

APPENDIX 1 IRON SLAG

By Lynne Keys

Introduction

- 1.1.1 A large assemblage (just over 171 kg) of iron slag and related material was recovered from a variety of contexts.
- 1.1.2 This assemblage appears to date to the Late Iron Age and Early to slightly later Roman periods. There was some evidence that structures described as “furnaces”, “kilns” or “hearths” may have been associated with the iron slag recovered from the site.

Methodology

- 1.1.3 With the exception of five soil samples, virtually all the slag appears to have been recovered by hand. The samples do not appear to have been taken to answer any metallurgical questions and contained no hammerscale but, conversely, contexts with large amounts of macro-slags were not sampled on site for micro-slags.
- 1.1.4 The slag examined was not washed and identification of types was often hampered because of the concreted clayey soil in which it was covered. Identification of slags resembling “slag pit blocks” was the more difficult because the slag was unwashed.
- 1.1.5 All the slag presented was examined by eye and categorised on the basis of morphology alone. Each category of slag within individual contexts was weighed separately and the smithing hearth bottoms were each individually weighed and measured to obtain their dimensions.
- 1.1.6 Since the slag was unwashed however, the soil in the bags was routinely examined by eye and with a magnet in an attempt to locate any micro-slags; the results are recorded under the entries for “hammerscale” in each context.

Quantification

- 1.1.7 All quantifications are listed in Table 5.1
- 1.1.8 Activities involving iron can take two forms:

1) the manufacture of iron from ore and fuel in a *smelting* furnace. The resulting products are slag (waste) and a spongy mass called an unconsolidated bloom which consists of iron with a considerable amount of slag still trapped inside.

2a) *primary smithing* (hot working by a smith using a hammer) of the bloom on a stringhearth, usually near the smelting furnace, to remove excess slag. The slag from this process will include micro-slags, particularly tiny smithing spheres

2b) *secondary smithing* (hot working) of an iron shape by a smith to turn it into a utilitarian object. This will also generate micro-slags: hammerscale flakes from ordinary hot working of a piece of iron, or tiny spheres from high temperature welding to join two pieces of iron.

Smelting

- 1.1.9 Several types of smelting slag were recovered: furnace bottoms, tap slag, and what looks like slag blocks. A tiny amount of dense slag, and some possible ore was also identified.

- 1.1.10 Furnace bottoms (resembling very large smithing hearth bottoms) derive from smelting in a covered bowl furnace where the slag sinks to the bottom with the bloom on top; sometimes the bloom is intermixed with the slag and the latter has to be broken up to extract it. The size of furnace bottoms are used to distinguish them from smithing hearth bottoms and some of the examples from Leda Cottages are *extremely* large (eg. those from contexts 8510 and 8560).
- 1.1.11 Another type of smelting furnace had a pit below it in which the slag was allowed to collect, rather than being tapped out of the furnace. The distinctive slag produced by this furnace is called a slag block (*Schlackenklotz* in German). Slag blocks are common in southern Scandinavia, north Germany and Poland but a few have been found mainly in eastern England dating to the early Anglo-Saxon period. The furnace above the slag pit was moveable so the slag could be left in the hole when the pit was full.
- 1.1.12 It has generally been believed until now that slag-pit furnaces were not in use before or during the Roman period in Britain but recent work on some Late Iron Age/Early Roman iron smelting sites seems to cast doubt on this assumption (see Comparative Material, below). Several very large pieces of slag resembling broken slag blocks were seen amongst the Leda Cottages material and require further examination when cleaned.
- 1.1.13 Tap slag is a dense, low porosity, fayalitic (iron silicate) slag with a ropey flowed structure. It is formed as the liquid slag is allowed to flow out continuously or intermittently through a hole in the side of the furnace along a specially made channel into a hollow in the ground. This removal of the slag facilitated retrieval of the bloom after the smelting operation. It is believed furnaces with tap holes replaced bowl furnaces in the Roman period as their efficiency was recognised.
- 1.1.14 With so many different types of smelting slags present it is also likely that some of the broken fragments which are heterogeneous in their makeup could be smelting rather than smithing slags. These slags, like smithing slags, contain charcoal and/or wood and may be magnetic in some parts. Where this may be the case it is mentioned in the comments column of Table 5.1.
- 1.1.15 Dense slag is of low porosity and also represents smelting activity but lacks the flowed surface of tap slag.
- 1.1.16 Several pieces of ore were found in context [8020], described as the fill of a probable kiln. These require examination by a geologist to determine whether they may be ore and, if so, to determine their source.

Smithing

- 1.1.17 Slags diagnostic of iron smithing take two main forms: bulk slags and micro slags. Among the bulk slags the smithing hearth bottom is the one least likely to be confused with slags produced by smelting. Its characteristic plano-convex-shape (which can sometimes be quite large) was formed as a result of high temperature reactions between the iron, iron-scale and silica from either a clay furnace lining or the silica flux used by the smith. The predominantly fayalitic (iron silicate) material produced by this reaction dripped down into the hearth base during smithing forming smithing slag which, if not cleared out, developed into the smithing hearth bottom.
- 1.1.18 Smithing hearth bottoms were found in numerous contexts on the site, often associated with smelting slags. This implies both activities were taking place on the

site and that the blooms produced by the smelting process were being further refined before being sent elsewhere.

- 1.1.19 Iron smithing also produced micro-slags (*hammerscale*) of two types: flake and spheroidal. Flake micro-slag resembles silvery fish scales and is the product of the ordinary hot working and hammering of a piece of iron where fragments of the oxide/silicate skin flake off from the iron and fall to the ground. Spheroidal micro-slags are small solid droplets of liquid slag expelled from within the iron during the primary smithing of a bloom or the fire welding of two pieces of iron. Hammerscale is not visible to the naked eye when in the soil but is highly diagnostic of smithing activity, often remaining in the area around the anvil and near the hearth when macro-slags have been cleared out of the smithy and dumped elsewhere. Since it is generally highly magnetic, its detection with a magnet while excavating can allow the spatial relationship of the anvil to the hearth to be recorded and can pinpoint the smithing activity more precisely.
- 1.1.20 What is particularly curious about the Leda Cottages assemblage is that the small spheres which one would expect on a smelting site if blooms were being subjected to primary smithing before being taken away, are very limited, indeed almost absent. What is present is flake hammerscale, representing secondary smithing of iron which has already been prepared for manufacture into objects.
- 1.1.21 This is difficult to explain: it may be that unconsolidated blooms were being taken away for primary smithing and the flakes represent iron which was brought in for general working in the settlement. It may be that the spheres are not as magnetic as they are said to be (this author has some experience of this from some sites) and that only careful washing of slag over a very fine mesh (not flotation - spheres float away) to retrieve microslags from the adhering soil may recover more evidence. It could be, however, that we need to look again at the evidence from recent sites where smelting was taking place and to examine the (apparent) anomalies being encountered (again see Comparative Material, below).

Provenance

- 1.1.22 The most significant groups in terms of iron slag were those variously described in site information as “furnace base”, “furnace superstructure”, “kiln” or “hearth”. Group 8300, feature 8355 is described as a furnace superstructure and contexts from it (8336, 8337, 8338, 8340, 8343, and 8347) produced both smelting slags and smithing slags. Other metalworking-related features would seem to be furnace base 8011 (context 8010), hearth 8014 (context 8012) and kiln 8018 (contexts 8015, 8017 and 8020).
- 1.1.23 Some other groups in ditch fills contained substantial and interesting groups of slag but their relationship to the metalworking area(s) is not known and this needs to be looked into before further work is undertaken.

Conservation

- 1.1.24 Alkali silicate slags and fayalitic iron slags do not deteriorate and so require no special storage or treatment. It is recommended that the slag be washed over fine mesh to clean it for further research and that all residues found in the mesh from each context are carefully dried, packaged and marked so they too can be examined more closely.

Comparative Material

- 1.1.25 Two non-CTRL sites in the south-east of England (Westhawk Farm, Kent and Thorpe Lea Nurseries near Egham), both at present being studied by Sarah Paynter of

English Heritage, exhibit similarities in associated slag types to West of Leda Cottages. Both appear to have slags of “slag pit” type associated with furnace bottoms and tap slag. At least one of these smelting sites also lacks the smithing spheres which ought to be associated with primary smithing of blooms but has flake hammerscale from secondary smithing.

- 1.1.26 Beechbrook Wood - another CTRL site - also had what appeared at the time of assessment to be a slag of slag pit type (context 1080) amongst its assemblage. It too lacked micro-slag evidence for primary smithing but produced evidence for secondary smithing.
- 1.1.27 In view of these discoveries, a seminar of those involved in the study of iron working waste has been suggested very recently to discuss some of the apparent “anomalies” we are finding when examining slag from some Late Iron Age and early Roman sites.

Potential for Further Work

- 1.1.28 There is great potential for further work on the slag, especially in view of the types which appear to be present. In addition to full publication, there is a possibility that the West of Leda Cottages slag could be included in a wider research programme of metallographic analysis in the Centre for Archaeology, English Heritage. This subject should be taken up with the relevant specialists at English Heritage (contact Sarah Paynter for discussion and time-scale). In any case, the site certainly merits publication as it will be of interest nationally as well as regionally.
- 1.1.29 Before this can happen, however, the assemblage should be cleaned - particularly those groups which are associated with furnace groups and those large amounts from ditches (this includes the very large furnace bottoms from context 8510).
- 1.1.30 Spatial analysis of the slags is required and this would involve working with project staff on the field side. I will need to do integrated work on the slag types and the types of site structures they were associated with, and to look at the morphology of structural evidence of furnaces etc. This will probably require extra library research to find parallels on other sites.
- 1.1.31 The possible ores in context [8020] require examination by a geologist to determine whether they are iron ores and, if so, their source.

Table 5.1: Quantification of iron slag by context (all weights are in g; all measurements in mm.)

Context	Sample No	Identification	Weight (g)	len. (mm)	br. (mm)	dep. (mm)	Comment
8498	861	hammerscale	none				
8006	800	cinder	8				
8006	800	dense	160				
8006	800	fired clay/hearth lining	150				
8006	800	hammerscale	14				flake & some sphere
8006	800	smithing hearth bottom	218	90	70	60	
8006	800	smithing hearth bottom	390	90	70	50	
8006	800	smithing hearth bottom	502	150	75	35	
8006	800	smithing hearth bottom	526	100	90	60	
8006	800	smithing hearth bottom	648	125	90	55	
8006	800	smithing hearth bottom	1246	140	115	60	may be furnace bottom
8006	800	undiagnostic	6940				very vesicular with charcoal
8006	800	vitriified hearth lining	286				
8008	80	fired clay/hearth lining	28				
8008	80	undiagnostic	714				tiny bits
8010	802	fired clay/hearth lining	324				
8010	802	furnace bottom	6620				
8010	802	hammerscale	1				flake & some spheres
8010	802	smithing hearth bottom	868	110	90	90	broken
8010	802	tap slag	2428				
8010	802	undiagnostic	2724				poss. smelting slag
8010	802	undiagnostic	6793				some poss. "slag pit" type
8012	803	cinder	2				
8012	803	fired clay/hearth lining	220				
8012	803	hammerscale	21				flake & some sphere
8012	803	tap slag	2072				
8012	803	undiagnostic	2				very magnetic
8012	803	undiagnostic	14				smithing slag?
8012	803	undiagnostic	98				runs
8012	803	undiagnostic	2142				
8012	803	vitriified hearth lining	744				
8012		cinder	4				
8012		furnace bottom	4880				or other smelting: very large chunks
8012		hearth lining	6				
8015	804	dense	144				
8015	804	fired clay/hearth lining	733				
8015	804	hammerscale	none				
8015	804	iron stud	2				
8015	804	tap slag	2066				

Context	Sample No	Identification	Weight (g)	len. (mm)	br. (mm)	dep. (mm)	Comment
8015	804	undiagnostic	176				smithing slag?
8015	804	undiagnostic	4590				
8017	806	hammerscale	5				flake & some spheres
8017	806	tap slag	20				
8017	806	undiagnostic	14				
8017	806	undiagnostic	14				runs
8020	805	fired clay/hearth lining	604				
8020	805	ore	6				requires geolog. i.d.
8020	805	roasted ore?	8				requires geolog. i.d.
8020	805	tap slag	1144				
8020	805	undiagnostic	1284				
8022	809	charcoal	1				
8022	809	cinder	84				
8022	809	fired clay/hearth lining	49				
8022	809	hammerscale	14				lots broken flake
8022	809	smithing hearth bottom	90	60	50	20	
8022	809	smithing hearth bottom	108	70	60	20	
8022	809	smithing hearth bottom	116	60	55	35	
8022	809	smithing hearth bottom	170	80	60	35	
8022	809	smithing hearth bottom	376	90	60	60	
8022	809	tap slag	714				
8022	809	undiagnostic	4				very magnetic - roasted ore?
8022	809	undiagnostic	518				poss. smithing slag
8022	809	undiagnostic	10282				
8022	809	vitrified hearth lining	90				
8026	807	fired clay/hearth lining	979				
8026	807	hammerscale	4				flake & couple tiny spheres
8026	807	iron object	8				
8026	807	iron rod/nail	14				
8026	807	smithing hearth bottom	208	95	65	35	
8026	807	smithing hearth bottom	960	125	110	65	
8026	807	tap slag	3883				
8026	807	undiagnostic	86				runs
8026	807	undiagnostic	472				broken smithing hearth bottom?
8026	807	undiagnostic	4209				
8026	807	vitrified hearth lining	408				
8032	810	undiagnostic	24				
8050	812	tap slag	84				
8051	813	undiagnostic	4				
8051	813	undiagnostic	24				runs
8060	827	hammerscale	none				
8097	814	undiagnostic	34				
8099		undiagnostic	24				
8102	834	undiagnostic	16				

Context	Sample No	Identification	Weight (g)	len. (mm)	br. (mm)	dep. (mm)	Comment
	8117	undiagnostic	656				
	8137	hammerscale	0				broken flake; not lot
	8137	smithing hearth bottom	591	110	90	55	
	8137	undiagnostic	364				
	8137	vitriified hearth lining	86				
	8138	undiagnostic	13				
	8143	829 hammerscale	none				
	8155	819 hammerscale	none				
	8163	818 fired clay/hearth lining	8				
	8163	818 hammerscale	0				some broken flake
	8163	818 iron rich cinder	4				
	8163	818 smithing hearth bottom	122	70	45	20	
	8163	818 undiagnostic	1158				vesicular
	8184	816 fired clay/hearth lining	48				
	8184	816 sample	0				a little broken hammerscale
	8184	816 tap slag	1042				
	8184	816 undiagnostic	90				
	8184	816 undiagnostic	416				runs
	8184	816 vitriified hearth lining	10				
	8184	cinder	44				
	8184	ferruginous concretion	16				
	8184	fired clay/hearth lining	492				
	8184	smithing hearth bottom	268	80	55	40	
	8184	smithing hearth bottom	340	120	80	40	
	8184	tap slag	9				
	8184	undiagnostic	296				
	8184	vitriified hearth lining	366				
	8192	817 fired clay/hearth lining	84				
	8192	817 fuel ash slag	84				
	8192	817 hammerscale	none				
	8192	817 iron	4				
	8192	817 undiagnostic	26				
	8192	817 undiagnostic	294				smithing hearth bottom frag?
	8192	817 vitriified hearth lining	148				
	8192	fired clay/hearth lining	220				
	8192	undiagnostic	38				
	8192	undiagnostic	66				iron rich slag
	8192	undiagnostic	116				smithing slag?
	8192	undiagnostic	272				smelting?
	8205	823 undiagnostic	54				
	8215	825 hammerscale	0				virtually none
	8231	fired clay/hearth lining	104				
	8231	undiagnostic	156				
	8231	undiagnostic	648				smithing slag?

Context	Sample No	Identification	Weight (g)	len. (mm)	br. (mm)	dep. (mm)	Comment
8243		fired clay/hearth lining	946				
8243		hammerscale	none				
8243		iron	6				
8243		smithing hearth bottom	234	70	60	35	
8243		smithing hearth bottom	1042	100	100	70	
8243		undiagnostic	32				smithing slag?
8243		undiagnostic	54				
8243		undiagnostic	560				runs
8248		cinder	16				
8248		undiagnostic	16				
8281	842	hammerscale	none				
8281		tap slag	852				
8309	836	fired clay/hearth lining	24				
8309	836	hammerscale	0				broken flake & 1 sphere
8309	836	undiagnostic	88				
8313	839	hammerscale	none				
8313	839	undiagnostic	24				
8313	839	undiagnostic	72				runs
8313		enamel frit	2				
8313		fired clay/hearth lining	74				
8313		undiagnostic	582				runny
8322	837	hammerscale	none				
8324	838	hammerscale	none				
8324	838	hammerscale	none				
8330	840	hammerscale	none				
8332	841	hammerscale	none				
8336	845	hammerscale	0				some broken flake
8336	845	undiagnostic	1598				heterogeneous
8336	845	vitriified hearth lining	1788				
8336		cinder	98				
8336		fired clay/hearth lining	236				
8336		undiagnostic	116				runs
8336		undiagnostic	330				broken SHB/furnace bottom
8336		vitriified hearth lining	820				
8337	846	hammerscale	0				1 sphere
8337	846	sample	0				charcoal & tiny silica runs
8337	846	sample	0				hammerscale: broken flake and 1 small sphere
8337	846	undiagnostic	278				
8337	846	undiagnostic	668				runs
8338		fired clay/hearth lining	46				
8338		undiagnostic	98				
8338		vitriified hearth lining	12				
8340		hammerscale	0				1 tiny sphere
8340		undiagnostic	182				
8340		undiagnostic	4930				large runs
8343	847	hammerscale	0				some flake & sphere, not lot

Context	Sample No	Identification	Weight (g)	len. (mm)	br. (mm)	dep. (mm)	Comment
	8343	undiagnostic	156				
	8343	undiagnostic	34				
	8343	undiagnostic	522				large runs
	8345	tap slag	524				
	8345	undiagnostic	676				smelting runs?
	8345	undiagnostic	1002				furnace slag
	8347	undiagnostic	260				runny
	8347	undiagnostic	436				
	8353	tap slag	326				
	8353	undiagnostic	16				
	8357	furnace bottom	1940	150	80	70	broken
	8364	cinder	106				
	8364	tap slag	74				
	8364	undiagnostic	60				smithing slag?
	8364	undiagnostic	150				
	8369	849 hammerscale	0				some broken flake
	8370	850 sample	0				a little hammerscale
	8370	daub	40				
	8370	fired clay/hearth lining	1				
	8370	stone?	82				
	8370	undiagnostic	38				smithing slag?
	8370	undiagnostic	66				
	8377	851 hammerscale	none				
	8380	852 hammerscale	none				
	8380	tap slag	206				
	8380	undiagnostic	28				
	8381	853 hammerscale	0				virtually none
	8387	854 hammerscale	none				
	8389	ferruginous concretion	220				
	8405	furnace bottom	1836				110mm high
	8405	smithing hearth bottom	292	100	60	45	
	8405	smithing hearth bottom	372	105	75	40	
	8405	tap slag	176				
	8405	undiagnostic	368				like smithing slag
	8405	undiagnostic	1018				
	8405	vitriified hearth lining	26				
	8441	856 hammerscale	none				
	8443	857 hammerscale	none				
	8445	858 hammerscale	none				
	8445	undiagnostic	576				
	8447	959 undiagnostic	144				
	8498	fired clay/hearth lining	88				
	8498	smithing hearth bottom	244	80	60	45	
	8498	undiagnostic	576				
	8499	860 hammerscale	none				
	8499	undiagnostic	1164				
	8510	bloom fragment?	300				very magnetic iron lump
	8510	dense	260				

Context	Sample No	Identification	Weight (g)	len. (mm)	br. (mm)	dep. (mm)	Comment
8510		fired clay/hearth lining	268				grey: furnace lining
8510		furnace bottom	3708	190	160	110	dirty
8510		furnace bottom	9979	250	200	140	
8510		furnace bottom	14520	310	270	180	dirty
8510		hammerscale	0				some broken flake
8510		tap slag	568				
8510		undiagnostic	938				
8510		undiagnostic	946				furnace bottom fragment?
8510		undiagnostic	1354				prob. smelting with runs
8510		undiagnostic	2270				vesicular with charcoal
8510		vitriified hearth lining	152				
8514		ferruginous stone	190				
8514		furnace bottom	6395	190	180	130	
8514		smithing hearth bottom	314	60	60	40	
8514		smithing hearth bottom	620	110	80	55	
8514		undiagnostic	544				smithing slag?
8514		undiagnostic	1782				heterogeneous makeup
8514		vitriified hearth lining	874				
8519		undiagnostic	68				
8520		fired clay/hearth lining	10				
8520		undiagnostic	44				
8523		undiagnostic	228				
8528		undiagnostic	492				
8530		undiagnostic	13				smithing slag?
8535	862	hammerscale	none				
8539		fired clay/hearth lining	6				
8539		tap slag	50				
8539		undiagnostic	90				
8560		furnace bottom	3500	230	190	120	dirty
8560		furnace bottom	5453	280	220	100	dirty
8563	863	hammerscale	none				
8579	865	hammerscale	none				
8580	864	sample	0				hammerscale flake
8580	864	sample	0				small runs