APPENDIX 1 – ASSESSMENT OF THE IRON SLAG

1.1 Iron Slag

By Lynn Keys

Introduction

1.1.1 A quantity of material identified as iron slag was recovered during excavation. Most of the material was collected by hand. None of the slag had been washed before assessment. Numerous soil samples were taken in a grid pattern from the metalworking area, which often contained broken hammerscale (a micro-slag produced by iron smithing). The slag was collected to determine the type of metalworking and the area where it had taken place.

1.1.2 Activities involving iron can take two forms:

I) - The manufacture of iron from ore and fuel (and, in later periods, a flux) 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.

II)- a) *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. b) *Secondary smithing* (hot working) of an iron shape by a smith to turn it into a utilitarian object or to repair it.

1.1.3 The two activities - smelting and smithing - generate slags, some of which are diagnostic of the process being carried out and others which are not.

1.1.4 This assemblage was recorded in accordance with the original Fieldwork Event Aims (see Section 2.2), in particular aims 6, 11 and 13.

Methodology

1.1.5 At assessment approximately 80% of the whole assemblage was examined and was categorised on the basis of morphology and colour. As no cleaning had taken place before assessment the slag was covered with dirt and occasionally identification of small fragments was difficult.

1.1.6 Each type of slag from each context examined was weighed and recorded. Smithing hearth bottoms were individually weighed and each was measured to obtain its length, width, and depth. Most of the soil samples were opened, some being emptied onto a tray, and examined for hammerscale and other micro-slags by running a magnet through the contents.

1.1.7 Contexts across the site were examined and quantified. However, since it was evident from the amount of slag in particular contexts that most came from the vicinity of a building in the north-east of the site, particular emphasis was placed on the slag from this area as the most important group and more of it was examined.

Quantifications

1.1.8 The total amount of slag examined and quantified was over 48 kg. The breakdown by context of each type and its total weight is given in Table 7.1.1.

Table 7.1.1: Quantification of all slag examined (measurements in mm)

ARC WHS98		**White Horse Stone**					
Context	**Sample**	**Identification**	**Weight (g)**	**Length**	**Breadth**	**Depth**	**Comment**
2016	3	Smithing hearth bottom	140	65	55	20	
2225		Undiagnostic	58				
4068		Smithing hearth bottom	540	125	95	40	
4123	44	Smithing hearth bottom	804	125	80	60	
4130		Undiagnostic	2				
4318		Undiagnostic	26				
4360		Undiagnostic	6				Possibly smithing
4508		Ore?	64				
4581	254	Undiagnostic	133				
4581		Undiagnostic	10				Runs
4583		Undiagnostic	46				
4860	378	Undiagnostic	34				
6096		Undiagnostic	10				
7006	730	Hammerscale	0				Broken flake
7008	540	Hammerscale	0				Broken flake
7008	540	Smithing hearth bottom	76	70	50	20	
7008	540	Undiagnostic	1218				Some with ore?
7008	735	Smithing hearth bottom	72	60	55	20	
7008	735	undiagnostic	308				Possibly smelting
7008	736	hammerscale	0				
7008	736	undiagnostic	932				
7010		Chalk	4				
7010		Smithing hearth bottom	60	70	50	15	
7010		Smithing hearth bottom	180	100	60	30	
7010		Undiagnostic	256				
7010		Vitrified hearth lining	90				
7012	696	Undiagnostic	10				
7012		Stone	12				
7012		Undiagnostic	134				
7013	650	Hammerscale	94				Large flakes and magnetic clay
7013	650	Non-ferrous waste	1120				
7013	650	Smithing hearth bottom	62	55	55	30	
7013	650	Undiagnostic	1436				
7013	650	Vitrified hearth lining	In above				Some with a green glassy surface
7013		Ore?	102				
7013		Smithing hearth bottom	80	70	50	15	
7013		Smithing hearth bottom	226	110	70	30	
7013		Smithing hearth bottom	862	115	100	40	
7013		Undiagnostic	850				
7013		Vitrified hearth lining	100				
7014	732	Soil, little hammerscale	0				
7015	541	Daub	2				
7015	541	Smithing hearth bottom	30	75	35	10	

ARC WHS98		White Horse Stone					
Context	**Sample**	**Identification**	**Weight (g)**	**Length**	**Breadth**	**Depth**	**Comment**
7015	541	Smithing hearth bottom	102	90	45	30	
7015	541	Smithing hearth bottom	110	80	55	20	
7015	541	Undiagnostic	18				
7015	541	Undiagnostic	3308				
7015	733	Smithing hearth bottom	84	75	50	20	
7015	733	Smithing hearth bottom	116	70	65	20	
7015	733	Smithing hearth bottom	284	80	90	45	very hard with sharp surfaces
7015	733	Undiagnostic	410				
7015	734	Hammerscale	0				Broken flake
7015	734	Smithing hearth bottom	152	85	50	30	
7015	734	Smithing hearth bottom	258	125	65	40	
7015	734	Undiagnostic	642				
7015	734	Undiagnostic	1462				
7016	737	Hammerscale	0				Sphere
7016	737	Undiagnostic	22				
7016	738	Undiagnostic	8				
7030	720	Undiagnostic	6				
7030	721	Undiagnostic	22				
7071		Flint	34				
7071		Smithing hearth bottom	804	160	80	60	
7071		Undiagnostic	442				
7071		Vitrified hearth lining	136				
7073		Smithing hearth bottom	68	65	50	25	
7073		Undiagnostic	106				
7073		Vitrified hearth lining	48				
7079		Hammerscale	0				
7079		Smithing hearth bottom	116	80	40	25	
7079		Smithing hearth bottom	148	80	45	40	
7079		Smithing hearth bottom	166	90	65	20	
7079		Smithing hearth bottom	188	75	65	40	
7079		Smithing hearth bottom	248	105	70	35	
7079		Smithing hearth bottom	344	95	75	50	
7079		Smithing hearth bottom	482	100	80	40	
7079		Smithing hearth bottom	506	110	100	40	
7079		Smithing hearth bottom	660	95	80	80	
7079		Smithing hearth bottom	732	110	70	80	
7079		Undiagnostic	10652				
7079		Vitrified hearth lining	560				Some with green glaze
7080	681	Undiagnostic	2012				
7080		Fayalitic runs	70				
7080		Hammerscale	0				Broken flake
7080		Lightly fired daub	42				

ARC WHS98		White Horse Stone					
Context	Sample	Identification	Weight (g)	Length	Breadth	Depth	Comment
7080		Smithing hearth bottom	42	55	40	30	Broken flint present in slag
7080		Smithing hearth bottom	50	50	45	10	
7080		Smithing hearth bottom	104	65	65	20	
7080		Smithing hearth bottom	106	65	50	20	
7080		Smithing hearth bottom	162	75	55	40	
7080		Smithing hearth bottom	168	75	65	20	
7080		Smithing hearth bottom	238	85	50	50	
7080		Smithing hearth bottom	276	85	50	50	
7080		Smithing hearth bottom	278	80	70	25	
7080		Smithing hearth bottom	294	85	85	30	
7080		Smithing hearth bottom	302	75	60	65	
7080		Smithing hearth bottom	306	95	75	55	
7080		Smithing hearth bottom	328	10	65	40	
7080		Smithing hearth bottom	388	105	80	30	
7080		Smithing hearth bottom	408	45	45	15	
7080		Smithing hearth bottom	452	110	70	45	
7080		Smithing hearth bottom	462	65	45	65	
7080		Smithing hearth bottom	752	10	70	100	
7080		Smithing hearth bottom	948	135	100	80	
7080		Smithing hearth bottom	1118	140	110	85	
7080		Stone	204				
7080		tap slag	342				
7080		Undiagnostic	2912				
7080		Vitrified hearth lining	24				
7138		Smithing hearth bottom	100	80	55	25	
7138		Undiagnostic	102				
7152		Smithing hearth bottom	142	80	70	25	
7152		Undiagnostic	124				
7152		Vitrified hearth lining	50				
7202	905	Hammerscale	0				Broken flake
7203	901	Undiagnostic	0				Examined, not weighted
7204	900	Soil, little hammerscale	0				
7204	903	Hammerscale	1000				Flake
7204	903	Smithing hearth bottom	82	70	55	10	

1.1.9 From Table 7.1.1 above it will be seen that much of the slag had to be allocated to the *undiagnostic* category, either because its production by either smelting or smithing could not be determined, or that it was too small for its original form to be suggested.

1.1.10 Smithing hearth bottoms are a type of slag highly diagnostic of smithing activity.

1.1.11 They were the result of high temperature reactions between the iron, iron-scale and silica from either a clay furnace lining or a 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 slag which, if not cleared out, developed into the characteristic plano-convex-shaped smithing hearth bottom in front of and below the tuyère (the hottest part of the hearth). Over a period of time, depending on how frequently smithing took place, the hearth bottom would continue to grow and could eventually impede the air flow from the bellows or greatly reduce the area of working. At this stage, or whenever a hearth was cleared out, its hearth bottom was discarded.

1.1.12 Outside the north-east area smithing hearth bottoms were rare, but within the pits containing slag they were numerous, pit 7009 having a large number (38) relative to the other slags present. The following table gives details of the hearth bottoms examined:

Table 7.1.2: Metrical details of the hearth bottoms examined

	Range	**Mean**	**Std deviation**
Weight (g)	30-118	300	264
Length (mm)	50-160	84	28
Width (mm)	35-110	64	17
Depth (mm)	10-100	37	21

1.1.13 Hammerscale is a micro-slag not visible to the naked eye when in the soil but it 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. It consists of two types: flake (resembling silver fish scales) and sphere (tiny balls). Each type is diagnostic of different types of smithing.

1.1.14 The presence of hammerscale, mainly broken flake, in the soil samples reveals that the smithing activity consisted mainly of simple hot hammering of pieces of iron to produce objects or repair them. Very little high temperature welding (to join two pieces of iron) was taking place.

1.1.15 Tap slag is a dense, low porosity, fayalitic (iron silicate - 2FeO.SiO2) slag with a ropy flowed structure rather like lava. It is generally thought to be the type of slag produced by the type of smelting furnace introduced during the Roman period or just before, so its presence in early Iron Age contexts is unusual. The characteristic structure of tap slag is the result of the liquid slag being allowed to flow out through a hole at the bottom of the smelting furnace. At the present time, however, discussion is taking place among archaeometallurgists as to whether slag tapping may have been introduced before the Roman occupation.

1.1.16 Another type of smelting furnace had a pit below in which the slag was allowed to collect, rather than being tapped out of the furnace. The distinct slag produced by this furnace is called a slag block. The example in context 7080 may well be an extremely large, but broken, smithing hearth bottom since no other examples were evident during the assessment.

1.1.17 Two contexts produced fragments of what may be iron ore (4508 and 7013). As no other examples were found these may represent pieces naturally present in the area.

Provenance

1.1.18 Most of the iron slag found on the site was from pits in the vicinity of the Early Iron Age building in the north-east of the site. Although the floor levels were not preserved, the presence of such a large percentage of iron slag in this area, combined with the presence of hammerscale, seem to indicate that the building may have served as a smithy for a period of time.

1.1.19 The pits (and their fill contexts numbers) most productive of slag were as follows:

pits:	**7007**	**7009**	**7011**
contexts:	7008	7010	7012
	7014	7013	7152
	7015	7079	
	7016	7080	
		7080	

1.1.20 Pit 7009 also produced the small amount of possible smelting slag and ore.

1.1.21 Groups from elsewhere on the site will probably not merit as much attention, although information on all contexts with slag was not available at the time of assessment. The small amounts recovered from the four-post buildings on the site are not significant and may be redeposited material.

1.1.22 The slag, although unwashed, is stable and unlikely to be affected by any factors of preservation.

Conservation

1.1.23 Iron slag, being fayalitic, requires no special storage conditions and is unlikely to be affected by further analysis. Decisions as to whether the assemblage can be discarded should only be made after more detailed work on the assemblage has been carried out and other relevant CTRL sites with iron slag have been examined and assessed.

Comparative material

1.1.24 Until recently very few smithies of any period had been identified. This picture is now changing, as techniques to recover more diagnostic evidence become better known. The dating of the ironworking contexts to the early Iron Age and the possible location of a smithing building makes this a nationally significant site for ironworking.

Potential for further work

1.1.25 This material has the potential to address themes concerning chronology, settlement, landscape and society (status, settlement organisation) and material culture (source of iron ore, methods of production and use).

Updated research aims

Chronology

- When does ironworking first appear at White Horse Stone? How long does the metalworking site continue in use? The date of this activity is at present uncertain: The pottery dating evidence from the associated features suggests an early-middle Iron Age date, but the presence of tap slag may suggest a later date. Radiometric dating of abundant charred material used as fuel has the potential to fulfil this objective.

Settlement, landscape and society

- What is the character of the ironworking debris from the Iron Age settlement? What range of material occurs and what activities do these represent? How does the distribution of this material relate to the possible post-built structure and pits?

Material culture

- What is the source of the iron from the iron working area and iron artefacts from cremation group 6131?
- Metalworking residues - A key question is the extent to which the residues are in situ and to what extent do they support the suggestion that a smithy was located on the site?.
- Technological aspects of Iron Age metalworking may be studied in relation to raw materials, smelting, smithing and finished metal artefacts. Further analysis may include metallographic analysis, which will provide information on the efficiency of the production processes and quality of the final product. Detailed description and quantification of the various residues (smithing slag, smelting slag, hammerscale, hearth bottoms, hearth lining, tap slag) will shed light on the relative importance of the activities represented and production processes. Further information may be supplied by considering patterns of disposal and the function of the features found in association with the metalworking residues.

Recommended further work

1.1.26 It is essential to ensure the dating of the ironworking contexts is definitely early Iron Age and not later as the site's significance rests on this.

1.1.27 The above updated research questions may be addressed by a programme of detailed recording, designed to assist analysis of the types of material associated with smithying activity. Any other iron objects found in the pits containing slag may provide evidence of the type of objects being repaired or manufactured.

- The possible iron ore identified during the assessment along with any further material found during recording will be subjected to petrological analysis in an attempt to identify probable sources.
- Spatial distribution, associations with pottery and other artefact groups and patterns of deposition will be examined to address research aims related to settlement, landscape and society concerning the organisation of the open settlement at White Horse Stone.