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# Assessment of archaeometallurgical residues from Stratford Road, Mickleton (9010)

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**Dr T.P. Young**

## Abstract

*This collection included three separate groups of pyrotechnological residues, one (represented by approximately 9.5kg of material) derived from ironworking (blacksmithing) and a second (represented by 1.5kg of material) being residues from a non-metallurgical process, perhaps a cereal-drying kiln. In addition, a third group of samples included fragments of coal, coke or clinker, again not necessarily of metallurgical origin. The three groups of materials occurred in distinct, separate, contexts and, to a large extent, also have distinct geographical distributions within the site.*

*The iron working residues comprise a small assemblage of dense plano-convex smithing hearth cakes (SHCs), ranging in weight up to just over 1kg and with an average weight of approximately 340g. The cakes show evidence of strong reaction between the slag and the hearth floor/walls that were rich in quartz sand. Although there are some parallels for this type of SHC, the assemblage differs markedly from most others in the region; the potential reasons for this are discussed. The smithing slags are widely distributed to the west-centre of the site in Period 2 and north-centre in Period 3. There is no large concentration of residues indicative of the location of a smithy.*

*The fuel ash slags (FAS) overlap in distribution with the smithing slags, but the majority (and all the larger fragments) are confined to the SW corner of the site. The FAS includes material that is fine grained, but much is extremely sandy, with a relatively low proportion of partial melt. This is likely to reflect the dominantly sandy nature of the substrate. Although the FAs resembles the so-called 'Iron Age grey' slag, which is probably associated with long-lived external hearths, the Roman age of the present material may suggest that it was more likely to have been formed in a cereal-drying kiln. The amount of FAS recovered was very low and, as with the ironworking residues, there was not certain origin.*

*A few samples yielded coal, coke or clinker. All of these were in extremely small quantities, so it was unclear if they represent Roman use of coal, or whether the small particles were intrusive.*

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# Methods

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

The examined materials are listed in Table 1.

This project was commissioned by Katie Marsden, of Cotswold Archaelogy.

# Results

### *Description of residues*

The submitted materials amounted to an overall total of approximately 11.3kg. The majority of the assemblage comprises residues from ironworking (9.5kg). A smaller proportion (1.5kg) comprises fuel ash slags, probably of non-metallurgical origin. The remainder includes some natural materials, fragments of iron, concretions and tiny quantities of coal/coal residues.

The stratigraphic distribution of the various classes of residue described below is presented in Table 2.

#### *Ironworking residues*

The dominant components of the ironworking residues are **smithing hearth cakes** (SHCs). These slag masses form within the smithing hearth just below the level of the air blast, from the reaction between iron and iron oxides lost from workpiece (iron oxidises rapidly at high temperatures, particularly at the temperatures close to its melting point required for forge welding; Young 2011c) and partially melted hearth wall that flows into the hearth from the area close to the blowhole, together with lesser contributions from fuel ash and welding flux.

The SHCs from Mickleton are plano-convex in shape, with a flat top, typically covered with dark glassy material and often with raised margins of sandy lining slag. The intact examples (16 examples with a total weight of 6.1kg) show a weight range from 149g to 1065g. The average weight was 381g (Table 3). The SHCs show an unusual homogeneity of form across this size range. The bases of the SHCs typically show a degree of interaction with sand over much of their area. The internal structure usually shows only a very low vesicularity (hence the apparent high density of these examples), with the microstructure dominated by elongate bladed olivine in the lower part (up to 20mm long in some instances), with a rather marked transition to a thin (3-4mm centrally, often thicker marginally and proximally) upper layer, with a more glassy appearance, although commonly also characterised by moderately large olivine crystals.

The SHCs contained very few particles of fuel, but where present these were entirely of charcoal; there was no evidence for the metallurgical use of coal.

A further 400g of material derives from a variety of SHC to which the term '**tongue**' has been applied (Young 2012c). These masses show a lower degree of reaction, with a thick upper layer of lining-derived slag, and pendent prills of iron-rich slag below (which do not form a continuous bowl). A gravelly example weighing 256g from pit [12670] was almost complete, and is included within the SHCs for calculation of the weight-frequency statistics.

**Hearth lining** is represented by approximately 480g of fragments. There are no examples which show the blowhole. Several prices show a right-angled base to the hearth ceramic, with slag extending below the overhang, with prills of flow-lobed slag with maroon surfaces apparently having flowed beneath the overhang in at least two pieces.

**Lining slag**, comprising prills and blebs of partially melted hearth wall that did not become incorporated within an SHC, provided a further 480g of residues. Lining slags are formed under the fluxing influence of both the fuel ash and of iron.

Some 459g of ironworking slags were classified as '**indeterminate**'. These were mainly slag fragments that were too finely fragmented to allow positive identification to one of the other classes.

#### *Fuel ash slags*

The **fuel ash slags** (FAS) are closely related to the lining slags described above. They result from partial melting of hearth materials under the fluxing influence of the fuel ash (for wood ash, this is dominantly the oxides of calcium and potassium). Because they are typically rich in alumina and silica they have a high viscosity, resulting in the trapping of gas as large vesicles (the gas deriving from the decomposition and dehydration of the parent material). The melting is always only partial, resulting in a texture with abundant relict grains (mainly of quartz), bound by a dominantly glassy slag phase.

The Mickleton FAS includes material with a range of composition, from typical FAS with a very porous (frothy) texture, with thin glass films through to denser varieties, rich in medium to coarse sand, a smaller number of large vesicles.

#### *Coal/coal residues*

A tiny quantity of coal, together with its residues of coke (the partially-burnt organic component) and clinker (an inorganic slag formed from the partially melted inorganic component), was recovered. Such materials need not have been of metallurgical origin. Indeed, given the very small particle size involved, it is impossible to exclude the possibility that some of this material might be intrusive.

#### *Other materials.*

A few fragments of iron and concretions were present, as was a single example of an entirely natural ion-rich rock.

### *Distribution of residues*

The stratigraphic distribution of the residues is illustrated in Table 2. The geographic origin of the various materials is illustrated in Figure 1.

The ironworking residues (Figure 1 upper) show two main concentrations – towards the SW of the centre of the site, in contexts provisionally assigned to Period 2,

and towards the north-centre of the site, in contexts provisionally assigned to Period 3. The FAS is concentrated towards the SW of the site, in contexts provisionally assigned to Period 2 (although the plan suggests that in several areas where both groups of residue occurs in Period 2, the FAS may occur in ditches which cut those yielding the ironworking residues). Very little of either class of material occurred in the south-eastern section of the site. There was very little coal, but the occurrences are evenly divided into contexts NW and SE of the trackway; its few phased occurrences are of Periods 3 and 4.

The materials do not occur in association with any likely sources of production. It is therefore entirely possible that the patterns of distribution may represent patterns of disposal, rather than production.

## Interpretation

*Ironworking*

The unusually dense and 'puddle-like' SHCs differ from the morphology and weight of SHCs recorded more typically on Roman rural sites (Table 3). There are three potential reasons for variation in these properties:

1. The unusual properties might reflect a fundamentally different process. Larger SHC weights typically represent SHCs from bloomsmithing (the working of raw iron bloom into usable iron), but those produced during Roman bloomsmithing typically weigh well over 1kg. The location of this site is an unlikely place (although not impossible) for processes associated with iron production. Other potential processes include remelting of iron for the purposes of dephosphorisation or of carburisation. In these cases, the slag cakes are poorly known, but resemble 'normal' SHCs, except that their upper surfaces may have been in contact with the iron being produced (and therefore not able to accumulate blebs and prills of melted lining). It is unlikely that a substantially

2. The influence of a quartz-rich sandy substrate to the hearth may have permitted good fluxing of the iron and iron oxides lost from the workpiece. A high degree of fluxing will lead to a more fayalitic (rather than wustitic) composition. Melts with a composition close to fayalite will have a lower viscosity and will therefore de-gas more easily. The low degree of vesicularity of the present examples is marked in comparison to that of typical wustite-rich SHCs. Iron (and/or iron oxide) particles often sink towards the base of the SHC as it forms, reacting with the slag if maintained at high temperature. In the current case, apparently with a quartz-rich sand substrate to the hearth, reaction with the iron would have proceeded readily, if maintained at high temperature. The fluid slag, and its reaction with the substrate, would have generated the indurated reaction zone along the base of the SHC, the coarse-grained fayalitic microstructure, and the flat-topped slag 'puddle'.

3. The nature of the blacksmithing undertaken at the sites may have been different. The weight of the SHCs reflects the amount of iron lost from the workpiece into the hearth. The amount of iron lost from the workpiece will depend on both the rate of iron loss (more iron will be lost during high-temperature processes, such as those involving forge welding) and on the duration of the work-period. The higher weight SHCs will derive from either work with a higher rate of iron loss, or a longer work period, or both. Heavier SHCs may be indicative of smithies kept constantly busy, rather than receiving intermittent, piecemeal, work.

Thus, although the SHC assemblage is very small, but the above discussion suggests that it was produced during either more concentrated work periods and/or during work with a higher proportion of high temperature tasks, than is typical on Roman rural sites. The weight distribution of the SHCs is thus different from most rural assemblages (e.g. Exminster, Young 2014g; Clevelands, Young 2016a; Uffington, Young 2015a; Ebrington, Young 2016; Table 3), but moderately close comparison could be made with the assemblage from Marsh Leys Farm (Young 2005a, 2011b), aa site in Bedfordshire in which ironworking was undertaken at one of a group of adjacent farmsteads. One potential interpretation of the data would be that the smithy was working on a more continuous basis than those involved in the creation of the lighter residue assemblages mentioned above. This might be because the smithy served a larger community (some of the examples above may represent estate smithies), or because the smithy was involved in some sort of 'industrial' production. The somewhat similar assemblage from Marsh Leys Farm was associated with a landscape in which some farmsteads were associated with ironworking and others with pottery manufacture, hinting that the ironworking was associated with specialised production, rather than simply *ad hoc* production, repair and maintenance (Luke & Preece 2011).

Although the SHCs are believed to present a more intense style of ironworking, their apparent density was also enhanced by the geological context and the propensity of the hearths to generate particularly fluid slags. The reaction of sand on the hearth floor with the growing slag cakes is strongly suggestive of the use of floor-level (i.e. cut) hearths, rather than waist-level (i.e. constructed) hearths. The observed overhang on the lower margins of preserved fragments of hearth ceramic, suggests that the ceramic hearth wall may have been constructed directly on the margins of the cut hearth. The evidence is insufficient to allow determination of whether a continuous wall was involved, or whether block tuyères were employed (a tuyère being a pre-fashioned ceramic element to carry the air blast into the fire, as opposed to a simple hole through a clay wall). An abrupt lower limit for the hearth ceramic was also observed at Uffington (Young 2015a), suggesting the use of a similar style of hearth.

The site ironworking assemblage was divided into two components – pieces from the central//western part of site, from contexts provisionally assigned to Period 2 (dominantly curvilinear ditches), and pieces from the central part of the site from contexts of Period 3 (a ditch extending perpendicular to the trackway and an associated pit). The residues from both areas are very similar and clearly relate to a single style of ironworking. There is no indication of an actual smithy, so the distribution of the residues probably represents a pattern of disposal.

The use of charcoal as fuel also separates this site from other contemporary examples. This presumably reflects the availability of either local woodland or purchased charcoal. The controls on the adoption of coal as fuel for smelting in the Roman period are poorly understood, and coal was certainly employed on sites equally far from the coalfields as is Mickleton (e.g. Uffington, Wiltshire Young 2015a; Ebrington, Gloucestershire, Young 2016b).

*Fuel ash slags*

The FAS slags from Mickleton are rather variable, but typically slightly denser and more sand-rich than comparable material from elsewhere. This is likely to reflect the substrate rather than a different mode of origin.

Fuel ash slags have been somewhat controversial in the past, in particular within the context of discussion of the 'Iron Age grey' slags that occur particularly in Middle Iron Age contexts in central and eastern England (Cowgill 2000, 2008; Cowgill *et al.* 2001; Swiss & McDonnell 2001; Young 2009, 2011; Young & Bowstead Stallybrass 2003).

Fuel ash slags are the product of the partial melting of silica- and alumina-rich hearth materials under the fluxing influence of alkali and alkali earth elements present in fuel ash. Wood ash is rich in both calcium and potassium for instance. FAS may be described as a 'buchite' – and they typically comprise a glassy melt, binding together relict quartz (and sometimes other mineral) grains. Thus, the key requirements for their generation are the intimate mixing of hearth substrate (or other silicate source), with the fuel ash at moderately high temperatures, with a lack of contamination by other materials (e.g. iron or copper).

More recent investigation of FAS has demonstrated that it may form in this way particularly within cereal drying kilns, and within open, long-lived, hearths. Examples of FAS have been described by Young from cereal kilns (2005b, 2010a, 2010b, 2015b, 2016c) and from large open hearths (Young 2005b, 2012a). Other potential sources of FAS include conflagration of wattle and daub structures and perhaps during lime-burning (Young 2012b).

The present material includes large blocks, as are more commonly found in FAS from large hearths (Young 2005b, 2012a, 2009), although such materials have also been recorded from cereal kilns (Young 2015b, 2016c). An origin in large external hearths is most likely for the 'Iron Age grey' slags (e.g. Young 2011a), but these seem to be typically a Middle Iron Age phenomenon – and may by indicative of contemporary taboos about cooking.

The present material appears firmly datable as mid-Roman, so an origin in large external hearths is probably unlikely, whereas an interpretation as residue from cereal kilns appears plausible. The residues themselves do not provide any diagnostic criteria to determine their precise mode of origin.

## Summary

The residues provide evidence suggestive of two separate pyrotechnological activities: cereal drying and ironworking. Neither group of residues is entirely typical of its class. In both cases a sandy subsoil is a significant factor in the observed compositional differences with other material.

In the case of the ironworking, despite the very small size of the collection which tempers the strength of any conclusion, the assemblage suggests an intensity of working that is unusual on rural sites. This may be indicative of the Mickleton smithy having been a specialised centre of production rather than a simple estate smithy for repair and minor works.

## Further work

The further scientific analysis of these residues would be capable of generating further useful detail and characterisation.

For the FAS, detailed mass balance might be capable of identifying the fluxing elements, and hence clarify the fuel (e.g. discriminate between wood, straw and cereal grains, which have different chemical compositions) and aid the interpretation of the slags.

For the ironworking slags, detailed mass balance modelling of the origin of these slightly unusual compositions would be of use in clarifying the process involved.

However, in neither case have the residues been related to their originating structures or features. This reduces the potential for detailed interpretation.

Should the potential source of either the ironworking waste or the FAS be determined during the post-ex process, then it is recommended that further scientific analysis of the residues is pursued. If the originating hearths/kilns are not located, then the limited benefit to understanding of the site archaeology probably means that the benefits of improved characterisation rom further analysis would not justify the additional expense.

Nonetheless, the materials are of importance and should be deposited with the site archive in the appropriate receiving institution.

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*Table 1: summary catalogue.*

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 11011 | | <1 | <1 | 1 | coke |
| 11047 | | 487 | 485 | 1 | SHC, 100x105x36mm, dense, plano-convex, dark glassy top with a few adhering sandy glass blebs, base has very sandy contact, interior not seen, very neatly symmetrical and flatly conical |
| 11047 | | <1 | <1 | 1 | ball of dark sandy lining slag |
| 11054 | | 21 | 21 | 1 | convoluted blebby mass of dark glassy sandy slag - either FAS or lining slag |
| 11054 | | <1 | <1 | 1 | coal |
| 11061 | | 11 | 11 | 1 | sandy pale glassy slag sheet, probably FAS rather than lining slag |
| 11094 | | 445 | 445 | 1 | SHC, 100x85x45mm, distinctly two-layer example, lower with large gravel (sandstone) clasts in places, upper darker, with small area of glassy top; top slightly dimpled, base shows deep fuel moulds and gravel |
| 11108 | | 19 | 19 | 1 | lobed dense slag with strongly maroon surface- probably from blowhole area of SHC top |
| 11110 | | 30 | 11 | 1 | lining slag sheet |
| | | | 19 | 1 | thin slag sheet, probably thin SHC fragment |
| 11118 | | 11 | 5 | 1 | prilly piece of lining slag |
| | | | 6 | 1 | concretion on elongate fragment of iron |
| 11122 | | 11 | 11 | 1 | ferruginous sandstone |
| 11144 | | 47 | 47 | 1 | exploding iron artefact |
| 11144 | | 5 | 4 | 1 | vitrified oxidised-fired, somewhat sandy, lining |
| 11203 | | <1 | <1 | 1 | pale FAS |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 11206 | | 6 | 6 | 1 | fragment of thin burr-like sheet, dark top with sandy lining slag, normal iron slag internally, incorporated sand on base |
| 11249 | | 69 | 69 | 1 | slagged vitrified oxidised lining; lining is fractured and has edges suggestive of deformation of the clay against a margin or edge of a repair perhaps, just possibly planar lower margin to the ceramic |
| 11286 | | 145 | 129 | 10 | fragments of small dense SHCs with tubular vesicles and altered burr-like base. Two largest piece join, fresh breaks on some of the smaller bits |
| | | | 14 | 3 | thin sheets of dark slag - probably lining attachment from SHC attachment areas |
| 11299 | | 24 | 24 | 1 | very thin sheet of burr-like slag |
| 11301 | | 33 | 13 | 1 | bleb of sandy lining slag |
| | | | 15 | 1 | small fragment of tongue-like material |
| | | | 4 | 1 | vitrified oxidised-fired lining |
| 11303 | | 1354 | 326 | 1 | 80x105x25mm, almost plano-convex SHC, very dense and thin, top smooth, puddle-like with raised blebs of sandy lining slag, base obscured by adhering sand |
| | | | 453 | 1 | 95x95x35mm, dense SHC with some coarse vesicularity in lower part, top just slightly dished, smooth puddle-like, some patches of sandy lining slag, base slightly worn to reveal vesicles |
| | | | 335 | 1 | 80x95x35mm, plano-convex SHC with raised lump of lining slag on one side, top planar, base with fuel dimples and charcoal, a few edges missing |
| | | | 69 | 1 | SHC fragments |
| | | | 165 | 1 | 35mm thick, 90mm wide dense burr with glazed planar top, internally stratified with coarse dark olivine at mid-height, base probably dimpled below adhering sand |
| | | | 6 | | fragments |
| 11305 | | 144 | 89 | 1 | fragment of extremely coarse-grained dense SHC, bladed olivine to 20mm, below well-marked lining-influenced dark upper layer, blebs of sandy lining slag rest on top, hint of maroon lobe extending from upper part perhaps below blowhole, base has burr-like interaction |
| | | | 16 | 1 | very dense, fine maroon-surfaced lobe |
| | | | 24 | 1 | marginal lining-rich fragment, probably same SHC as two items above |
| | | | 9 | 3 | small lining slag fragments, possibly related to above pieces |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 11312 | | 149 | 149 | 1 | small dense SHC, plano-convex with raised lip of gravelly slag, 70x50x35mm, base dimpled with poor charcoal impressions, body of slag very dense and coarse, top paler and vesicular |
| 11317 | | 427 | 427 | 1 | 90x105x35mm, very dense thin SHC, top only slightly dished and has a few adhering lining slag blebs, base with very small fuel dimples. All surface partially with sandy accretion obscuring further details |
| 11324 | | 38 | 38 | 1 | fragment of tongue-like material - coarsely sandy dark lining slag over a series of dense pendent lobes |
| 11396 | | 75 | 45 | 2 | bloated ceramic, grey |
| | | | 26 | 2 | bloated fired ceramic, red-brown colour |
| 11410 | | 2 | 2 | 1 | vitrified oxidised-fired lining |
| 11412 | | 5 | 5 | 1 | slightly lobate very sandy FAS/lining slag, one raised lobe is slightly maroon |
| 11414 | | 7 | 7 | 2 | dark sandy FAS |
| 11428 | 1 | <1 | <1 | assm | 5 stone, 2 grey fired clay, 1 iron slag |
| 11435 | | 3 | 3 | 1 | nub of bloated sandy ceramic |
| 11443 | | 93 | 93 | 19 | some certain SHC fragments plus fine debris probably from SHCs |
| 11445 | | 144 | 144 | 2 | fragments of weathered dense SHC, rusty, dense, sandy bases and slightly prilly internal structure |
| 11500 | | 18 | 7 | 2 | vitrified oxidised-fired lining |
| | | | 1 | 1 | slightly bloated and vitrified grey clay |
| | | | 1 | 1 | sandy concretion? |
| | | | 7 | 2 | blebs of iron slag |
| 11566 | | <1 | <1 | assm | bloated pale FAS |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 11614 | | <1 | <1 | 4 | slag debris |
| 11647 | | 388 | 324 | 1 | 80x100x35mm, plano-convex SHC, 'D'-shaped in plan, with raised lip of sandy lining slag along curved side, base is steep on that side, more gently towards straight side, base shows burr like attachment to sand below, top planar and dark |
| | | | 58 | 4 | fragmented block from below blowhole, base of ceramic is planar with horizontal sheet of flow lobes extending 20mm behind line of wall face below, ceramic is inclined formed slightly, has neat dished vitrified surface to front (i.e. below blowhole and in angle of top of attached SHC. |
| | | | 4 | 1 | piece of dark micaceous ceramic or similar, does not appear to lava, but micaceous ceramic is different from all the other pieces here, dark colour hints at possible mould? |
| 11693 | | 455 | 455 | fragmented | 140x100x60mm block of pale grey coarsely vesicular FAS - similar to 'iron age grey', vesicles to 20mm; crudely wedge shaped, with stone? impression on thick side and dark flowed lobes on thin. Very sandy, pale |
| 11776 | | 45 | 45 | 2 | dark sandy flowed bloated ceramic, probably a dark variety of FAS rather than lining, convoluted shape, carries small clasts of highly bloated slate grey glassy material |
| 11843 | | 4 | 4 | 3 | fragments of lining slag |
| 11843 | | 4 | 4 | 1 | sandy FAS |
| 11872 | | 15 | 15 | 1 | grey sandy vesicular FAS |
| 11909 | | <1 | <1 | 1 | bleb of dark sandy lining slag |
| 12094 | | 41 | 41 | 2 | SHC fragments |
| 12190 | | 343 | 343 | 1 | block of coarsely vesicular dense sandy FAS with dark, locally maroon, surfaces and pale interior |
| 12284 | | 84 | 84 | 1 | block of bloated and slightly deformed grey ceramic |
| 12323 | | 172 | 169 | 2 | fragments from small SHCs, very dense, black glassy top with blebs of sandy lining slag, larger piece shows internal layering, both possibly from same cake but no join |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 12392 | | 3 | 3 | 1 | vesicular FAS, fine, moderately dark in areas |
| 12402 | | 16 | 16 | 1 | gravelly lining slag, fractured piece. |
| 12422 | | 7 | 7 | 1 | vitrified oxidised-fired ceramic, very fine grained ceramic, but vitrified layer is black and sandy |
| 12504 | | 149 | 149 | 1 | neat two layer SHC - lower layer is of dense slag with dimpled surfaces above and below, upper layer is gravelly lining slag in smaller pad, 65x80mm lower, 55x40mm upper, whole 65x80x35mm, base shows some quite large lobes, attachment area shows very fine pale grey clay |
| 12649 | | <1 | <1 | 1 | pale highly bloated FAS |
| 12671 | 3 | 1049 | 489 | 1 | 90x110x50mm, concavo-convex SHC, rather 'rusty', with accretion obscuring detail; base irregular with accretion possibly hiding central groove |
| | | | 185 | 2 | denser SHC fragments |
| | | | 150 | 5 | slag nubs of irregular form, moderately low density, and no obvious derivation from SHCs |
| | | | 9 | 1 | gravelly slag fragment |
| | | | 58 | 2 | pieces of thick vitrified lining |
| | | | 103 | 7 | flowed lining slags |
| | | | 55 | | fragments |
| 12671 | | 106 | 97 | 1 | fragment from irregular complex slightly prilly SHC, rather like deep example from (12672) |
| | | | 6 | 1 | vitrified surface of lining slag |
| 12671 | | 301 | 256 | 1 | large complex mass like a tongue, but very irregular; 90x100x40mm, gravelly |
| | | | 37 | 5 | other fragments of lining-related slag |
| 12672 | 4 | 197 | 71 | 35 | mostly blebby fragments of low density slag |
| | | | 32 | 9 | fragments of slightly denser slag |
| | | | 6 | 1 | vitrified oxidised lining |
| | | | 8 | 2 | reddened flow lobes of denser slag |
| | | | 4 | 1 | fragment of iron |
| | | | 72 | 1 | fragment of what appears to be a low-density small SHC |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 12672 | | 226 | 73 | 2 | broken elongate curved vitrified lining sheet, probably deformed when removed hot |
| | | | 114 | 1 | thick oxidised lining with slag, vitrified on two surfaces at right angles, one now internal; interpretation not clear, possibly vitrified on repaired fracture? |
| | | | 19 | 1 | oxidised-fired vitrified lining |
| | | | 11 | | fragments |
| 12672 | | 601 | 171 | 1 | SHC, 60x80x40mm, irregular biconvex SHC with well-flowed lobes and very coarse olivine around glassy areas on top; spikey margins, base obscured |
| | | | 384 | 1 | 80x105x60, deep SHC with two layers, internally very vesicular, externally shows charcoal clasts on top and on base; small areas of glass on top, with some sandy lining slag; base shows fuel moulds and tendency to become coarsely prilly towards margins |
| | | | 39 | 8 | fragments |
| 12672 | | 1065 | 1065 | 1 | 160x110x70(50)mm, planar-topped elongate SHC, with attached forward inclined vitrified oxidised-fired lining, shows maroon lobe penetrating wall blow blowhole, some lining slag on upper surface, top slightly dimpled probably but rusted; base has extended slag spike, possibly an early-formed displaced crust fragment, |
| 12685 | | 7 | 7 | 3 | variably sandy FAS |
| 12697 | | 9 | 9 | 2 | dark FAS |
| 12715 | | 15 | 15 | 3 | coarsely vesicular FAS, broad indentation on glassy surface of largest piece |
| 13038 | | 121 | 44 | 1 | bloated grey ceramic |
| | | | 74 | 1 | irregular sheet of pale grey FAS, base shows cream-coloured sandy material with red and grey rounded ceramic clasts; upper part is foliated vesicular FAS with one side of 20mm deep depression in surface |
| 13247 | | 12 | 2 | 1 | vitrified oxidised-fired lining |
| | | | 10 | 1 | SHC fragment |
| 13263 | | 10 | 3 | 3 | fine iron slag |
| | | | 6 | 4 | gravelly lining slag |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 13366 | | 431 | 185 | 5 | irregular lumps of coarsely granular lining slag- i.e. small amounts of melt binding gravel of up to 30mm |
| | | | 70 | 1 | fragment of tongue - gravelly lining slag on top, fuel dimpled prilly dense slag below |
| | | | 119 | 1 | dense dimpled crescent of slag - possibly a tool mark detached from an SHC base |
| | | | 42 | 7 | fragmented block of vitrified oxidised-fired lining with thick slag layer |
| 13391 | | 13 | 13 | 1 | highly slagged, oxidised-fired lining |
| 13475 | | 56 | 56 | 4 | fragments of finely vesicular pale slag in ferruginous concretionary material |
| 13527 | | 20 | 20 | 1 | pad of dark lining slag, smooth dark top, prilly and indented below -possibly tongue |
| 13649 | | 65 | 63 | 1 | broken block of very sandy lining/FAS slag, flowed into crude right-angled form |
| 14152 | | 6 | 6 | 1 | convoluted prilly piece of sandy lining slag or FAS - but moderately dense |
| 14304 | | 10 | 3 | 1 | rim sherd from dark pottery with beaded rim and with smoothed external surface, void rich on external surface, internally pelletal with some coarse sand |
| | | | 6 | 1 | dark fragmental/layered material with orange core - possibly wood rather than charcoal |
| 14457 | | 487 | 480 | 1 | fragmented SHC, 120x105x40mm, dense, shallow; base shows interaction with hearth floor like burr, only distal 30mm free of floor - so formed on very inclined wall or floor, possibly in an inclined orientation |
| 14562 | | 69 | 65 | 1 | small prilly mass from below SHC attachment area, with some attached ceramic |
| | | | 4 | 2 | probably fragments from above |
| 14670 | | 101 | 101 | 1 | small block of mottled bog iron ore/iron pan |
| 15074 | | 59 | 59 | 9 | SHC debris - possibly all from a single fragment |
| 15124 | | <1 | <1 | 1 | burnt coal shale |
| 15169 | | 59 | <1 | 1 | bloated pale FAS |
| | | | 53 | 3 | vesicular slag fragments in rusty ferruginous concretions |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 15224 | | <1 | <1 | 1 | coke |
| 15466 | | 5 | 4 | 1 | small fragment of clinkery-looking dark coloured slag with irregular surface, maroon on one face, probably the upper surface of an SHC from near the blowhole |
| 15502 | | <1 | <1 | 2 | roundwood (twig) charcoal |
| 15617 | | 4 | 2 | assm | coal fragments |
| 15710 | | 6 | 6 | 1 | very sandy coarsely vesicular FAS |
| 15815 | | 2 | 2 | 5 | FAS variably white to dark grey |
| 15822 | | 18 | 18 | 2 | very sandy lining or FAS; highly bloated |
| 15824 | | 222 | 222 | | fragmented block of pale FAS broadly similar to that from 11693 |
| 15915 | | 2 | 2 | 1 | vitrified oxidised-fired lining |
| 16168 | | 63 | 63 | 1 | part of small dense SHC - potentially an almost complete tiny example, but this is not certain |
| 16240 | | 11 | 11 | 1 | thin slag sheet with dense and sandy lining layers |
| 16341 | | 128 | 128 | 2 | vitrified lining, oxidised, both pieces show join from orange to red, but don't join; one may be blowhole margin, both pieces are suggestive of some sort of edge; matrix silty with some fine sand, friable, porous |
| 16516 | | 61 | 60 | 1 | fragmented sheet of vitrified lining, almost planar, reverse dark, purplish and very sandy, face black glass, but where sand protrudes is greenish |
| 16524 | | <1 | <1 | 1 | vitrified oxidised-fired ceramic |
| 16886 | | 7 | 7 | 1 | vitrified oxidised-fired slightly sandy lining |

| context | sample | s wt | l wt | l no | notes |
|---|---|---|---|---|---|
| 16889 | | 160 | 159 | 1 | 55x85x40mm, unusual prilly SHC with maroon dished top bearing adhering maroonish prills/blebs, very slightly incomplete |
| 17191 | | 5 | 5 | 3 | pale FAS |
| 17566 | 45 | <1 | <1 | 7 | 6 particles of coke, 1 of clinker |

*Table 2: Summary of facies of residues by context, grouped by residue assemblage type.*

| c | cut | context notes | period | spot date | SHC | tongue | indet. slag | hearth ceramic | lining slag | sandy FAS | FAS | coal | concretion/ iron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Group 1: FAS** | | | | | | | | | | | |
| 11054 | 11053 | ditch fill, natural silting | 2 | MC1-C2 | | | | | | 21 | | <1 | |
| 11061 | 11060 | ditch backfill | 2 | RB | | | | | | 11 | | | |
| 11203 | 11202 | secondary ditch fill, natural silting | 2 | C1 | | | | | | | <1 | | |
| 11396 | 11395 | fill of ditch, natural silting | 2 | MC1-C2 | | | | | | | 71 | | |
| 11412 | 11411 | fill of ditch, natural silting | 2 | LC1-C2 | | | | | | 5 | | | |
| 11414 | 11413 | fill of ditch, natural silting | 2 | MC1-C2 | | | | | | 7 | | | |
| 11566 | 11563 | 4th fill of ditch, natural silting | 2 | | | | | | | | <1 | | |
| 11693 | 11691 | 2nd fill of ditch, natural silting | 2 | RB | | | | | | | 455 | | |
| 11776 | 11773 | 3rd fill of ditch, intentional backfill | 2 | | | | | | | | 45 | | |
| 11843 | 11841 | 2nd fill of ditch, natural silting | 2 | LC1-C2 | | | | | | 8 | | | |
| 12190 | 12189 | Fill of linear ditch | 2 | | | | | | | 343 | | | |
| 12284 | 12282 | fill of linear ditch | 2 | | | | | | | | 84 | | |
| 12392 | 12391 | fill of linear ditch | 2 | MC1-LC1 | | | | | | | 3 | | |
| 12649 | 12647 | fill of linear ditch | 2 | | | | | | | | <1 | | |
| 12685 | 12681 | fill of posthole | 2 | | | | | | | 7 | | | |
| 12697 | 12696 | fill of linear ditch | 2 | | | | | | | | 9 | | |
| 13038 | 13036 | Fill of pit | 2 | MC1-C2 | | | | | | | 118 | | |
| 13649 | 13647 | 2nd Fill of linear ditch terminus | 2 | C1 | | | | | | 63 | | | |
| 14152 | 14151 | 1st Fill of linear ditch terminus | 2 | LIA-C1 | | | | | | 6 | | | |
| 15710 | 15711 | Fill of circular posthole | 2 | C1-C2 | | | | | | 6 | | | |
| 15815 | 15814 | Fill of curvilinear ditch | 2 | C2-C3 | | | | | | | 2 | | |
| 15822 | 15821 | 2nd Fill of curvilinear ditch | 2 | | | | | | | 18 | | | |
| 15824 | | SE-NW aligned linear ditch | 2 | RB | | | | | | | 222 | | |
| 12715 | 12714 | fill of linear ditch | 2/3 | C2-C4 | | | | | | | 15 | | |
| 11435 | 11434 | fill of ditch, natural silting | 3 | MC1-C2 | | | | | | 3 | | | |
| 15169 | 15168 | 2nd Fill of linear ditch | 4 | | | | | | | | <1 | | 53 |
| 17191 | 17189 | 2nd Fill of sub-rectangular | 7 | C1-C2 | | | | | | | 5 | | |
| 11872 | | | | | | | | | | 15 | | | |

| c | cut | context notes | period | spot date | SHC | tongue | indet. slag | hearth ceramic | lining slag | sandy FAS | FAS | coal | concretion/ iron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Group 2: Coal** | | | | | | | | | | | |
| 11011 | | | | | | | | | | | | <1 | |
| 15124 | | | | | | | | | | | | <1 | |
| 15224 | 15223 | E-W aligned linear ditch | 4 | MC1-C2 | | | | | | | | <1 | |
| 15617 | | | | | | | | | | | | 2 | |
| 17566 | 17564 | 2nd fill of sub-oval pit | 3 | | | | | | | | | <1 | |
| | | **Group 3: smithing** | | | | | | | | | | | |
| 11047 | 11098 | pit fill, dark organic silting | 2 | MC1-C2 | 485 | | | | <1 | | | | |
| 11094 | 11093 | ditch fill, natural silting | 2 | RB | 445 | | | | | | | | |
| 11110 | 11109 | ditch fill, lower natural silting | 2 | LC1-C2 | 19 | | | | 11 | | | | |
| 11118 | 11116 | ditch fill, upper natural silting | 2 | LIA-C1 | | | | | 5 | | | | 6 |
| 11144 | 11142 | lower ditch fill | 2 | MC1-C2 | | | | 4 | | | | | 47 |
| 11206 | 11205 | ditch fill, natural silting | 2 | LIA-C1 | 6 | | | | | | | | |
| 11249 | 11248 | ditch fill | 2 | MC1-C2 | | | | | 69 | | | | |
| 11286 | 11287 | ditch fill | 2 | | 143 | | | | | | | | |
| 11299 | 11298 | gully fill, natural silting | 2 | RB | 24 | | | | | | | | |
| 11301 | 11300 | curvilinear fill | 2 | | | 15 | | 4 | 13 | | | | |
| 11303 | 11302 | ditch fill, natural silting | 2 | | 1354 | | | | | | | | |
| 11305 | 11304 | ditch fill, natural silting | 2 | | 138 | | | | | | | | |
| 11312 | 11311 | ditch fill, natural silting | 2 | LIA-C1 | 149 | | | | | | | | |
| 11317 | 11338 | ditch fill, natural silting | 2 | RB | 427 | | | | | | | | |
| 11324 | 11323 | ditch fill, natural silting | 2 | MC1-C2 | | 38 | | | | | | | |
| 11410 | 11408 | 2nd fill of ditch, natural silting | 2 | MC1-C2 | | | | 2 | | | | | |
| 11445 | 11444 | fill of ditch, natural silting | 2 | C1; C14-C15 | 144 | | | | | | | | |
| 11614 | 11613 | fill of pit, intentional backfill | 2 | | | | 4 | | | | | | |
| 11647 | 11646 | fill of ditch, natural silting | 2 | C1 | 382 | | 4 | | | | | | |
| 11909 | 11908 | fill of pit, natural silting | 2 | RB | | | | | <1 | | | | |
| 12094 | 12093 | fill of N-S aligned linear ditch | 2 | LIA-C2 | 41 | | | | | | | | |
| 12323 | 12324 | fill of linear ditch | 2 | | 169 | | | | | | | | |
| 12402 | 12403 | fill of linear ditch | 2 | | | | | | 16 | | | | |
| 12422 | 12421 | fill of linear ditch | 2 | LIA-C1 | | | | 7 | | | | | |

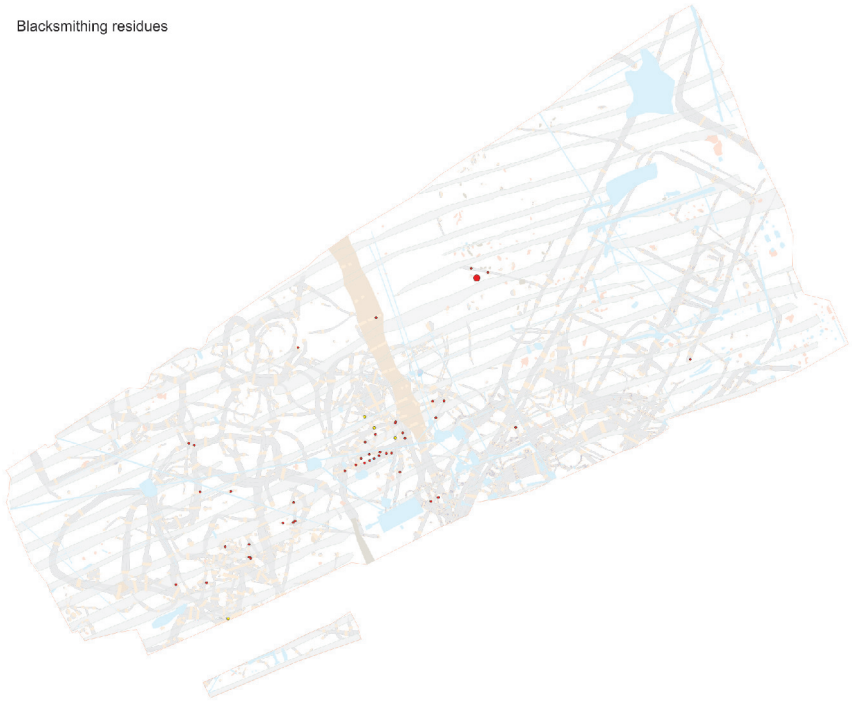
| c | cut | context notes | period | spot date | SHC | tongue | indet. slag | hearth ceramic | lining slag | sandy FAS | FAS | coal | concretion/ iron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12504 | 12503 | fill of linear ditch | 2 | RB | 149 | | | | | | | | |
| 13247 | 13245 | 2nd Fill of curvilinear ditch | 2 | LC1-C2 | 10 | | | 2 | | | | | |
| 13263 | 13262 | 1st Fill of linear ditch | 2 | IA-C1 | | | 3 | | 6 | | | | |
| 13366 | 13364 | 2nd Fill of linear ditch | 2 | MC1-LC1 | 119 | 70 | | 42 | 185 | | | | |
| 13391 | 13389 | 2nd Fill of linear ditch | 2 | LC1-C2 | | | | 13 | | | | | |
| 13475 | 13474 | Fill of linear ditch | 2 | MC1-C2 | | | 56 | | | | | | |
| 13527 | 13524 | Fill of curvilinear ditch | 2 | RB | | 20 | | | | | | | |
| 14457 | 14456 | 1st Fill of linear ditch | 2 | MC1-LC1 | 480 | | | | | | | | |
| 15466 | 15465 | Fill of linear ditch | 2 | | 4 | | | | | | | | |
| 15915 | 15914 | 1st Fill of curvilinear ditch | 2 | | | | | 2 | | | | | |
| 16168 | 16167 | Fill of linear ditch | 2 | MC1-C2 | 63 | | | | | | | | |
| 16240 | 16238 | 2nd Fill of curvilinear ditch | 2 | LC1-C2 | 11 | | | | | | | | |
| 16524 | 16522 | 2nd Fill of curving ring ditch | 2 | MC1-C2 | | | | <1 | | | | | |
| 11443 | 11442 | fill of ditch, natural silting | 3 | LC1-C2 | 93 | | | | | | | | |
| 12671 | 12670 | fill of oval pit | 3 | RB | 771 | 256 | 205 | 58 | 155 | | | | |
| 12672 | 12670 | fill of oval pit | 3 | C2-C4 | 1692 | | 161 | 139 | 73 | | | | 4 |
| 14562 | 14551 | Upper Fill of terminus | 3 | LC2-C4 | 69 | | | | | | | | |
| 16886 | 16884 | 2nd Fill of linear ditch | 3 | RB | | | | 7 | | | | | |
| 16889 | 16887 | 2nd Fill of linear ditch | 3 | RB | 159 | | | | | | | | |
| 11108 | 11107 | pit backfill | 9 | C19-C20 | | | 19 | | | | | | |
| 15074 | 15075 | Fill of pit | 10 | | 59 | | | | | | | | |
| 11144 | | | | | | | | 4 | | | | | |
| 11428 | | | | | | | <1 | | | | | | |
| 11500 | | | | | | | 7 | 8 | | | | | 1 |
| 16341 | | | | | | | | 128 | | | | | |
| 16516 | | | | | | | | 60 | | | | | |
| | | Overall total 11.131kg | | | *7605* | *399* | *459* | *480* | *533* | *513* | *1029* | *2* | *111* |

*Table 3: Comparison of the SHC weight-frequency distribution with that of other comparable Roman assemblages. Weights in gram.*

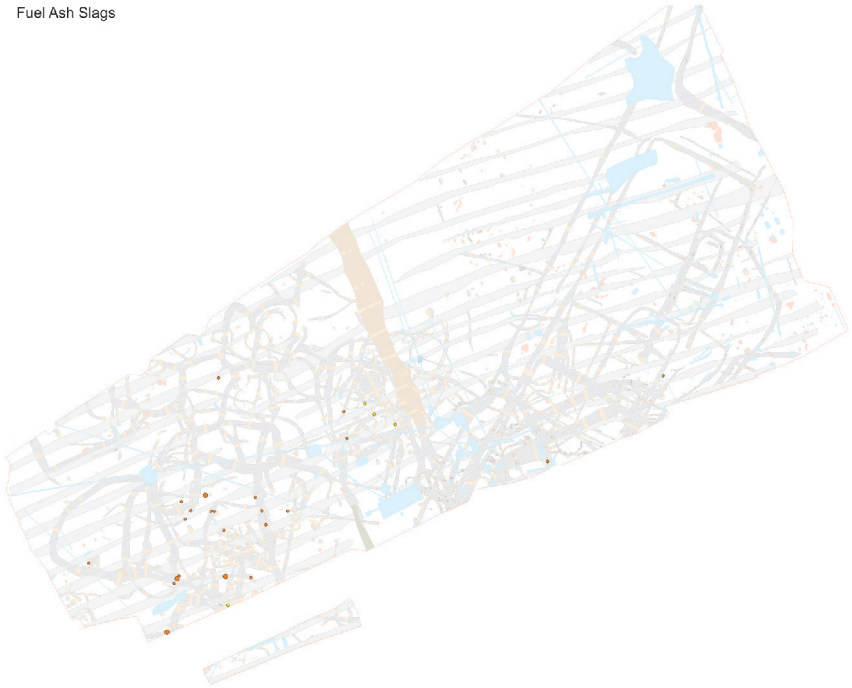
| Site: | Exminster | Uffington | Cleevelands | Ebrington | Neath | Carmarthen | Ware | Bulmore | Caerleon Priory Field | Marsh Leys Farm | Mickleton | Cowbridge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference: | Young 2014b | Young 2015a | Young 2016a | Young 2016b | Young 2013b, 2014a | Crew 2003 | Young 2014c | Young 1999 | Young 2013a | Young 2005 & 2011b | This project | Barford 1996 |
| | charcoal | coal | coal | mixed | charcoal | ? | charcoal | mixed | charcoal | charcoal | | coal? |
| *SHC count* | 107 | 57 | 57 | 37 | 47 | 136 | 70 | ? | 18 | 30 | 16 | ? |
| *SHC min. wt* | 32 | 36 | 50 | 53 | 74 | 100 | 36 | 127 | 146 | 60 | 149 | 175 |
| *SHC max. wt* | 482 | 614 | 530 | 628 | 630 | 820 | 952 | 770 | 600 | 824 | 1065 | 700 |
| *SHC mean wt* | 127 | 137 | 176 | 180 | 244 | 227 | 246 | 270 | 294 | 333 | 381 | 403 |
| *% <150g* | 100% | 72% | 44% | 46% | 32% | ? | 44% | ? | 11% | 23% | 13% | ? |
| *% <500g* | 100% | 98% | 98% | 97% | 89% | 94% | 82% | ? | 83% | 77% | 94% | ? |
| *%>1000g* | | | | | | | | | | | 6% | |
| *Site Type* | rural | rural | rural | rural | *vicus* | urban | urban | urban | military | rural | rural? | urban |

Figure 1

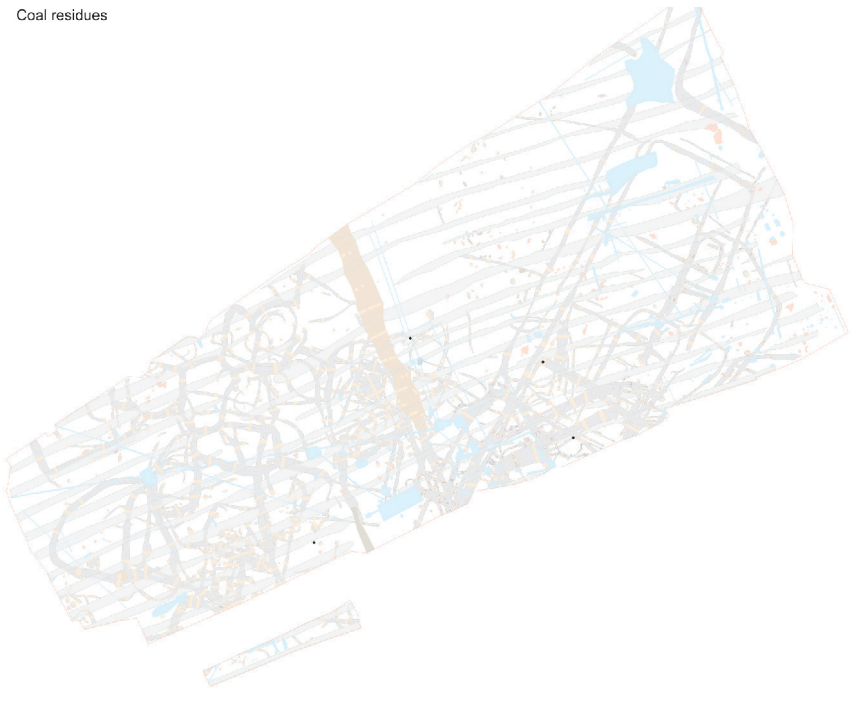
Blacksmithing residues



Fuel Ash Slags



Coal residues



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