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Assessment of materials from Langford Solar Farm

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Abstract

The submitted assemblage comprised 126 picked fragments of residues with a total weight of approximately 104.5kg from 17 distinct archaeological contexts, plus 10 sieved sample residues with a combined weight of 6kg. The collection was dominated by the 84.8kg of residues recovered from the various fills of pit F146.

The archaeometallurgical residues were entirely from iron smelting in a non-slag tapping furnace and very closely resembled the slag previously recovered from the site in-situ within the basal pit of a furnace (F803).

The present material confirms the general description of the smelting residues from the site: the slag comprises two elements, a basal dense slag mass comprising amalgamated flow lobes of slag that descended into a wood packed pit, typically with a 'free upper surface' and an 'upper block' comprising a dense concavo-convex slag sheet with prilly slags with charcoal below. The evidence for the 'upper blocks' was incomplete in the previously described material. The most complete of basal indicates a total weight of about 13kg (the complete mass recovered in 2019 may have weighed as much as 20kg once the associated small fragments had been taken into account) and the most complete of the 'upper blocks' suggested they weighed approximately 4.5kg. The furnace of the 2019 work produced an estimate 4.3kg of slag from its middle fill largely derived from a putative 'upper block'. At least two of the 'upper blocks' showed a depression of the dense sheet in the centre of the furnace, with evidence for deformation of the underlying prilly slags. This suggests that downward force was used either to dislodge the bloom from the slag during its extraction or, perhaps more likely, to displace the slag block during furnace clearance.

Two pits adjacent to the excavated furnace F803, pits F164 and F166 were described in the interim report either as furnaces (p2) or not (p4); the residues they contained were not certainly indicative of their being furnaces, although if the large slag block from context (168) could be demonstrated to have occurred right-way-up and close to the base of pit F166, the argument for that it being a furnace might be strengthened.

The total recovered assemblage is thus equivalent to the slag production of approximately five smelts, providing a minimum for the re-use of F803.

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Methods

All materials were examined visually, using a low-powered binocular microscope where required. The identifications of materials in this report, as an assessment during which no instrumental analysis was undertaken, are necessarily limited and must be regarded as provisional.

The material described here derives from an excavation undertaken at Langford Solar Farm, Devon (ACD2892) undertaken by AC Archaeology in 2023 (Etheridge & Rainbird 2023). The excavation was a follow up to the discovery of an early medieval slagpit furnace in a field evaluation on the site in 2019 (Rainbird 2020). The residues from this furnace were described in detail previously (Young 2021).

This assessment was conducted in August 2023 and was commissioned by Naomi Payne of AC Archaeology.

Results

General nature of the assemblage

The submitted assemblage comprised 126 picked fragments of residues with a total weight of approximately 104.5kg from 17 distinct archaeological contexts, plus 10 sieved sample residues with a combined weight of 6kg. The catalogue of the assemblage is present in Table 1.

The collection was dominated by the 84.8kg of residues recovered from the various fills of pit F146. A synthesis of the material recovered by context is presented in Table 2.

The archaeometallurgical residues were entirely from iron smelting in a non-slag tapping furnace and very closely resembled the slag previously recovered from the site in-situ within the basal pit of a furnace (F803) (Young 2021).

Iron smelting residues

The most abundant facies of slag was material formed of amalgamated flow lobes, often very dense, but commonly surrounding voids, representing the moulds of horizontally laid wood. The wood pieces were commonly over 100mm in length, sometimes certainly split wood but sometimes either roundwood or semi-roundwood, and typically in widths of up to 40mm, but occasionally larger. The moulds commonly show transverse ridges, corresponding to transverse cracks in the wood that formed as it charred – a characteristic feature separating the moulds of the wood pit packing from those of the charcoal fuel.

These dense slags typically formed a mass with a rounded base, sometimes approaching a hemisphere in shape. The diameter of these blocks is typically a little over 200mm, widening slightly as they expand upwards into a more cylindrical shape.

The outside surface of these masses usually displays the shape of the individual flows of slag, usually 5-10mm in thickness and up to 40mm wide. The slag shows a shiny, almost black, surface. It is this morphology that, when viewed with the slag cake inverted, was described by Allen as resembling a 'pile of dung', (Pine *et al.* 2009) at a an early medieval (7th-9th century) site at Clearwell, Glos.

A very important feature of these slag masses is that their upper surface commonly resembles tapped slag, with raised flow lobes (although these may be interrupted in some examples by further pieces of the wood packing). This has been described as a 'free surface'.

A single fragment of the margin of one of these slag masses shows clear surface impressions as well as internal moulds of the stems of grass or cereals. This was also noted as a minor component of the pit-packing in Furnace F803.

The presence of a separate slag mass higher in the pit was proposed on some incomplete evidence from Furnace F803. The new material provides better evidence for the nature of these 'upper blocks'. Their characteristic structure is a dense sheet-like layer of up to about 30mm thickness of slag at the top (although overlain by a small amount of charcoal-bearing slag in one example), overlying porous, charcoal-rich slag formed of small prills.

A probably intact example of an 'upper block' weighs 4520g and a partial example with a weight of 3780g was probably also equivalent to an original weight of approximately 4500g.

In two examples, the dense sheet was depressed in an area approximately corresponding to the centre of the furnace. The slag below the offset area of the sheet was observed to be deformed and brecciated. This deformation could be associated with bloom removal but is perhaps more likely to be associated with the extraction of the slag.

There was almost no furnace structure present within the residues. A small quantity (592g) of a low density, soft, pink slightly vesicular material was present in context (149). This is only tentatively identified as furnace ceramic, for it was unlike typical technical ceramics in lacking quartz temper and there were no pieces that displayed a vitrified surface. It is possible that this is instead a highly weathered natural lithology.

Iron ore

The present material contained a few small grains of iron ore, amongst which a ferruginous sandstone was particularly prominent. Grains with a ruddle coating were also observed and these were probably derived from boxstones. This evidence is entirely consistent with the better assemblage identified in the bottom of furnace F803 (Young 2021).

Manganese-rich granules

Three samples yielded a high proportion of particles, sorted as slag, but which were natural manganese rich granules (or peds). These are manganese equivalents to the better-known iron pan.

In Sample <8> (context (168)) they were a small proportion of the sieved residues, but in Sample <12> (context (193)) there was just a single slag fragment in the sieved sample and in sample <11> (context (174)) there was no slag present at all.

Interpretation

The new evidence largely corroborates the interpretation of the iron smelting technology made previously (Young 2021). The new information does add somewhat to understanding of the slags that formed in the upper part of the slagpit, which were only incompletely preserved in Furnace F803.

The slag assemblage is confirmed as being in two parts – a lower slag mass formed of amalgamated flow slags within a mostly wood-packed pit and an upper block formed directly below the bloom.

The separation of these two components of the slag assemblage, allowing the formation of the free surface on top of the lower mass, is a key feature. It indicates high slag fluidity. The existence of such a surface on top of the large slag blocks formed below furnaces of the Drengsted/Scharmbeck type in Denmark/Germany and similar furnaces in Poland has caused much debate and controversy, with some workers suggesting that it must indicate the presence of a physical barrier between the slag pit and the area of the furnace in which the bloom forms (see Madera *et al.* 2018 for a discussion of these ideas). There is no evidence for such a feature in the present example, and it is

probably associated with the rapid descent of hot fluid slag near the blowing wall bypassing the cooler upper part of the furnace pit.

That early medieval small furnaces could produce slag cakes with a free slag surface can be seen as contributing to poor understanding of many furnace examples where such slags have been erroneously interpreted as tapslag cakes formed outside the furnace. Such misidentification can be avoided by the observation that the free slag surface does not oxidised surface layers on the flow lobes – they are black in colour and do not show the maroon veneer so characteristic of true tapped slags. Unfortunately, this common misidentification is extremely difficult to correct when dealing with legacy reporting. The recorded presence of tapslag in 'tapping pits' with the lack of furnace bases attributed to truncation may indicate examples. The reported occurrence of both tapping furnaces and non-tapping furnaces on the site at Clearwell (Pine *et al* 2009) for instance, may actually conceal a potential close analogue for the smelting technology at Langford.

The evidence for the use of the site at Langford suggests that there was no working of the blooms produced in the furnace beyond, presumably, the initial post-extraction compaction. Contrary to a statement in the interim report (Etheridge & Rainbird 2023, 5), there has been no hammerscale recovered from the site.

There is no known local settlement and the ore provenancing evidence provided by Young (2021) indicates that the ore was extracted from some considerable distance (at least 7km). This makes it extremely likely that the context for the smelting site would have been woodland – with the ore being moved to the locus of charcoal production.

Although it is tempting to view such a site as 'fairly isolated rural industry set up in an ad hoc manner to meet the needs of the rural community' (Etheridge & Rainbird 2023, 1), an alternative view would be that short-lived furnace sites importing ore from a distance may be indicative of being part of a larger structured industry with furnaces constructed to follow woodland coppicing rotation.

For an industry with a structure larger than its component isolated woodland smelting sites, the smithing part of the *chaîne operatoire* can be located more centrally for ease of administration, centrality of access and to exploit a different charcoal source. Examples of this could be sought in the early medieval of Ireland in both secular (with specialist bloom processing sites such as Borris, Young 2009a and Ballinglanna North, Young 2009b) and ecclesiastical contexts (e.g. Clonfad, Young 2012) and perhaps more locally in the smithing site at Burlescombe (Young 2018). It is worth noting that, for instance, in contrast to the multiple early medieval smelting operations known around Hemyock (Rainbird & Young 2015; Smart et al, 2018; Young et al. 2022, the corresponding smithing site has yet to be found.

The site might also be viewed slightly differently depending how many furnaces it contained. Two pits adjacent to the excavated furnace F803, pits F164 and F166 were described in the interim report either as furnaces (p2) or not (p4); the residues they contained were not certainly indicative of their being furnaces and they appear to be a little too large to be furnaces. Their interpretation, or at least that of pit F166, might need to be reviewed if the large slag block in context (168) occurred right-way-up close to the base of the pit. The field records might be worth re-examining to see if this was the case (note: this large slag block of 6280g appears to have been wrongly allocated to (148) instead of (168) in the table of finds).

The new material adds little to understanding of the source of the ore beyond present knowledge (Young 2021). The present material did contain a few small grains of iron ore, amongst which a ferruginous sandstone was particularly prominent. Recent work at Dunkeswell (Young 2023) shows that the ore materials at Langford differ in detail from those of the Dunkeswell area. The ores of the nearest outcrops of the Clay-with-flints (the escarpment above Broadhembury) have not been examined in equivalent detail.

One addition to understanding from the present work is that most of the slag occurred within a pit where it appears to have been deliberately deposited. The pit may have potentially originated as a source for the furnace clay; it does not appear to be directly associated with the iron working or the production of charcoal. The dumped slag clearly indicates the furnace was used on multiple occasions, with the slag pit cleared between smelts, something that could not be directly demonstrated by Furnace F803. The slag assemblage recovered is extremely unlikely to represent all the slag ever produced on the site, but its weight indicates that, if Furnace F803 was the only furnace on the site, it must have been used at lest six times. In practice, this is likely to be a great underestimate.

Further work

Detailed analysis of the new suite of residues would be unlikely to add significantly to the understanding of the process gained from the detailed analysis of the residues from Furnace F803.

Consequently, no further analytical investigation is recommended.

However, it is strongly recommended that all residues from the site (from 2019 and 2023) are deposited in their entirety with a suitable repository. These materials should be fully published, probably in a specialist journal, with careful illustration. Because this is a small and short-lived site, the residues have a very close association with each other and thus provide a very important assemblage for the understanding both of the evolution of iron smelting in the early medieval and of the ore source.

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Table 1: summary catalogue, weights in g, assm = assemblage of small pieces not individually counted

C	S	label	location	S. wt	lt. wt	lt. no	notes
101			box 1		3780	2	fragmented crudely plano-convex block; estimated weight of complete block c. 4500g; smooth flat to slight concave proximally, the 30mm upper slab drops downwards distally with disrupted slag below, lower part prilly, presumed wall contact moderately steep, but no induration of wall.
					1145	2	broken block of amalgamated flow slags with charcoal clasts
					300	1	possibly worn block of very dense flow slags with wood moulds
109			box 9		28	1	fragment of dark-surfaced flow slag with tapslag like lobes on top
					40	1	accreted fragment of amalgamated flow slags
124			box 1		192	7	dark prilly flow slags, some forming sheets, probably formed around wood clasts
					8	1	slag fragment, sandy with pinkish contact surface on one side - presumably wall contact, thin sheet c 5mm thick maximum
					134	1	highly accreted lump of slag - no details visible
					38	3	small pieces of dense prilly slag with charcoal
130			box 4		3745	1	triangular slab of charcoal-rich slag, top raised on edge but appears to be smooth and dished away from margin - 300 x 300 x 140mm (decreasing to 50 in smooth area)
					698	12	fragments of charcoal-rich slag
					120	2	slags formed of coalesced prills
135			box 1		32	1	small fragment of slag with fuel moulds, slightly oxidised surfaces
137	2		box 9		398	assm	fine slag debris, accreted, some charcoal, some reddish material that may be fired clay.
143			box 1		62	1	prilly slag with fuel clasts, prills vary from dense iron slag to more FAS types, angular fragment
					18	1	isolated dark prilly flow slag with shiny surface.
143	10		box 9		638	assm	clean assemblage of mostly grey flow slag. Some pieces of accreted debris, apparently basal slag pit material
147			box 1		352	1	irregular block of slag, one smooth (? non-wetted) surface shows some cereal/grass stem impressions; Internally rich in fine charcoal (probably) but shows strong foliation suggesting more fine packing
					324	1	block with well-formed flow lobes in almost black shiny slag, but grades to charcoal bearing material through block
					228	1	amalgamated flow slags with fuel clasts and moulds

			170	1	irregular lump of charcoal-rich slag
			556	1	irregular block of dense grey flow slags around wood moulds
			664	1	accreted (and worn?) slag block, no visible features
			1790	1	dene flow slags around multiple parallel wood pieces, wood > 130 x 30mm
			570	1	base of slag mass, finely dimpled exterior to 20mm crust, interior lobed/prilly slags
			82	4	small fragments of charcoal-bearing slag
147		box 3	7520	1	biconvex mass of prilly/flow-lobed slag with some wood moulds, 230x240x160mm, inclination of layers within the mass hint it may have rested at an angle, rather than simply symmetrically on base of furnace
			4060	1	somewhat cuboidal block of slag. One planar edge appears original - but its orientation is problematic. The block appears to include a 45mm thick denser sheet - but it is unclear if this was horizonal and a rear contact. Understanding might be able to be improved by fracturing off some of the adhering clayey material
147		box 10	504	1	block of dense burr slag with entrained pale grey ceramic, passes from massive into amalgamated lobes
			1055	1	irregular fragment with concave dense sheet 20-35mm thick above fine amalgamated prills
			534	1	irregular mass of amalgamated prills overlain (?) by more irregular material
			930	1	block of amalgamated flow slags - concretion attached with charcoal fragments
			48	2	fragmented piece of charcoal rich slag
			10	2	indeterminate fragments of flow lobes
			48	1	rounded ferruginous piece - unclear if actually slag or just slag attached to rounded pebble
147	5	box 9	1235	assm	large assemblage, almost entirely slag (430g in large fragments), rare fragments of burnt (probably - red surfaces) dense ferruginous sandstones.
147		box 10	262	1	irregular dense slag fragment, possibly from burr region
			1105	1	heavily accreted piece, prilly below, dense slab possibly above - intense corrosion suggests a high iron content.
			894	1	irregular dense massive block - probably from burr region
148		box 7	1705	1	finely prilly FB fragment - 190 x 140 x 90mm
			4640	1	part of FB with tapslag like upper layer (dark; free surface), prilly lower part, large wood moulds - 200x170x120mm
			1450	1	charcoal rich FB block - 120 x 120 x110
			1545	1	amalgamated prills with large wood moulds, 130mm long length noted, 140 x 100 x 110
148		box 9	10585	1	around 80% of dense basal block of amalgamated flow slag. Flow slag extends with strong flow lobes from one end and enclosed large blocks of wood (presumably) at least 120mm across. 210 x 240 x 180mm. Flow lobes prominent on the sides - like Allen's cowpat morphology?

148			box 4	336	1	irregular slag fragment, large roundwood surfaces below, fuel charcoal above
				432	1	heavily accreted slag block, amalgamated flow slag with wood moulds
				134	1	dimpled basal flow with wood mould on upper surface
				144	1	amalgamated prills with fuel clasts
				488	1	dense slag block broken in two containing several large wood/charcoal fragments - probably tips of wood
				1025	1	amalgamated almost black flow slags with large wood moulds
				346	1	almost black flow slags around large wood moulds,
				218	1	prilly slag with small charcoal slag clasts
				918	1	irregular block of dense amalgamated flow slag, includes probable basal contact
				280	3	irregular amalgamated prilly blocks
				12	4	small fragments
				366	1	fractured block of somewhat vesicular slag
148			box 5	4520	1	plano convex block, upper hollow filled with charcoal rich wispy material mostly; then dense dished slag sheet, 30mm on edges, but interior not seen; lower part charcoal bearing grey slag with secondary reddening. 260x210x130mm
				2275	1	irregular dense block of dark amalgamated prills around fuel fragments
				306	4	dense prilly slags, one with grey wall contact, in small fragments
148	3	>4mm	box 9	1325	assm	large assemblage, almost entirely slag, rare charcoal and rare piece of almost black botryoidal crusts. Includes 2 pieces, total weight 342g of sub-discoidal sheet, piece has slightly odd texture - basal crust/SHC or has it been impacted?
149			box 5	786	1	angular block from top of amalgamated flow slag block, upper surface shows raised flow lobes, internal features include 30mm diameter roundwood, side has rounded flow lobes
				352	1	angular block of very dense slag with wood moulds
				4595	1	highly accreted block of amalgamated flow slag. 220x170x129mm. One face is rounded, but unclear if this is base or wall.
				38	2	pink vesicular material, as in bag 2
149			box 6	2400	1	angular block of charcoal rich slag 170x130x130mm
				1230	1	very dense block showing part and side and base of amalgamated dark flow slag, base shows large wood imprints, side shows flow lobes
				392	1	small fragment of prilly slag with indurated all contact, plus a thin sheet of detached vitrified wall material vertically within block
				500	1	very dense block of lobate/burr material with wood moulds on surface, arts of surface show secondary reddening
				554	7	curious soft vesicular pinkish material - possibly melted hearth wall or stone, very low density
149	4	>4mm	box 9	1470	assm	large assemblage, mixture of materials, fine slag debris dominates, but also fired clay, some small amount of stone (chert, Mn-mineralised sandstone) and traces of iron ore. Ore is in thin dark grey sheets with reddish ruddle coating.

149		box 2	4820	1	heavily accreted slag block with rounded faces - appears to include flow slags but of a porous structure (charcoal?). 210x180x170mm. the 210mm may be the height with the block coming from a rounded corner of the pit?
149		box 2	4250	1	heavily accreted rounded block of charcoal bearing prilly slag, 200x 180 x 130mm
			1720	1	very dense block of amalgamated flow slag, appears to be foot of wall and part of base - both with non-wetted lobes, massive internally, passing up into top with open lobs and charcoal impressions, 100 x 100 x 90mm tall
			448	1	complex block of amalgamated flow slags with crude wood moulds
			452	1	very heavily accreted block of slag, exposed piece of charcoal on 'top'
			282	7	fragmented charcoal rich friable slag
151		box 10	1590	1	heavily accreted slag mass - probably amalgamated prilly material
			2275	1	heavily accreted slag mass - in two layers, lower part amalgamated prills, upper part 35-50mm dense sheet - 120 x 130 x 130mm
151		box 1	8	1	slagged and vitrified wall fragment - wall resembles pinkish material from other contexts, but not obviously vesicular
153		box 6	6590	1	heavily accreted irregular block with amalgamated flow lobes - but details and way-up unclear
159		box 9	44	1	fragment of basal crust (?), flat surface with low relief flow lobes at one end, reverse side shows some fuel/wood impressions, up to c15mm thick
167		box 10	1075	1	heavily accreted slag lump - coalesced prills with large wood or charcoal - 155 x 110x 70mm
167	7	box 9	290	assm	rather scrappy, derived appearing slag assemblage. Pieces of red sandy material not certainly cermaic may be rock. Slag represent cross section of textures from site
168		box 7	6280	1	complete biconvex slag mass, amalgamated small prills, hints of impressions of wood on lower surface, upper surface coated in rusty charcoal rich material, 220 x 190 x 125
168	8	box 9	254	assm	scrappy of assemblage of mainly slag, rare possible fired clay grains, abundant manganese granules, very rare ore grains
169	9	box 9	98	assm	scrappy assemblage with some flow slag fragments, but mainly accretion and stone
174	11	box 9	98	assm	no slag, this is a collection of manganese nodules, some are reddened and may have been heated
193	12	box 9	224	assm	assemblage of manganese granules up to 12mm, most smaller. Single fragment of vesicular slag noted (of similar grain size)

Table 2: Summary totals of materials by context.

C	Slag			Lining?		Context notes
	wt	no	fines?	wt	no	
101	5225	5				Subsoil
109	68	2				Fill pit F108
124	372	12				Fill feature F123
130	4563	15				Fill ditch F129
135	32	1				Fill posthole F134
137			assm			Fill pit F136
143	80	2	638g assm			Fill pit F142
147	22941	26	assm			Upper fill pit F146
148	33050	28	assm			5th fill pit F146
149	22227	19	1470g assm	592	9	3rd fill pit F146
151	3873	3				Fill pit F150
153	6590	1				2nd fill pit F146
159	44	1				Fill ditch segment 158
167	1075	1	assm			Upper fill pit F166
168	6280	1	assm			Middle fill pit F166
169			assm			Lower fill pit F166
174	0	0				Upper fill pit F173
193	1	1				Fill pit F192

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