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Crucibles, Moulds and Slag from Whitehall Farm, Kelk, E. Yorkshire

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Introduction

Partial excavation of the Iron Age Enclosure at Whitehall Farm, Kelk, E. Yorkshire (NGR TA 108 601) was undertaken by the Centre for Wetland Archaeology. This was part of the ongoing Humber Wetlands archaeological survey and followed field walking, a topographical survey and a geophysical survey using magnetometers of the 2.9ha site (Linford 1998). One large Stewart box of metal working debris weighing about 0.8kg was recovered from the site and sent to the English Heritage Centre for Archaeology for analysis.

Objectives

In examining and analysing the material from Kelk, the following questions had to be considered (Fletcher, forthcoming).

1. What metal working debris is there and what is the distribution over the site?
2. How does the material compare with similar assemblages from other locations?
3. What is the archaeological importance of this material and what is the full potential of this material?

Background to Site

The site of Kelk is a small, three sided, double ditch enclosure. It lies on glacial till and is thought to be Iron Age in date from the artefact assemblage, though some Roman pottery was found from field walking. The site lies adjacent to the area that would originally have been a river channel for the River Hull and is thought to be part of a lowland Iron Age landscape.

Examination and interpretation of the metalworking debris

All the material was visually examined and classified into the standard categories used by the English Heritage Centre for Archaeology. Classification can vary between specialists and the terms used are explained below. The total numbers of fragments examined are listed in the table below. Each find was given a Lab ID number to make identification of individual finds easier. These are given in a full listing of finds in Appendix 1.

Table 1 Metallurgical debris from Whitehall Farm, Kelk, E. Yorkshire

Interpretation	Fragments
crucible fragments	11
fuel ash slag	15
mould fragments	34
sprue cup fragments	6
fired clay	7
total	73

Explanation of classification

Crucibles are the vessels in which metal is melted so it can then be poured into a **mould**. They are made of clay in various forms. During the Iron Age a triangular form is very common; they are found on many sites across lowland Britain (Bayley 1989, 292).

Fuel ash slag is a lightweight and light-coloured material. It can, but need not, be produced during metalworking activities. Such slag can also be derived from accidental high temperature fires or processes such as cremation and firing ceramics.

Moulds are the containers in which metal objects are cast. They take many forms and can be made from a variety of materials. The identifiable mould fragments from Kelk appear to be from investment or lost wax moulds. This technique involves making a wax model that is then covered in clay, forming the mould. The mould is then heated and the wax poured out, leaving a fired clay mould for the metal to be poured into. Once the metal has been poured into the mould and has cooled, the mould is then broken open to reveal the metal object. The destruction of the mould means that each one can only be used once and accounts for the fragmentary state of the moulds when they are found archaeologically.

Sprue cups are easily identifiable parts of moulds. They are the funnel shaped hollows at the top of the mould into which the molten metal is poured. Sprue cups form an integral part of an investment mould, being connected to runners which feed the molten metal into the area of the mould where the object being cast is formed.

Fired clay is clay that has been fired but shows no sign of being deliberately shaped. It is possible that the clay performed some function such as being part of a hearth or daub. It is equally possible that the clay has been accidentally fired.

Methodology

Following the careful examination of all finds their surfaces were analysed non-quantitatively by X-ray fluorescence (XRF) analysis to identify the types of metal that had been in contact with them. XRF is a non-destructive technique. It works on the principle that every element will generate its own slightly different characteristic X-rays when bombarded with X-rays from a source. By identifying these secondary characteristic X-rays, elements present within a material can be identified. However, quantitative analysis of material is difficult by this method due to a number of factors.

The proportions of metals found within crucibles and moulds depend both on the original compositions of melt and their chemical nature. Elements such as zinc are very volatile and so diffuse into the crucible or mould walls (Bayley 1992, 817-8). When analysed it is well represented even if originally it only formed a very small part of the melted metal (Barnes, no date). Analysis of moulds can be difficult, and often even when a mould has been used for casting no trace of metal is detected. This is due to the relatively short period of time that the mould is in contact with the molten metal (Wilthew et al 1991, 142).

Results

Only low levels of metals were detected on most finds. This indicates a skilled craftsman was at work, but means that positive identification of the alloys worked are even more difficult than usual.

Crucibles

Crucible rim (Lab ID6) was from a deep vessel, probably triangular though not enough survives to be able to confirm this. The fabric of this crucible was very fine with a large amount of fine quartz sand temper. It was a grey colour indicating that it had been heated under reducing conditions. It shows signs of light vitrification and some bloating at the rim edge indicating that the crucible had been heated from above. XRF analysis of the crucible showed it had been used for copper alloy melting.

Two rim fragments (Lab ID's 4,5) joined (see Figure 1, Appendix 2). The form appeared to be a hybrid, with features of both shallow Iron Age triangular crucibles, like those from Gussage All Saints (Spratling 1979, 125-49), and of early Roman hemispherical crucibles like those from Colchester Castle (Bayley 1984, 45-50) and was similar to that from Sutton Walls (Tylecote 1986, 96-97). The estimated maximum capacity of the crucible was 30ml. The fabric was very heavily tempered with quartz sand, with slightly larger occasional fragments of quartz. The crucible was grey in colour indicating heating under reducing conditions. It was not possible to identify the composition of the alloy that had been melted in the crucible.

Three fragments (Lab ID's 2, 10, 11) join forming the pouring spout of a triangular crucible similar to the form from Gussage All Saints (Spratling 1979, 125-49) (see Figure 2, Appendix 2). The fabric contains large amounts of quartz sand. A small amount of grog (ground up pottery) also appears to have been used as temper. The crucible was grey, indicating it had been heated under reducing conditions. Like the other crucibles, it is possible to say this crucible was used for melting copper alloys but their exact composition is unclear.

One other crucible fragment (Lab ID 1) survives. The rim fragment fabric was, like the majority of the crucibles, a heavily fine-grained quartz-tempered fabric. The crucible appeared to have been heated under reducing conditions. Although there were no traces of copper detected, it is likely that this crucible had been used for copper alloy melting. The high volatility of zinc and arsenic compared with copper caused these elements to become trapped in the fabric and so enhanced their detection.

Three very small fragments (Lab ID's 7, 8,9) all of the same fabric were originally thought to be from a crucible. The fabric included a few very small quartz grains and a few grog particles as well. The fragments were too small and abraded to allow an original form to be identified. They had been heated under oxidising conditions. The largest of the fragments (c.18x17mm) showed slight traces of zinc whilst the other two fragments showed no traces of any non-ferrous metal suggesting they were not crucible fragments.

One sherd (Lab ID 3) had also been thought to be from a crucible. However XRF analysis found no traces of non-ferrous metals, and it is concluded that the object was a piece of pottery. There was much less temper in this pot than in the crucibles and a much higher proportion of grog with only slight amounts of quartz present. This pot had been fired under oxidising conditions.

All the positively identified crucibles from the site appeared to be hand made and were of forms typical of the late Iron Age (Bayley 1989, 293-4). No visible traces of metal survived on the surfaces, some of which had been heavily abraded. Zinc was detected on most crucibles sometimes at high levels. However this does not necessarily mean that zinc was a significant component of the alloy being melted.

The fabric of most of the crucibles seems to be similar to that of crucible Fabric 2 from Gussage All Saints with the high content of very fine-grained quartz sand as the temper (Howard 1980). However, the crucibles are not heavily vitrified like many of the crucibles from Gussage All Saints.

Slag

The majority of slag recovered from Kelk was fuel ash slag. It is unlikely to derive from metalworking activities though slight traces of copper were found in one piece and slight traces of zinc in another. This was probably due to post-depositional contamination from the soil as only two fragments from the same context had slight traces of metals present. The slag is most likely to have formed in an accidental fire.

One fragment of hearth lining (Lab ID 58) was recovered, which showed slight traces of copper. It is a heavily glazed piece of clay and probably came from close to the tuyère which is the hole in a furnace or hearth through which bellows are connected to provide a controlled air supply into the fire. No other slag was recovered from the excavation.

Moulds and sprue cups

The 40 mould fragments from the site are of mixed quality. On ten of these mould fragments, it is possible to identify parts of the object being cast. In addition, there were six sprue cup fragments. The remaining fragments are thought to be from investment moulds, but no specific detail or original surface survives. All the mould fragments are partially reduced fired (near the inner surfaces) and partially oxidised fired; typical firing patterns of clay moulds. The fabric of the moulds can be split into two groups. There were 13 mould fragments of Fabric 1 which has very fine quartz sand temper similar to that of the crucibles' fabric but there was much less temper in the moulds. Fabric 2 has much coarser sand with fragments of coarse quartz sometimes up to 3mm in size. There are also grains of mica present. Again, there is less temper present than in the crucibles. Very few traces of finer materials on the inner surface of the moulds were noticed, as were seen at Gussage All Saints (Foster 1980, 39). Their scarcity was probably due to the heavily abraded condition of many of the moulds. There were 27 mould fragments of Fabric 2, including all the sprue cups. These fabrics are very similar to those found at Weelsby Avenue, Grimsby (Foster 1995).

The mould fragment (Lab ID 19) appeared on initial examination to be the inner part of a terret mould similar to some of those from Gussage All Saints (Foster 1980, 12-3). However, on closer examination it became apparent that a channel ran from one corner through the middle of the mould. For any metal object to have been removed from this mould it would have had to be further broken, thus suggesting that this mould was either unused or had contained a failed casting. The mould appears to have been for a ring with another ring running on it, similar to a bridle link (see figure 3, Appendix 2 for mould and reconstruction of casting). There is a slight decoration on the edge of the curved part of the mould. The pattern, of hatched design, has broken off. It was impossible to run XRF analysis on any surface that would have been in contact with the metal cast due to the complex shape of the mould. This mould was of Fabric 1.

Two mould fragments (Lab ID's 24, 25) appear to be parts of moulds for flat bars. They may have traces of relief decoration but much of the original surface has been heavily abraded. The width of the bar from the large fragment would have been about 23mm. Both moulds have traces of zinc detected by XRF, indicating that they were probably used for copper alloy casting. Both fragments were of Fabric 1.

One mould fragment (Lab ID 23) is a round loop shape (see Figure 4, Appendix 2). It was difficult to run XRF analysis on any surface that would have been in contact with metal and no traces of metals were found. Another of the moulds from this context (Lab ID 20) had a very slight circular depression (diameter 17mm) which had been heavily abraded. This mould showed traces of zinc surviving, probably indicating a copper alloy had been cast in it. Lab ID's 20-23 are of Fabric 2.

Six mould fragments of interest were found in Context 312, Small Find 9. The first is for a decorative terminal (Lab ID 30) (see Figure 5, Appendix 2). This mould had traces of zinc present on the surfaces in contact with the metal. The second mould (Lab ID 48) has a small circular depression (diameter 9mm) and is similar to stop knob end moulds from Gussage All Saints (Spratling 1979, 138-40). The mould would have been used to make a pin that was then attached to an end of a bar to stop it sliding too far through a loop on equipment such as bridles (Foster 1980, 18). This mould (of Fabric 1) showed traces of zinc, copper and possibly of lead indicating that a copper alloy had been cast in it.

Two further mould fragments (Lab ID's 27, 32) appear to be from the outer edges of plain terret moulds. They are not from the same mould as Lab ID 19 as the diameter of the castings are slightly different, but may be from a mould of this shape rather than a standard terret mould. They are both of Fabric 1.

The last two fragments (Lab ID's 45, 46) join to form a small shape like a boat. No trace of non-ferrous metals could be identified on these fragments but this is probably due to the lack of original surfaces. These fragments are of Fabric 2.

Perhaps the most diagnostic pieces of moulds found at Kelk were the remains of sprue cups (Lab ID's 68-73). In total six fragments were found, all of which were Fabric 2. One survives almost complete (Lab ID 73) (see figure 6, Appendix 2). This sprue cup along with three other fragments showed clear signals of zinc being present from XRF analysis. Two of these fragments (Lab ID's 70, 71) also had traces of copper. Lab ID 70 has a droplet of metal surviving on the surface. The last fragments (Lab ID's 68,69) showed no metal traces under XRF analysis. Like the sprue cups from Gussage All Saints, the runners appear to be circular (Foster 1995, 51).

Fired clay

The fired clay was examined and showed no signs of having been moulded. The clay had occasional large stones and chips of quartz included, but did not appear to be heavily processed. Two fragments (Lab ID's 17, 18) showed slight zinc contents perhaps indicating that the clay had been heated in close proximity to the copper alloy processing. There was no other indication to suggest that the clay had been used in a metal working process.

Conclusions

The analysis of material from Whitehall Farm, Kelk indicates non-ferrous metalworking, most probably bronze casting, occurred on the site. Although much of the collection is heavily abraded, it is potentially an important group of material. It is the only known collection of non-ferrous metal working debris from the Wolds area of Yorkshire from this period. It is difficult to establish the type of equipment that has been cast on this site due to the poor surface survival of the moulds. It is unlikely that production on the scale of Gussage All Saints or Weelsby Avenue, where several thousand mould fragments were found, was occurring as there are only a few fragments surviving (Foster 1995, 58). However both at Gussage All Saints and Weelsby Avenue the majority of metal working debris was found in a single pit or ditch (Foster 1980, 7; 1995, 49). It is possible that a similar pit or ditch exists at Kelk, which has not been excavated. The finds represent a minimum of 10 moulds and 4 crucibles but there is currently not enough material to suggest major production was occurring. However, non-ferrous metalworking occurred on this site, as there are too many finds for them just to be stray finds. It is possible that these finds do not represent their original dumping place but have been redeposited, accounting for their sparse distribution. Further excavations might resolve these problems.

Ceramic Material, not associated with metalworking debris

Pot from three contexts; context 026, context 028 small find 2 and context 028/032, were also sent to the English Heritage Centre for Archaeology. The potsherds all had traces of organic residues present. Unfortunately, analysis of these residues could not be undertaken, as suitable equipment was not available. If further excavations or research were to occur at Kelk, it would be worth getting them analysed, especially if further pots with organic residues are discovered.

Acknowledgements

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Appendix 1

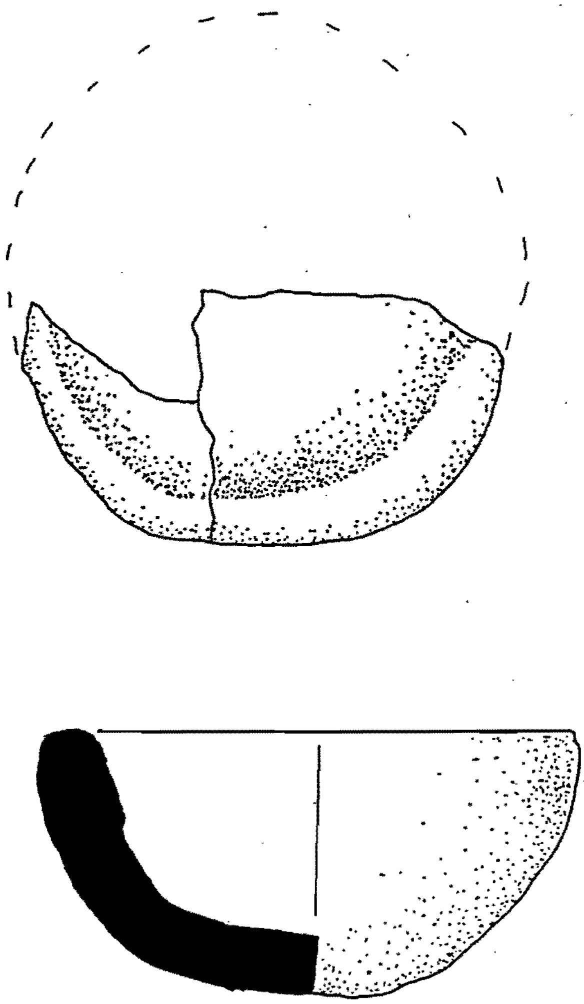
Lab ID No	context	key-id	material	quantity	Elements detected by XRF
1	304	TA108601.BU	crucible	1	Zn, ?As
2	314	TA108601.BY	crucible	1	Zn, Cu, ?As
3	328	TA108601.CC	?crucible	1	-
4	19-23?	TA108601.BH	crucible	2	Zn, Cu
5	19-23?	TA108601.BH	crucible		Zn
6	28/32?	TA108601.BN	crucible	1	Zn, Cu, Sn
7	312 9	TA108601.BX	crucible	5	Zn
8	312 9	TA108601.BX	crucible		-
9	312 9	TA108601.BX	crucible		-
10	312 9	TA108601.BX	crucible		Zn, Cu
11	312 9	TA108601.BX	crucible		Zn, Cu
12	318	TA108601.BZ	fired clay	1	-
13	328	TA108601.CC	fired clay	1	-
14, 15, 16	333/332	TA108601.CE	fired clay	5	-x3
17, 18	333/332	TA108601.CE	fired clay		Znx2
19	26	TA108601.BI	mould frag.	1	-
20	312	TA108601.BW	mould frag.	4	Zn
21	312	TA108601.BW	mould frag.		-
22	312	TA108601.BW	mould frag.		Zn
23	312	TA108601.BW	mould frag.		-
24	314	TA108601.BY	mould frag.	2	Zn
25	314	TA108601.BY	mould frag.		Zn
26	318	TA108601.BZ	mould frag.	1	-
27	312 9	TA108601.BX	mould frag.	25	-
28	312 9	TA108601.BX	mould frag.		Zn, Cu, ?Pb
29	312 9	TA108601.BX	mould frag.		Zn
30	312 9	TA108601.BX	mould frag.		Zn
31	312 9	TA108601.BX	mould frag.		Zn, Cu
32	312 9	TA108601.BX	mould frag.		-
33	312 9	TA108601.BX	mould frag.		Zn
34	312 9	TA108601.BX	mould frag.		Zn
35	312 9	TA108601.BX	mould frag.		Zn, Cu
36	312 9	TA108601.BX	mould frag.		Zn
37	312 9	TA108601.BX	mould frag.		-
38	312 9	TA108601.BX	mould frag.		-
39	312 9	TA108601.BX	mould frag.		-
40	312 9	TA108601.BX	mould frag.		Zn, Cu
41	312 9	TA108601.BX	mould frag.		Zn, Cu
42	312 9	TA108601.BX	mould frag.		Zn, Cu
43	312 9	TA108601.BX	mould frag.		Zn
44	312 9	TA108601.BX	mould frag.		Zn

45	312 9	TA108601.BX	mould frag.		-
46	312 9	TA108601.BX	mould frag.		-
47	312 9	TA108601.BX	mould frag.		Zn
48	312 9	TA108601.BX	mould frag.		Zn, Cu, ?Pb
49	312 9	TA108601.BX	mould frag.		Zn
50	312 9	TA108601.BX	mould frag.		no XRF done, fragment too small
51	312 9	TA108601.BX	mould frag.		no XRF done, fragment too small
52	333/332	TA108601.CE	mould frag.	1	-
53, 54, 55, 56	306	TA108601.BV	slag	5	-x4
57	306	TA108601.BV	slag		Cu
58	314	TA108601.BY	slag	1	Cu
59	328	TA108601.CC	slag	1	-
60, 61, 62, 63, 64, 65	333/332	TA108601.CE	slag	7	-x6
66	333/332	TA108601.CE	slag		Zn
67	UNSTRAT		slag	1	-
68, 69	312 9	TA108601.BX	sprue cup	6	-x2
70	312 9	TA108601.BX	sprue cup		Zn, Cu
71	312 9	TA108601.BX	sprue cup		Zn, Cu
72	312 9	TA108601.BX	sprue cup		Zn
73	312 9	TA108601.BX	sprue cup		Zn

Key to XRF data	
All elements are listed in order of decreasing XRF signal strength.	
This does not directly relate to their original abundance.	
? A possible trace of this element was detected	
-	No metallic element detected
Zn	Zinc
Cu	Copper
Pb	Lead
Sn	Tin
As	Arsenic

Appendix 2 – Figures (Scale 1:1)

Figure 1
Crucible (Lab ID's 4, 5)



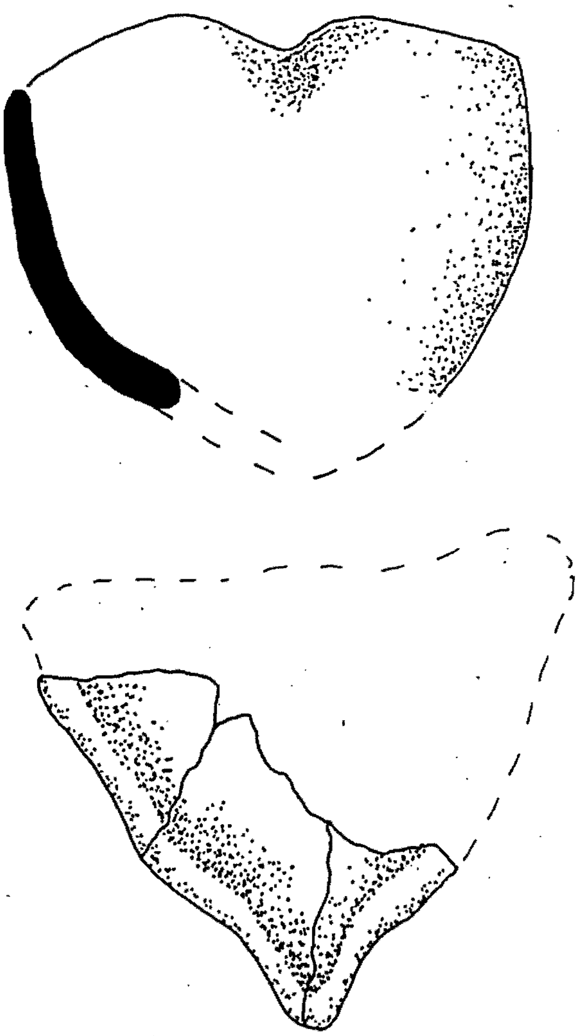
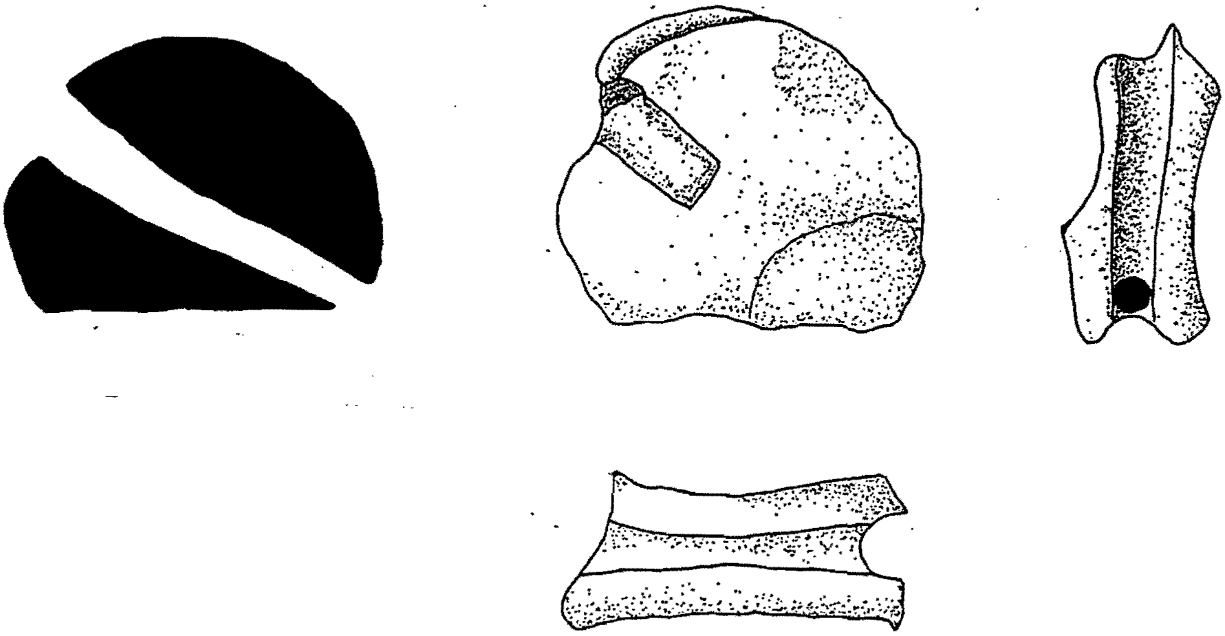


Figure 2
Crucible (Lab ID's 2, 10, 11)

Figure 3
Investment mould (Lab ID 19)



Reconstruction of casting

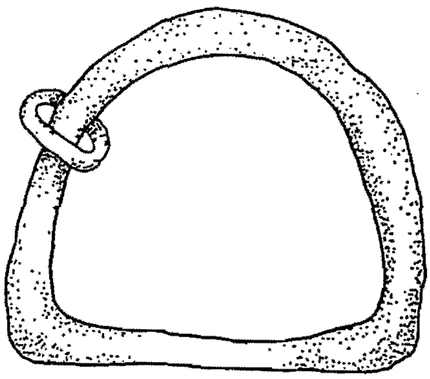


Figure 4
Investment mould for loop (Lab ID 23)

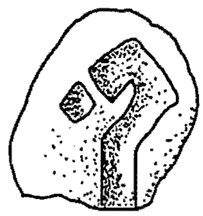


Figure 5
Investment mould for terminal (Lab ID 30)

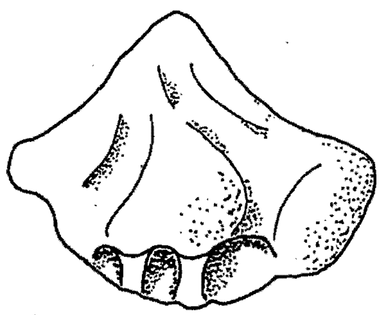
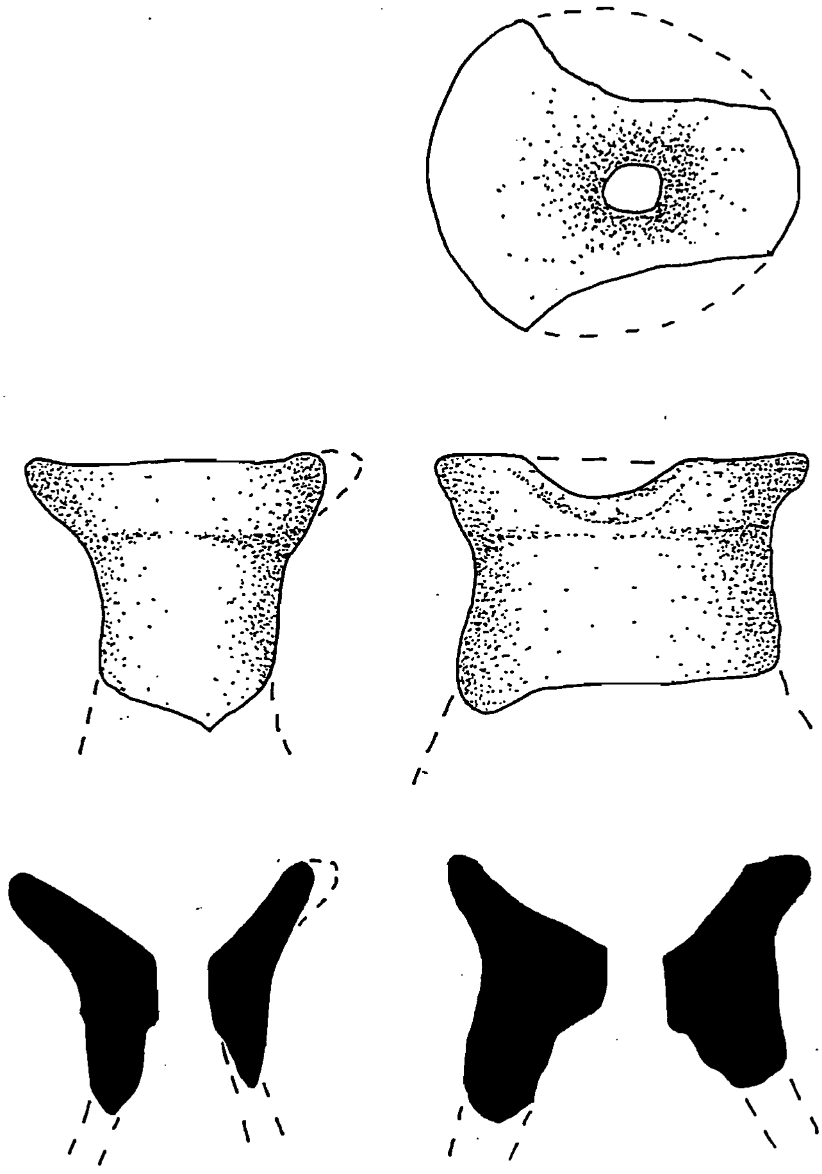


Figure 6
Sprue Cup fragment (Lab ID 73)



Whitehall Farm, Kelk Summary Helen S. Bowstead Stallybrass

This Iron Age enclosure produced small quantities (0.8 kg) of debris from copper alloy melting and casting including crucibles, investment moulds and their sprue cups. There was also a small amount of fuel ash slag and one fragment of hearth lining.