very high proportion of Roman rural sites. Recently-investigated assemblages of such residues include those from Cleevelands (Young 2017a, 2018a), Kingswood (Young 2017c) and Trowbridge (Young 2009a, 2009b). In addition, there are analyses of coal-fuelled smithing slags from Frocester (Thomas 2000). Other similar assemblages, but for which no analysis has been undertaken include that from Uffington (Young 2015b). There are also several recently-described assemblages of the same period which had employed charcoal as fuel (e.g. Ebrington, Young 2016a; Exminster, Young 2014b; Caerleon, Young 2017d; Mickleton, Young 2017b; Neath, Young 2013, 2014a; Thornbury, Young 2018c), in addition to the charcoal-fuelled material from Kingswood (2017c) of which only those from Neath, Caerleon, Thornbury and Kingswood have been the subject of detailed analysis.

The coal-fuelled SHC assemblage also includes some large examples, with a fragmented example (11148) having a total of 672g of fragments and a 774g example from (10259) that was probably coal-fuelled. These compare with maximum SHC weights at Cleevelands of 530g and at Uffington of 614g (see Young 2018a, Table 4, for comparative data). They are instead more closely comparable with the maximum size of SHCs from 'urban' smithies such as Carmarthen (820g; Crew 2003). It has been argued (Young 2017f, 3; Young 2018a, 13) that the small size of typical SHCs from rural sites is not only a dominance of low-iron-loss tasks, but also discontinuous forge operation. Some circumstances might lead to those parameters being otherwise, even in rural settings (e.g. busy smithies on large estates or smithies engaged on supply of large numbers of fittings for a particular task, such as a building project or the construction of a cart).

The paucity of intact SHCs at Lockleaze is striking. Only three reasonably intact examples were found within the assemblage, all of moderately large size. To some extent a similar situation was found on the site at Kingswood (Young 2017c) with just nine intact examples within an assemblage examined in detail of 49kg. These assemblages are in stark contrast to that from Cleevelands (Young 2018a) with its 176 intact SHCs and equivalent slag masses (in a 60kg assemblage) or the 57 SHCs from the 14kg assemblage from Uffington (Young 2015b). It is likely that the lower density of residues across the excavated areas at Lockleaze indicates either haphazard disposal or, more likely, a high degree of residuality, compared with the focused primary deposition of the waste at Cleevelands.

The association of some good microresidue assemblages with the northern range of the villa, with its 'hearth' and 'oven', raise the question of whether either (or both) of these structures served a metallurgical purpose. The identification of Roman smithing hearths with any real degree of structural preservation is relatively rare, so extraction of further detail on the structures and the microresidues might shed further light on the later Roman smithing operation.

The occurrence of a single sherd of crucible in association with the microresidue assemblages around the north range of the villa indicates the copper alloy casting was undertaken at least on occasion. A similar low level on non-ferrous work was undertaken on some of the other sites mentioned above as showing blacksmithing evidence (none was recognised at Kingswood, a single sherd of crucible was recovered at Uffington, a single sherd of crucible was also found at Cleevelands, a small group of crucibles and other technical ceramics was reported from Frocester Court villa and a single fragment of possible mould and a single fragment of copper-alloy embedded in hearth lining were found at Post Farm, Thornbury).

Further work

The assemblage has a high potential to provide additional useful information through further analysis.

The unusual smelting technology is deserving of further characterisation as are the examples of iron ore, in order to determine as far as possible the source of the ore and the likely yield from the smelting.

The evidence provided by charcoal-fuelled smithing slags could be further investigated to determine whether it represents bloom smithing alone, or whether there was an early phase of charcoal-fuelled blacksmithing prior to the introduction of the use of coal.

It is of some interest to clarify whether the charcoal fuelled smithing and iron smelting are pre- or post-Roman conquest.

The stratigraphic context of the assemblage needs refining as better understanding of the dating develops in order to try to refine understanding of the onset of the use of coal.

The coal fuelled smithing has two interesting aspects that could be further investigated: the unusually large SHCs and the possibility of a smithy within the northern range of the villa. Although the stratigraphic distribution of coal-fuelled SHCs makes the villa unlikely to have housed the only such smithy on the site, it is the occurrence of both physical hearth remains and good microresidue assemblages that makes this possible facility of enormous interest. Detailed analysis of microresidues (after Young 2011a) may aid understanding of both the nature of the smithing technology and of the nature of the metal being worked.

Any analysis phase campaign of analysis of residues would thus need to be accompanied by updating of the stratigraphic background and interrogation of the field records from the possible smithy area.

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Table 1: summary catalogue of submitted materials by context. Assm = assemblage.

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
106			70	70	1	irregular small lump of charcoal-rich slag
205			41	41	1	worn fragment of dense slag, internally flow lobed and has probable cereal impressions
306		coal	1.5	1.5	1	coal
904			1945	1780	1	large irregular FB block with medium to coarse charcoal
				156	4	dense slags, one at least showing good marginal crust, with external cereal impressions
926			100	92	1	most of small SHC, irregular 'wispy' top and deeply dimpled base, irregular in shape and orientation not completely certain, very rich in coal and shale inclusions
				8	1	small fragment of similar SHC, vesicular iron slag bearing coal shale in abrupt contact with sandy lining slag, possibly along a fracture
10014			382	382	1	amalgamated flow slag around medium wood moulds, appears rather viscous, includes limestone clast, base has some possible cereal moulds but not quite conclusive
10025	2	coal	5		assm	charcoal
10031			22	22	1	small fragment of deeply dimpled pale slag, probably coal-fuelled SHC fragment
10091			90	90	1	pale deeply dimpled nub with coke, part or all of a crude SHC-like mass
10122			52	52	1	small fragment from the margin of a dense SHC probably of medium-large size, coke clast
10231			70	20	1	heavily slagged oxidised lining
				70	2	pale surfaced dark glassy dimpled slag fragments - both probably coal-fuelled SHC fragments

Context	Sample	Label		Sample wt (g)	Item wt (g)	Item No.	Notes
10259	slag			1540	218	1	incomplete rounded clinker SHC, coke clasts
					156	1	fragmented rounded clinker SHC
					1166	40	fragments of coal residue-bearing SHCs and associated slag fragments and flowed material
10259			683	952	774	1	90x120x70(40) mm incomplete large SHC, dark dimpled base has included coked material, locally shows tubular vesicles above base, but dense all way though bowl, top of bowl concave with granular top, edges of top are raised and rusty, locally with charcoal-bearing accretion (just possibly charcoal was within the marginal slag)
					30	1	60x25x5mm approximately, iron bar fragment
					62	1	low dense pale dimpled mass, has apparently both charcoal and coked residue embedded in base
					74	1	dense (smithing?) slag in rounded nub, has some fine charcoal inclusions
					12		bits
10259			8133	314	314	1	rounded and rusted mass of slag - forming very irregular shape, contains medium charcoal, heavily lime impregnated in places
10284				36	36	2	slightly sandy reddened clinker sheet fragments
10285				2.5	2.5	1	sandy lining slag spikey bleb
10285		coal		1.3	1.3	1	coal
10333				40	40	1	oxidised fired ceramic with deep black vitrified slag
10364				612	566	1	wedge-shaped block involving burr-like contact with reduced-fired wall. Wall full of coarse quartz and rounded mudstone/ceramic particles. Lower surface and also curving round thin side and onto top are impressions of cereal packing. Some lobes of dark slag are intrusive into the wall. Main body of slag block massive
					48	9	small chips of slag similar to the main block
10428				222	222	1	dense bulbous basal flow lobes, around charcoal, but very base has suggestion of a few cereal stems

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
10510	1		8	8	1	small weathered iron slag fragment
10597			144	144	1	amalgamated curved flow slag, very dense
10619			182	134	1	broken piece of basal sheet - finely lobate base with hint of cereal marking, overlain by slag with fine-medium charcoal, all oddly secondarily reddened and haematised
				48	1	dense amalgamated flow slag with surface cereal imprints
10638		coal	15	15	4	coal
10639			982	982	1	dense block of slag, dimpled base, 35mm dense crust (where broken seen to have fine charcoal clasts), overlain by up to 30mm of charcoal rich slag (charcoal to 25mm), capped in one place by contact with a lump of coarse-grained red sandstone/fine conglomerate. 115x95x80mm overall. probably from a furnace, just possibly part of a very large SHC
10679			36	36	1	small worn fragment of conventional tapped slag, in narrow parallel flows, shiny maroon top, dull lightly concave base
10705			40	40	1	fragment of charcoal-rich slag, medium charcoal
10742	4	coal	41		assm	coal (some burnt)
10742	4		<1	<1	2	slag fragments
10763	slag		1215	28	1	grey, slightly plastic appearing, flow slag
				50	1	fragment of thin rough slag sheet
				1137	1	somewhat fragmented large wedge-shaped block of slag 150x125 up to 48mm thick, planar (basal?) rough contact, all other surfaces fractures, slag full of small-medium charcoal clasts, up to 12mm crude crust (as in 50g piece), top possibly visible near thin edge as a vaguely smooth but irregular surface
10796			10	10	1	tiny chip of vesicular slag with cereal moulds

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
10799			9	9	1	fragment of goethitic vein/joint filling
10808			462	462	1	fragmented angular lump of slag with medium-sized charcoal
10854			2435	642	1	slag block, run through with cereal moulds
				170	4	grey waxy amalgamated flow slags
				1000	1	large massive FB block with just hint of pale flow lobes on one side
				212	2	irregular lumps of pale grey, slightly granular slags
				214	5	other charcoal -bearing slags, some with degrees of being internally prilly
10854			352	10	4	weathered slag scraps
				70	1	indurated and vitrified pale ceramic with swirled application
				176	1	fragment of SHC, weathered to reveal larger olivine growing into ?glass
				26	1	sliver from margin of SHC
				10	1	botryoidal goethite growing on coarse sandstone substrate
				28	2	low density slags full of cereal moulds
				18	1	grey flow slag passing around fuel mould
10884			74	74	1	pale dimpled slag nub - probably part of small coal-fuelled SHC
10885			410	280	1	90x90x45mm, prilly pale SHC, truncated hemispherical shape, pale deeply dimpled base between prills, margins of top show larger hollow lobes, centre of top slightly depressed with lining slag glaze, coke in interstices and some shaley bits towards top
				108	1	fragment of similar SHC
				10		bits
10945			420	420	1	75x100x50mm, irregular mass of charcoal-bearing slag, topped by arcuate crude flow lobes of more purely fayalitic composition. Probably but not certainly an odd SHC
10995			3.8	3.8	1	partially melted extremely sandy lining or even red sandstone clast

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
11067	6	mag material	3.5		assm	slag fragments and large droplets
11092			386	292	1	rather truncated semi-conical shaped dimple-surfaced dense SHC, 65x80x40mm, dense. Probable charcoal inclusions
				86	1	fragment of ?twisted slag with lobed top and dimpled base, internal flow lobed with pale ceramic and charcoal between lobes
11093			36	36	1	highly worn fragment of flow-lobed flow slag; dense, equant fragment
11148			672	672	1	fragmented into 15 plus pieces but probably originally one large rounded vesicular pale mass, with probable coke clasts - so probably a coal -fuelled SHC
11222	15	coal	<1		assm	coal
11233	8	coal	<1		assm	coal
11233	8	ind waste	2.5		assm	slagged clay and iron-rich accretion
11258	9	hammerscale	4		assm	coarse FHS, slag droplets, some slag fragments and some sandstone
11258	9	coal	12		assm	coal
11258	9	ind waste	7	7	assm	mostly coke, but also slag and rare charcoal
11258	9	slag	14.5	11.8	1	rounded lump of clinkery maroon-surfaced slag
				2.7	assm	bits including several droplets
11277	11	hammerscale	39		assm	coarse FHS and droplets
11277	11	0.5mm res	11		assm	minor hammerscale, mostly sand and coal

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
11277	11	1.0mm res	215		assm	scale- and sand-rich coal dust
11277	11	coal	403		assm	coal (some burnt)
11277	11		222		assm	mixed assemblage with smithing floor concretions (some based on nails, other on ?amorphous iron), coke, coal, slag, droplets
11291	10	coal	<1		assm	coal
11292			254	148	1	incomplete dense SHC, flat plate-like top over dense slag with coke, with dimpled lobate base
				8		slagged oxidised lining
				98	7	similar SHC fragments
11301	13	hammerscale	<1		assm	slag debris
11301	13	coal	<1		assm	coal
11305	12	coal	<1		assm	coal
11305	12		<1		assm	fragments of frothy FAS, plus 2 pieces of blue glassy vitrified FAS
11368	64	coal	<1		assm	coal
11384	23	hammerscale	<1		1	single FHS fragment
11399		slag	18.5	18.5	2	dimpled grey slag with coke, one with contact with hearth wall
11401			194	124	1	worn core of dense microprilly SHC
				62	1	small flap-like mass with smooth dark top and prills with coke below, prob c. 80%
				6		bits

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
11426			956	956	1	dense possible plano-convex slag lump, but only a fragment; 90x130x55mm, has distinct basal crust but uniformly dense; body has large rounded vesicles, some charcoal clasts near margin - probably part of a large charcoal-fuelled SHC
11447	25	mag material	<1		assm	rusty concretion, potsherd, slag fragments
11447	25	slag	6.5		assm	low density frothy FAS, in one piece grading from clay with a planar surface
11471	22	coal	30		assm	coal
11471			62	4	1	slagged grey clay
				28	2	dimpled grey smithing slag with coke
				24	1	flow lobe, probably from base of smithing slag
				1		bits
11471	22	slag	28.5		assm	some large smithing floor fragments, mostly clinkery slag blebs and flows, sandy ferruginous concretions and one tiny sherd of crucible
11485			18	18	2	2 pieces of clinkery slag, one with large coal shale flake
11499			68	68	2	scraps of probably charcoal-rich smithing slags, one piece shows highly viscous wall melt interacting with fuel clasts
11517			296	296	1	dense lobate charcoal bearing slag, almost hidden in sandy charcoal-rich accretion
11585	87	coal	<1		assm	coal
11608	103	ind waste	<1		assm	small collection of slag droplets and one piece of coarse FHS
11622	62	hammerscale	7		assm	rich assemblage of small slag droplets, 1 or 2 pieces might just be SHS

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
11622	62		99		assm	coal (trace of slag droplets)
11622	62	clinker	14		assm	mostly coke, with a few slag fragments, slag droplets and at least one piece of smithing floor concretion
11622	62	ind waste	220		assm	mostly coal and coke, but some slag droplets and coarse FHS
11622	62	slag	102		assm	mostly slag as bleb and droplets, but also some sandy concretions, smithing floor accretion, coke, coarse FHS and one piece of possible vitrified crucible sherd
11631	88	coal	<1		assm	coal
11631	88	ind waste	<1		assm	small number of fragments of coked material
11632	89	coal	<1		assm	coal
11632	89	slag	24		assm	fragments of fibrous goethite, together with red siltstone host. Possibly an ore cleaning waste residue
11767			744	392	1	amalgamated flow slags, finely lobed, well developed cereal impressions
				364	2	irregular masses of charcoal -rich slag, one which has traces of cereals on prilly margin
11794			614	588	1	110x75x50mm, poorly compacted charcoal-rich slag attached to vitrified grey wall, no surfaces preserved
				20		bits
11801	98	hammerscale	<1		assm	FHS, droplets, slag fragments
11957			1180	1180	5	charcoal-rich basal crust, possibly hint of cereal in some but not certain, one fragment shows a piece of FHS in one of its vesicles

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
11980			20.45	20.45	2	2 pieces, probably from same original piece, of grey dimpled slag with coke in a small fractured nub
12095		slag	66	66	1	botryoidal stalactitic goethite
12102		slag	1060	1060	1	fragmented large block of charcoal-rich FB, charcoal to 30mm
12127		slag	52	52	1	highly vesicular slag fragment with some cereal moulds
12127	108	hammerscale	<1		1	single spheroid, possibly SHS as metallic lustre, but has accessory lobe
12165	109	coal	<1		assm	coal
12165	109	clinker	<1	<1	1	indeterminate; probably burnt organics
12168	100	ind waste	3020		assm	large amount of ashy clinker. Some forms amalgamated masses of clinker, ash and coal dust. Some pieces show a planar surface on a white sandy material - unclear if this was a sandy substrate or mortar
12176			172	46	1	dense slag with crude flow lobes around charcoal fuel
				66	1	dense flow slag with lightly maroon surface and probable contact of surface with straw. Internally vesicular with 1 large void with rust, possibly indicating loss of iron clast, fracture has probable gypsum
				70	2	crudely flowed slag with irregular lobes and dimpled surfaces, variable. Contain clasts of coke/coal shale
12196		slag	38.6	38.6	1	fragment from the margin of a SHC, probably small, top smooth, black, base finely dimpled with coke inclusions
12229			308	308	1	block of charcoal-rich slag, irregularities on one surface may be tool marks from the base of a large SHC
12247			338	338	1	internally finely prilly/blebby dense slag, prob from large SHC, a few gravel clasts and rather more of coke/coal shale. Top very slightly reddened and smooth, base dimpled, locally with some tubular vesicles. Just a broken fragment and whole hard to judge - maybe this is 60%, just above tubular vesicle layer there is rusting suggesting iron inclusions

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
12353	110	coal	<1		assm	coal
12392	116	clinker'	<1		assm	tiny fragments apparently of coked organic matter
12392	116	coal	<1		assm	coal
12394	117	coal	<1		assm	coal
12427	113	hammerscale	<1		1	single slag droplet
12427	112	coal	<1		assm	coal
12427	113	coal	<1		assm	coal
12429	115	coal	<1		assm	coal (some burnt)
12429		slag	6.7	6.7	1	fired clay debris containing square-sectioned mineralised iron
12479	114	coal	<1		assm	coal
12492			4.2	4.2	1	finely prilly/lobate highly weathered grey slag
12552			22	22	1	highly weathered flow slag fragment, apparently with cereal impressions
12559			722	722	4	flow slag and finely lobate slag grading into more massive sheet. All with abundant cereal/grass impressions
12563	118	coal	209		assm	coal
12563	118	1mm res	842		assm	some stone, plenty of FHS, some slag, rare charcoal, a few molluscs, dominated by coal dust

Context	Sample	Label	Sample wt (g)	Item wt (g)	Item No.	Notes
12563	118	2mm res	512		assm	stone, slag, but dominated by coal with minor coke
12563	118	magnetic residue	960		assm	debris from smithing floor, iron-cored concretions of up to 80mm, some attached to lining fragments, fines rich in flake hammerscale
12563	118	slag	78		assm	mostly fragments of, or complete, rounded slag blebs and droplets
12563	118	0.5mm res	82		assm	sand, flake hammerscale, trace of fired clay, trace of rust, but mostly coal
12701			1000	1000	3	640, 348 and 16g fragments of similar material. Largest has thick lower crust, charcoal rich above, each to approximately 25mm, top and base both rough, middle piece probably also rough top and prilly base, again large charcoal inclusions, both probably, but not certainly fragments from very large SHCs
12743			198	198	1	fragment of slag sheet up to 40mm thick, weathered slightly pale, vesicular, rich in small charcoal clasts
12759			546	546	3	fragments of slag sheet with rough lower surface, lightly curved and flow lobed upper, internally highly vesicular - both surfaces show cereal impressions
12792			34	34	1	broken small disc-like fragment of dense slag with fine charcoal, probably part of a small SHC
12904			848	264	1	irregular block of rusty slag with internal and external cereal impressions
				582	2	amorphous blocks of charcoal-rich slag, large piece may have small area with cereal internally too
12922			406	406	1	rather internally massive tapslag-like block, slightly siliceous looking slag, top in grey flow lobes, base also shows lobes, locally reddened (flown over ore fines??) and has fired clay trapped in interstices, internally some vesicles (probably flow tubes), but margins of flow lobes don't show.
121036			244	244	1	equant cuboidal block of haematite ore, paler fine material is separated by veins/cracks filled with dark botryoidal haematite
121047			7.3	7.3	1	oxidised lining with attached highly vesicular dark slag

Table 2: summary of residue types by context. SHC = smithing hearth cake, FHS = flake hammerscale, FAS = fuel ash slag.

Context	iron	cereal	desne flow slag	charcoal SHC	indet charcoal slag	coal SHC	indet	lining	lining slag	ore	FHS	droplets	coal	coke	charoal	clinker	FAS	Smithing floor	crucible	total
106					70															*70*
205		41																		*41*
306													1.5							*1.5*
904		156			1780															*1936*
916						100														*100*
10014		382																		*382*
10025															5					*5*
10031						22														*22*
10091						90														*90*
10122						52														*52*
10231						70		70												*140*
10259	30			74	314	2158														*2576*
10284																36				*36*
10285									2.5				1.3							*3.8*
10333								40												*40*
10364		614																		*614*
10428		222																		*222*
10510							8													*8*
10597			144																	*144*
10619		182																		*182*
10638													15							*15*
10639					982															*982*
10679			36																	*36*
10705					40															*40*
10742							<1						41							*41*
10763			28		1137		50													*1215*
10796		10																		*10*
10799										9										*9*
10808					462															*462*
10854		670	188	202	1214		222	70		10										*2576*
10884						74														*74*
10885						388														*388*
10945				420																*420*
10995								3.8												*3.8*
11067												y								*0*
11092				378																*378*

Context	iron	cereal	desne flow slag	charcoal SHC	indet charcoal slag	coal SHC	indet	lining	lining slag	ore	FHS	droplets	coal	coke	charoal	clinker	FAS	Smithing floor	crucible	total
11093							36													*36*
11148						672														*672*
11222													<1							*0*
11233								2.5					<1							*2.5*
11258							y				y	y	12	7	y	11.8				*30.8*
11277											y	y	y	y			y			*0*
11291													<1							*0*
11292						246		8												*254*
11301									<1				<1							*0*
11305													<1				<1			*0*
11368													<1							*0*
11384											y									*0*
11399						18.5														*18.5*
11401						62	124													*186*
11426					956															*956*
11447							y										6.5			*6.5*
11471						28	24	4				y	30					y	y	*86*
11485						18														*18*
11499				68																*68*
11517					296															*296*
11585													y							*0*
11608											y	y								*0*
11622											y	7	99	y				y	y	*106*
11631													<1	y						*0*
11632										24			y							*24*
11767		756																		*756*
11794					588															*588*
11801							y				y	y								*0*
11957		1180																		*1180*
11980						20.5														*20.5*
12095										66										*66*
12102					1060															*1060*
12127		52										y								*52*
12165													<1							*0*
12168																3020				*3020*
12176			46			70	66													*182*
12196						38.6														*38.6*
12229				308																*308*

Context	iron	cereal	desne flow slag	charcoal SHC	indet charcoal slag	coal SHC	indet	lining	lining slag	ore	FHS	droplets	coal	coke	charoal	clinker	FAS	Smithing floor	crucible	total
12247						338														*338*
12353													<1							*0*
12392													<1	<1						*0*
12394													<1							*0*
12427												<1	<1							*0*
12429	6.7												<1	y						*6.7*
12479													<1							*0*
12492							4.2													*4.2*
12552		22																		*22*
12559		722																		*722*
12563							y				y		209		y			960		*1169*
12701				1000																*1000*
12743					198															*198*
12759		546																		*546*
12792				34																*34*
12904		846																		*846*
12922			406																	*406*
121036										244										*244*
121047								7.3												*7.3*
total	*36.7*	*6401*	*848*	*2484*	*9097*	*4465.6*	*534.2*	*205.6*	*2.5*	*353*	*0*	*7*	*408.8*	*7*	*5*	*3068*	*6.5*	*960*	*0*	*28889.7*

Table 3: as Table 2 but sorted into context groups. SHC = smithing hearth cake, FHS = flake hammerscale, FAS = fuel ash slag.

Context	iron	cereal	desne flow slag	charcoal SHC	indet charcoal slag	coal SHC	indet	lining	lining slag	ore	FHS	droplets	coal	coke	charoal	clinker	FAS	smithing floor	crucible	total
	Group 1a: iron ore																			
10799										9										*9*
11632										24			y							*24*
12095										66										*66*
121036										244										*244*
	Group 1b: cereal-packed slagpit																			
205		41																		*41*
904		156			1780															*1936*
10014		382																		*382*
10364		614																		*614*
10428		222																		*222*
10619		182																		*182*
10796		10																		*10*
10854		670	188	202	1214		222	70		10										*2576*
11767		756																		*756*
11957		1180																		*1180*
12127		52										y								*52*
12552		22																		*22*
12559		722																		*722*
12759		546																		*546*
12904		846																		*846*
	Group 1c: flow slags																			
10597			144																	*144*
10763			28		1137		50													*1215*
12176			46			70	66													*182*
12922			406																	*406*
	Group 1d: charcoal-fuelled SHC																			
10945				420																*420*
11092				378																*378*
11499				68																*68*
12229				308																*308*
12701				1000																*1000*
12792				34																*34*
	Group 1e: miscellaneous charcoal-fuelled																			
106					70															*70*
10639					982															*982*

Context	iron	cereal	desne flow slag	charc SHC	indet charc	coal SHC	indet	lining	lining slag	ore	FHS	droplets	coal	coke	charoal	clinker	FAS	smithing floor	crucible	total
10705					40															*40*
10808					462															*462*
11426					956															*956*
11517					296															*296*
11794					588															*588*
12102					1060															*1060*
12743					198															*198*
	Group 1f: tapped slags																			
10679			36																	*36*
	Group 2: coal-fuelled SHC																			
916						100														*100*
10031						22														*22*
10091						90														*90*
10122						52														*52*
10231						70		70												*140*
10259	30			74	314	2158														*2576*
10884						74														*74*
10885						388														*388*
11148						672														*672*
11292						246		8												*254*
11399						18.5														*18.5*
11401						62	124													*186*
11471						28	24	4				y	30					y	y	*86*
11485						18														*18*
11980						20.5														*20.5*
12196						38.6														*38.6*
12247						338														*338*
	Group 3a: microresidue-rich																			
11258							y				y	y	12	7	y	11.8				*30.8*
11277											y	y	y	y			y			
11384											y									
11608											y	y								
11622											y	7	99	y				y	y	*106*
11801							y				y	y								
12563							y				y		209		y			960		*1169*
	Group 4: minor assemblages																			
10285									2.5				1.3							*3.8*
10333								40												*40*

Context	iron	cereal	desne flow slag	charc SHC	indet charc	coal SHC	indet	lining	lining slag	ore	FHS	droplets	coal	coke	charoal	clinker	FAS	floor	cruc	total
10510							8													*8*
10742							<1						41							*41*
10995								3.8												*3.8*
11067												y								
11093							36													*36*
11233								2.5					<1							*2.5*
11301									<1				<1							
11447							y										6.5			*6.5*
12427												<1	<1							
12492							4.2													*4.2*
121047								7.3												*7.3*
	Group 5: Coal and coal-residue only																			
306													1.5							*1.5*
10025															5					*5*
10284																36				*36*
10638													15							*15*
11222													<1							
11291													<1							
11305													<1				<1			
11368													<1							
11585													y							
11631													<1	y						
12165													<1							
12168																3020				*3020*
12353													<1							
12392													<1	<1						
12394													<1							
12429	6.7												<1	y						*6.7*
12479													<1							
total	*36.7*	*6401*	*848*	*2484*	*9097*	*4465.6*	*534.2*	*205.6*	*2.5*	*353*	*0*	*7*	*408.8*	*7*	*5*	*3068*	*6.5*	*960*	*0*	*28889.7*

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