SeaClean Wight Pipelines

Archaeological Assessment Report

Volume 3 – Appendix 5: Metalworking Debris

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Appendix 5

Metalworking Debris

An assessment of the metalworking debris from the SeaClean sites, Isle of Wight
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With comments on the bronze composition
by
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1. Introduction

This report should only be considered as an initial assessment of the material examined, and its archaeological and archaeo-metallurgical setting on the Isle of Wight. Other than the examination of a single bronze prill no detailed analytical work has been carried out. The Isle of Wight has not featured on any publication of archaeo-metallurgical importance, so that it is difficult to put the material in its local or regional setting. Unfortunately, the Isle of Wight section of the systematic survey of British metalworking sites being carried out by the Material Science-Based Archaeology Group, at the Department of Materials, Oxford University is unlikely to be completed before December 2001. The geological background for this report relied entirely on the British Geological Survey Memoirs of the Isle of Wight and geological parallels on the English mainland known to the author. For full publication of the sites some further fieldwork work looking for possible ore sources and other possible smelting sites should be carried out.

2. Methodology

For this assessment all the material was classified on the bias of external morphology, colour, density, magnetic response and response to a small metal detector. For iron-working and iron-production processes the following main classes observed on these sites were[1] –

- X **Fired-clay** - mainly from the heat altered zone underlying the hearth lining.
- X **Hearth lining** - fired and vitrified clay from the walls of the hearth or tuyere blocks from the hottest zones of the hearths or furnaces.
- X **Intermediate slag** - with characteristic intermediate between those of slumped hearth lining and bulk iron-working slag.
- X **Smithing hearth bottoms** - dense blocks of slag formed during iron forging..
- X **Undiagnostic dense iron slag** - small flows, drips, and assorted fragments of dense iron slag.
- X **Tap slag** - formed by the solidification of runs of molten slag run out from the iron smelting furnace.
- X **Metallic iron** – here 'metallic iron' means the pieces of metal that are not parts of identifiable objects, burnt iron, or pieces of slag with a considerable iron content
- X **Iron ore**- iron-rich rock capable of producing metallic iron when reduced in a ancient furnace.
- X **Natural** - natural object which were initially classified as metal-working debris
- X **Hammer-scale** - iron oxide scale or spheres formed by the heating and working of iron.

Copper-working

Most copper working processes will only produce the first three of the above classes but there also could be present where casting activity –

- X **Crucible fragments**
- X **Mould fragments**

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[1] See appendix 1 for more detailed descriptions of the material classes, and English Heritages guidelines: Archaeometallurgy (Bayley et al 2001) for more descriptions of the processes involved.

- X **Prills and splashes of metal** - on the one site that did produce evidence of copper-working these prills appeared to be embedded in 'iron' slag.
- X **Areas of copper-glazed hearth lining and 'slag'.**

A brief summary of the conclusions from this study of the metal-working debris for each site is given in section 3 below. A fuller discussion of the evidence, together with further data provided by an examination of the metal artefacts and magnetic residues from some of the environmental samples is given in section 4.

3. Sites –Summary

3.1 Site 5 PRN 3966 Great Briddlesford Farm

The metal working debris from this site was mixture of that generated by smithing and that produced by iron smelting activity. The quantity of material recovered, just over 13kg, was small. Thus, it is likely that the excavation only cut the edge of the site. At the moment this is the only medieval iron-smelting site identified on the Isle of Wight, although place name evidence suggest that there may be others in the area. Given that the site is close to a Cistercian grange, the possible associate with the Cistercian monastery at Quarr should be considered.

3.2 Site 32 PRN 4028 Havenstreet

This site produced just under twelve kilogrammes of metal working debris, which included evidence for late Iron Age copper casting and iron working being carried out in the same workshop. The amount of hammer scale recovered from the environmental sample from ditch context 24 makes it like that the debris was moved directly from the floor of the workshop to be dumped in the ditch. However, the nature of the archaeology and the excavation means that it is not possible to identify the location of the workshop although a number of likely hearths were excavated.

3.3 Site 33 PRN 4551 West of Chillingwood Copse, Havenstreet

The debris from this Romano-British site was typical of the debris from iron-smithing activity. The quantity of debris recovered (10.7kg) was not large but typical of a small workshop. However, unusually three of pieces of iron off-cuts were recovered, these were two pieces of thick bar/billet and one of sheet. This raw metal would repay further study.

3.4 Site 7 PRN 4158 West of Willingham Lane, Thorley

Only a little less than 1.5 kg of iron working debris was recovered from this site, which is only sufficient to indicate that iron working activity had occurred in the area. The collection is typical of the background spread of debris that is found on many rural excavations.

3.5 Other sites

The debris from most of these sites was either totally corroded iron (Sites 13 and 17), the result of possible relatively modern contamination (Site 16). The piece of what appears to be tap slag from site 43 suggests the possibility of an iron smelting site in the vicinity.

4. Site Details

4.1 Site 5 PRN 3966 Great Briddlesford Farm

This was the only SeaClean site to produce extensive evidence of iron smelting activity. This evidence came in two forms tap slag and hearth/furnace lining (see Table 1). The sort of furnace used to smelt iron in Southern England has changed a number of times from the Late Bronze Age to the Industrial revolution. The use of slag tapping furnaces starts in the Late Iron Age and runs into the Romano-British Period. Then sometime in the Early Post-Roman period there was a change to what are called slag pit furnaces over a large but as yet undefined part of southern England. These were, in turn, replaced by more developed type of slag tapping furnace. It is not clear when this change from slag-pit back to slag tapping technology occurred, but it is likely to have occurred before AD 1100, although the evidence from the western and northern parts of the British Isles shows that some smelting traditions carried on locally long after they were abandoned elsewhere.

Although some residual late Roman pottery (third to fourth centuries) was found on this site, the contexts in which the metallurgical debris as found which had pottery dated from the Late Saxon through to about AD 1300. The metallurgical debris was in an excellent state of preservation indicating that that the material was relatively undisturbed and was probably deposited relatively close to the location of the furnace and should be associated with the later pottery. This is further emphasized by a number of pieces of hearth lining from the 'dead-zone' from well below the tuyere level of the furnace were recovered – as these do not reach particularly high temperatures they are very fragile. These would not have survived a single winter in the active soil zone. One of these blocks from context 29 was sufficiently large to indicate that the base of the furnace had at least one portion with low radius of curvature. This would suggest that the furnace was either a large diameter domed furnace similar the Late Iron Age example from Minepit Wood, Rotherfield, Sussex (Cleere 1972, 14) or it could be from the relatively flat sides of the 14th century bloomery from the same site (Money 1974). Given the other dating evidence the later would seem to be the more likely. Other pieces of hearth lining showed that the furnace had been relined with clay at least once.

In addition to the tap slag and hearth lining material, only three pieces of smithing hearth bottom type material were recovered, composing only 12.9% of the total weight of the debris from this site. Two of these from context 7 were of slightly different form from those seen on other SeaClean sites. Both of these were larger than recovered on small domestic iron-working sites, and one of them was towards the top of the normal weight range for smithing hearth bottoms (compare Figure 1 and Figure 2). These two larger hearth bottoms could well have been generated during the forging of the raw bloom into an iron billet.

Only one piece of iron ore was recovered (Context 4). This was of, on visual inspection, what appeared to be high quality box ironstone. The site is situated on the Hamstead beds which are mainly sands and clays, but do contain in the lower part a 25cm thick green clay band with ironstone nodules. In the 18th century these nodules were collected from Hamstead Bay on the west of the Isle and sent to Swansea for smelting. This bed should pass within less than one kilometer of the site and might well have been exposed in the side of one of the local streams.

The quantity of tap slag recovered (6.1kg) was rather small for an iron-smelting site, where such a site might be expected to have generated several tonnes, if not tens of tonnes of tap slag. Therefore, it is likely that the excavation only caught the edge of the site. Given, that very few medieval bloomeries from this period from the south of England have been excavated (Alsted [Ketteringham 1976] and Minepit Wood), the site is potentially important. In both those cases the furnace structures were not well enough preserved for them to be reconstructed in an unequivocal manner. If a geophysical survey was carried out ahead of the excavation the bloomery and its enclosing building might well have been detected.

In addition to the possibility of recovering important information about the structure of 13th century bloomeries, the site could provide useful archaeo-metallurgical information as little is known about the efficiency or iron smelting processes at this period, using this type of ore, nor about the type of metal that might have been produced. There is some circumstantial evidence that some iron-smelting sites were producing steel, or even cast iron for refining much earlier that previously admitted (Mack et al 2001). It is difficult to judge whether this site was an efficient iron-smelting site without further analysis of the slag, ore and hearth lining. The work of Morton and Wingrove suggested that the medieval iron smelters were producing slag with higher calcium contents. Calcium acts a flux replacing iron in the slag, making the smelting process more efficient but at the price of increasing the slag melting temperature unless very carefully controlled. From the present evidence it is not clear whether the increase in calcium content seen by Morton and Wingrove was the result of the deliberate addition of limestone to the charge, or due to the use of ores with higher calcium content. Analysis of this material would be interesting in terms of this debate as the ores used would not naturally be calcium rich.

The only other possible evidence for iron smelting from the Isle of Wight known to the author before the present study was a small amount of tap slag recovered from excavations associated with Brading Roman Villa. There may well be other iron smelting sites of unknown date on the Isle as there are a couple occurrences of the name Blacklands about a kilometre west of Briddlesford Farm. Elsewhere in the England, (Devon and Herefordshire) this name is a strong indicator of the presence of iron smelting sites due to the high charcoal content of the soil.

Table 1 Table of Metallurgical Debris from Great Briddlesford Farm by type and context

Class	Context 1	Context 4	Context 7	Context 25	Context 26	Context 29
Hearth Lining Fired Clay					168.7	
Hearth Lining Vitrified		283.8	185	160	101	2963.7
Intermediate slag		710				
Smithing Hearth Bottoms	118.4	98.2	50.2	197.5	208	
Large Hearth Bottoms			1570			
Tap Slag		3245	715	228.7	1951.5	
Iron Ore		11.6				
Natural		58.4				
Metallic iron		101				

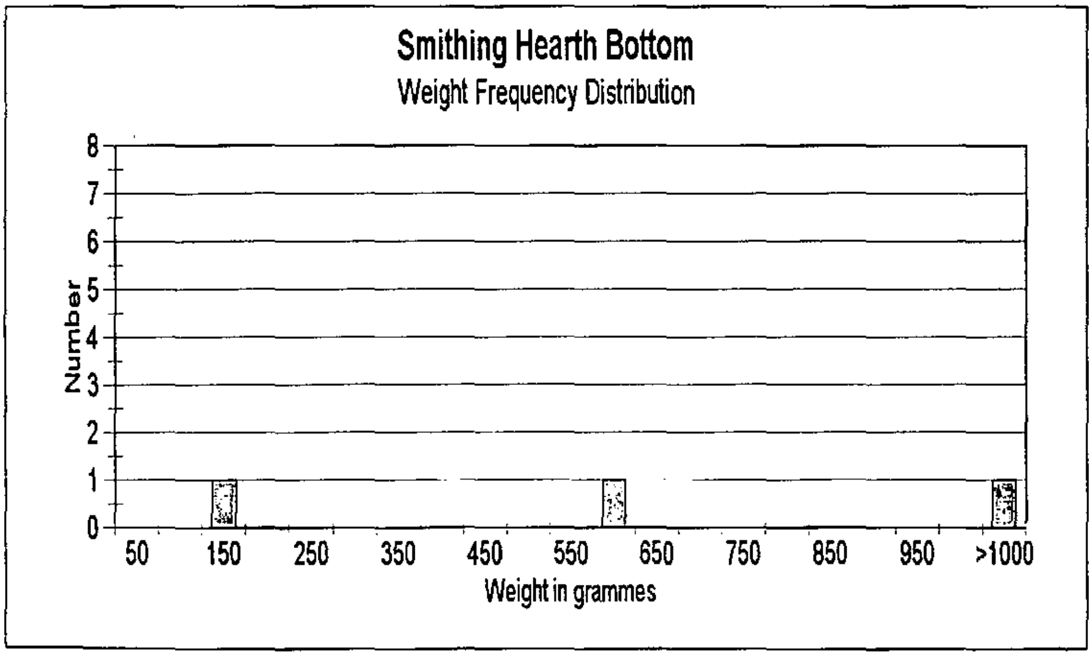

Figure 1 Weight frequency distribution for smithing hearth bottom slag from Great Briddleford Farm – total of 3 pieces

4.2 Site 32 PRN 4028 Havenstreet

Copper-working

The majority of the metalworking debris from the Havenstreet site came from a single context, the fill of a ditch or gulley (24). The site produced evidence for both iron-working in the form of undiagnostic iron working slag, and smithing hearth bottoms, and for copper alloy working in the form of a nearly complete triangular crucible, mould fragments and iron slag and hearth lining contaminated with copper alloy glaze and metal prill. The shallow triangular crucible form is characteristic of Middle to Late Iron copper alloy working. On the British mainland they were used from the about the start of the third century BC to the middle of the first century BC (Northover pers. comm.). This coincides with the ceramic period indicated by the rest of the pottery from context 24.

There were a number of specks of copper corrosion products on some of the denser and intermediate density slag as well the crucible. This shows that the same hearth was used for both copper and iron working, probably at the same time. One of these masses of corrosion was carefully lifted from a piece of intermediate density slag and was found to contain a prill of relatively uncorroded bronze the composition of which is given in Table 2.

Table2 Composition of Bronze prill from slag sample IOW 046, PRN 4028.24.19 average of 13 analyses

	Fe	Co	Ni	Cu	Zn	As	Sb	Sn	Ag	Pb	Bi	S	Au
IOW 46	0.15	0.02	0.09	89.26	0.01	0.32	0.18	9.84	0.01	0.07	0.02	0.00	0.02

Comments on the composition of metal residues from an Iron Age crucible - IOW03-Cu

The range of tin contents in the small area analyses (up to 18.12%) demonstrates the presence of the ∀• eutectoid. Typically Ni, Sb will segregate to the tin-rich phase and this is seen here with maxima of 0.18% Ni and 0.50% Sb associated with the maximum 18.12% Sn. The very low silver content also shows a maximum (0.03%) in this phase.

The range of impurity patterns in Iron Age copper alloys in southern Britain has been discussed by Northover in a number of excavation reports, with a full classification given in that for Maiden Castle (1991a, Table 42). The composition falls into his group 2c, essentially an As/Sb/Ni/Ag pattern with As>Sb and Ni>Ag.

Since the corpus of analysed Iron Age copper alloys derives in the main from post-excavation studies and not from wider surveys the recorded distribution of a composition type may be very uneven and possibly misleading. On the other hand, the analysis of stratified material does permit a reasonable estimate of the distribution of the type through time. One area from which the impurity pattern appears to be largely absent is the south and southwest, with only one example from Maiden Castle (phase 6H), four from Danebury (1 cp6, 2 cp7 and 1cp8)(Northover 1991b), and none from Mount Batten (Northover 1988) and possibly only four from South Cadbury (a pair of button-and-loop fasteners. a piece of U-shaped binding and a piece of casting waste; Barrett et al., 2000; Northover 2000). There is also a small number of examples in casting waste from Hengistbury head (Northover 1987).

Group 2c has so far proved most common in the Snettisham hoards from Norfolk, occurring in Torcs, ingot bracelets and rings; in eastern England it also features in the Ringstead, Norfolk hoard, and in the Colchester bowl and mirror handle, and in a mirror handle from Billericay Towards the midlands it appears in the several components of a sword scabbard from Hunsbury, Northamptonshire (Barnes 1985) and a small number of objects from Beckford, Worcestershire (Northover unpublished) which come mainly from LIA-RB1 contexts and include the pestle of a medicine mortar and a Nauheim derivative brooch. Further west there is one example from the hillfort at Croft Ambrey, Herefordshire and half a dozen occurrences at Merthyr Mawr, Glamorgan (casting waste, sheet and a ring; Northover, unpublished).

Viewing these results as a whole this composition type is most common from the end of the second century BC to the early first century AD. At the beginning of this period the triangular crucible was the norm in southern Britain but by the end was being superseded by round, bowl-shaped forms (cf. Northover and Palk 2000). On this basis we can suggest that this crucible most probably belongs to the later 2nd century or 1st century BC.

We may also note that the bronze is unleaded, and that leaded bronze began to be more frequent at the end of the 1st century BC. It is not possible to say what the origin the bronze was as it may well have been recycled a number of times with some mixing. There are copper types which have been attributed to a British origin, notably one with low Sb and Co>Ni, very common in the south and south-west, and one with a Zn impurity from the Welsh Marches. Group 2c avoids both those areas, and with its importance in eastern England a continental origin seems most likely. In the Bronze Age the Isle of Wight was a centre for reprocessing bronze brought across the Channel (Northover 2001) so the melting of imported bronze in the later Iron Age is very plausible.

Iron-working

The evidence of iron working is predominated by the smithing hearth bottom type slag, with this type of material making up over 56% of the weight of the collection (Table 3). The weight frequency distribution of the hearth bottoms is much heavily weighted towards the lighter end of the distribution (Figure2) than was the case for the smelting site at Great Briddlesford Farm. This sort of distribution is likely to have been produced by general-purpose black-smithing activity associated with the production and repair of artifacts for immediate local use.

A number of pieces of slag had pieces of flint or chert incorporated into there structure. These do not appear to have come from the furnace lining as this is in the main composed of uniform sandy clay. The attachment of some of the hearth bottoms to the hearth lining and some of the hearth lining would suggest

Table 3 Table of weight of metallurgical debris by type and context from Havenstreet

Material Class / Context	24	28	31	36
Crucible	85.7	9.1	95.63	
Mixed metal-working	165.6			
Fired Clay	89.0			
Hearth Lining Vitrified	2143.8		556.0	4
Intermediate Slag	940.8		6.8	
Undiagnostic Iron Slag	1407.9		40.6	
Smithing Hearth Bottom	6788.5			
Natural – Rock	120.8			
Metallic Iron	29.7			

that tuyere blocks or block tuyeres were being used. A perfectly useable hearth can be made simply by piling charcoal up against a clay plate with an air blast hole through the centre (a tuyere plate). To save charcoal and make the fire easier to control other stones would be set around the charcoal. It may be that flint or chert cobbles were used for this purpose, and these would occasional crack due to effect of the heat, with the resulting flakes ending up in the slag. Such tuyere blocks can be mistaken for loom weights as they are usually fragmented by heat action so that only a small section of a straight side and a portion of the central hole survive on those examples that can be definitely identified.

The location of the metalworking debris deposit may be significant. At other Iron Age occupation sites, such as Gravelly Guy, Oxon, there was a preference for deposition of metal-working debris, and copper-working material, in particular, near the terminations of boundary ditches (Salter unpublished). This may have a ritual associated with metalworking, or simply the nearest convenient place to get rid of the rubbish.

Further work

Further useful information could be obtained by further work on the smithing hearth bottoms with a high metallic iron content. The number of Iron Age crucibles studied is also limited a sample from the crucible would add to the database of crucible fabrics.

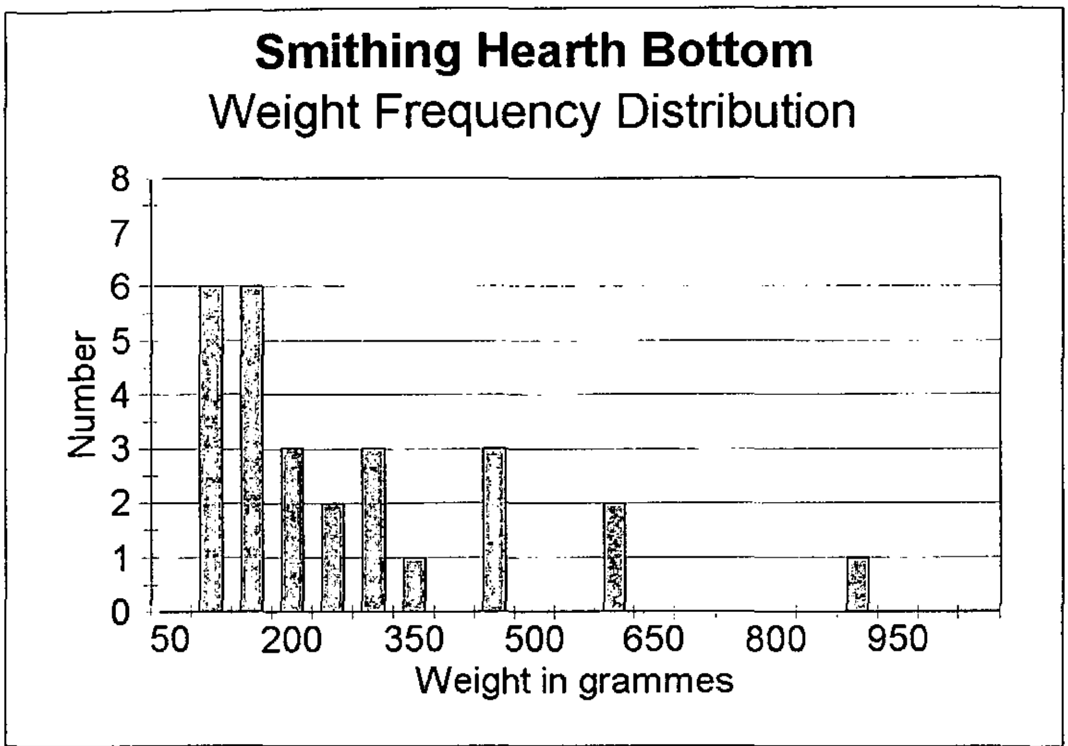

Figure 2 Smithing Hearth Bottom weight frequency distribution for Havenstreet – total of 27 pieces

4.3 Site 33 PRN 4551 West of Chillingwood Copse, Havenstreet

Even without the evidence from the slag, the iron artifacts (in particular those termed anvil fragments in the iron artefact report) from context 2.21 indicated that there was black-smithing activity on the site. Two of these were clearly bars of trade iron – bloom forged out into a thick bar or billet. One of these billets showed a clear cut-mark down one side, and the larger rectangular-sectioned bar showed signs of a hot tear fracture. A third piece of thick sheet material showed cut marks and one end appeared to have been upset ready for welding.

Figure 3 shows that weight distribution of the forty-five smithing hearth bottoms recovered is heavily weighted towards the smaller sizes. This would indicate a predominance of small quick smithing jobs with a minimum of welding activity, using predominantly thin section metal. Smithing hearth bottoms tend to be larger when welding of thick section bar, when a large number of complex welds have to be performed, or when the smith makes a mistake and the metal burns to slag. Although there are a couple of pieces where this has occurred, the metal losses are not above those normally seen on an Iron Age or Romano-British smithing site. The smithing hearth bottoms and some of the other types of slag did show one unusual characteristic – the presence of a large number of fragments of chert or flint partially incorporated into the slag. Some smiths use a high silica flux to aid welding, this silica has to be finely divided so that it reacts rapidly with the iron oxide on the surface of the object to be welded. However, the chert fragments in the slag would not have been added as a flux as they were typically 8-20 mm across. This may indicate that ground level hearths were being used with the result that material from the surround soil became incorporated into the slag. This pattern of slag with a high rock fragment content was seen at the Iron Age Havenstreet site (PRN 4028 Site 32). However, the loss of metal to slag seems to have gone down compared to site 32. In general it would seem that the Iron Age use of floor level hearths continued into the third and four centuries AD but with a slight improvement in smithing technique.

Table 4 The metallurgical debris from Site 33 West of Chillingwood Copse by debris class and context

Material Category / Context	2	4	8	13	16	19	28	31	33
Hearth lining -Fired Clay	49.2	15.6					3.9		
Hearth lining – Vitrified	202.5	87.2		1.7	8.7	4.3	8.0	339.4	
Intermediate Slag	80.9	246.6			15.0		16.0	662.0	
Undiagnostic Iron Slag	459.5	253.3	63.9	156.9	24.0	280.1	155.8	2097.5	317.2
Smithing Hearth Bottom	374.6	348.9		109.3	183.9		108.9	3280.9	610.3
Possible Iron Ore								44.8	
Metallic Iron	146.0		9.5		4.6				

Some of the material described as hearth lining had some of the characteristics of mould debris, but as there was no other evidence for copper or other non-ferrous metalworking activity, it was thought unlikely that this material was mould fragment, however, it may have been briquetage.

Further Work

The off-cut material would pay further analysis to determine the type of iron alloys being used, and whether the billet/trade bar type material is fresh bloomery metal, or recycled metal. The possible file should be sampled to determine if it is such.

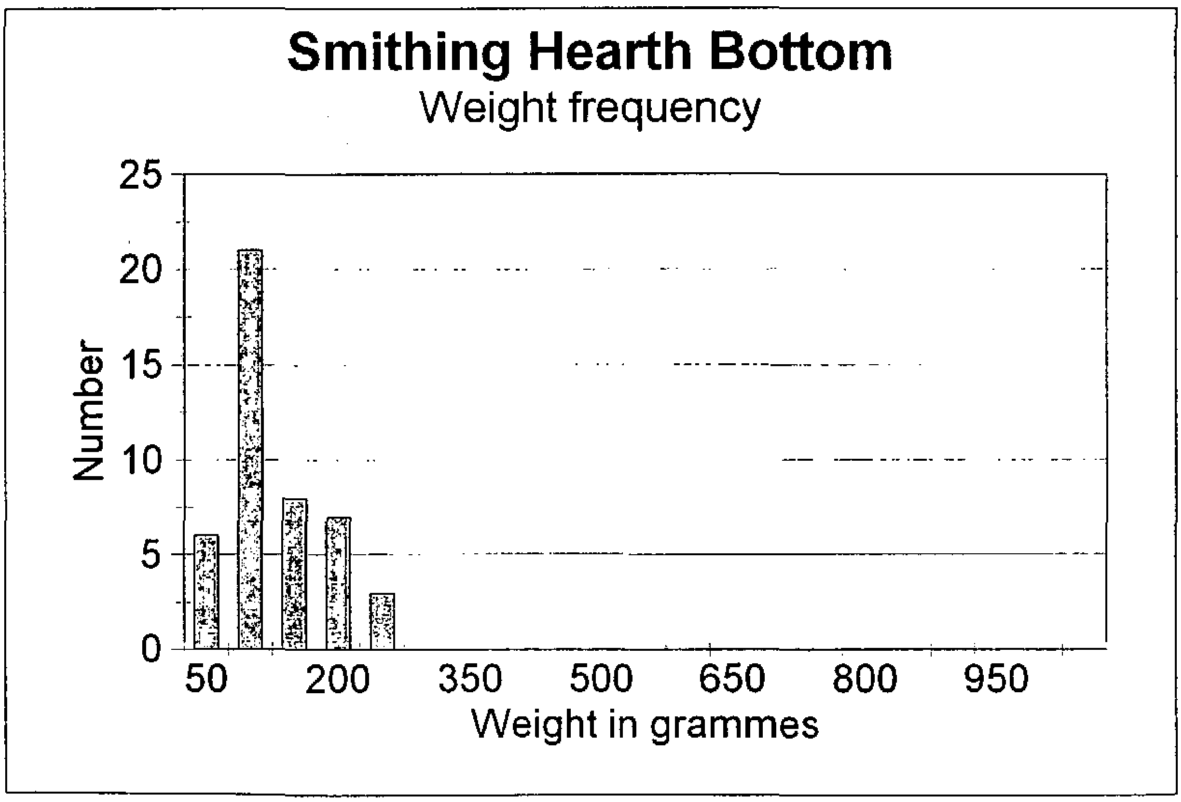

Figure 3 Smithing hearth weight frequency distribution for the Chillingwood Copse site, Havenstreet

4.4 Site 7 PRN 4158 West of Willingham Lane, Thorley

A small collection of iron working debris including one piece of metallic iron that appears to have been accidentally burnt in the smithing hearth. There were two pieces smithing hearth bottom type slag, one small (44 g) and one large (638 g). Given this very limited sample there is very little that can be said about the sort of work that this represents, other than a limited amount of black-smithing was carried out.

Material Class	Weight
Hearth Lining – Vitrified	158.8
Intermediate slag	554.4
Smithing Hearth Bottom	682.4
Metallic Iron	36.8
Natural – rock	3.7

It may be worth sampling the fragments of partially corroded scrap iron, and the partially burnt piece in particular to determine the sort of metal being worked.

4.5 Site 13 PRN 3965 North-east of Dorehills Farm

A single fragment of corroded metallic iron from context 4 was not considered to be evidence for metalworking on this site.

4.6 Site 16 PRN 4186 Ningwood

All four piece of slag from the Ningwood site was of the undiagnostic iron working type. However, a couple of the pieces, one from each of the contexts, were slightly unusual in that they had inclusions of the sort that occur when coal or coke was being used as fuel. The material on the surface of the slag was too poorly preserved to tell if it was local coal from the Mesozoic or Tertiary sediments or whether it was imported carboniferous material.

Coal was used extensively as a fuel for iron working (but not iron smelting) during the Romano-British period even in areas well outside the coalfields. However, it is not known when coal began to be used again for smithing. There are historical recorded for its use in the early 1600s, however, recently circumstantial evidence for the use as early as AD 1200 has come from the south Midlands. If these contexts are uncontaminated by post-1600 AD material, they would be worth sampling to confirm the use of coal, and just possibly identifying the nature of the fuel used.

Weight of ironworking slag from Ningwood by Context

Context	Weight
2	91.6
8	163.1

4.7 Site 43 PRN 4034 North-east of Westridge Farm, Appley

A single small piece of probable iron smelting tap slag was recovered from context 3. This may indicate that there is a bloomery site nearby, or that a slag dump was being reused for hard core. Given the medieval date of this site, this may indicate that further field work in this area will help to define the extent and nature of the iron smelting industry at this period.

4.8 Site 17 PRN 4178 South of Lower Dodpits Farm

A single fragment of corroded iron from context 5 was not considered to be evidence for metalworking on this site.

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Appendix 1

Fired-clay

This could be from the lining of a hearth or furnace but generated by any high temperature process such as cooking, pottery-making, cremation, etc.

Hearth-lining

This consisted of material from the hearth or furnace lining that had been heated to temperature sufficiently high to start to vitrify the outer layer. Although these temperatures can be achieved in non-metallurgical processes, they are necessary for most metal working processes. As the working temperature of the hearth increases the vitrification of the hearth-lining becomes progressively more severe. Until the point the hearth lining begins to flow and slump, helped by the fluxing action of the alkali elements from the fuel ash and material shed from the metal.

Intermediate slag

This consists of material that is formed by the reaction of the vitrified and slumped hearth lining material with the denser bulk slag. Again the process is aided by the alkali elements in the fuel. This class includes true fuel ash slag, as well as vitrified soil and other debris that has entered the hearth or furnace by accident.

Smithing hearth bottoms

Iron hardens rapidly as it is forged so that most iron-working process require the metal to be heated to at least annealing temperatures (700-900 °C depending on the alloy) to soften it, if not worked at those temperatures. As iron is heated to annealing temperature the surface of the metal oxidizes forming a film of iron oxide, which will crack and spall off into the hearth just in front of and below the blowing-hole. Here the iron oxide will react with the fuel ash and flows of hearth-lining vitrification to form a dense compact lump of slag. These are often plano-convex in cross-section, near circular, or D-shaped in plan view, with one broken edge where it was originally attached to the hearth lining below the blowing-hole. These lumps of slag would be removed when they start to make the hearth inefficient by causing a cold spot or when the hearth was cleaned at the start of a new smithing session. Smithing hearth bottoms may be discarded within the confines of the smithy, but they are more often dumped a short distance away, or used as hard core. However, on Iron Age sites the location of the slag may have some greater significance than simply a useful source of material to fill in a damp spot. African ethnographic work has shown that the iron-workers often propitiate the spirits with offering including ore, fuel and slag. On a number of Iron Age sites investigated by the author slag and other metal-working waste has been found in enclosure boundary ditches, and in particular associated the terminals of those ditches. These small dumps of slag may be a type of special deposit having a spiritual dimension as argued by Hill and other, or it could simply be a result an archaeological excavation bias. However, when there are enough hearth bottoms from a site to construct weight distribution histograms it is possible gain some information about the type of iron-working that was being carried out.

Small smithing hearth bottoms –

The English Heritage Centre for Archaeology guideline: Archaeometallurgy (Bayley, et al, 2001) suggest a minimum weight of about 100gs for a smithing hearth bottom, but on these and other sites studied by the author slag samples with the same morphology including the characteristic break-way line as light as 50gs have identified. In addition, small-scale relatively low temperature experimental smithing by the author and episodes of smithing by a professional smith have produced similar small hearth bottoms after one or two hours work forging small objects such as nails and arrow-heads. For this assessment the small hearth bottoms were initially classified as those between 50 and 250g.

Large smithing hearth bottoms –

To build up larger masses of slag requires a greater input of material than would occur if bar, rod or strip was being hammered to shape. Rapid loss of iron oxide or iron-rich slag to the hearth can be the result of a number of different type of forging processes, such as welding, bloom or billet forging, all processes which require higher forge temperatures than for simple hot-working. As the temperature of the hearth is increased from annealing heat to welding heat the rate of oxidization increases very rapidly, and eventually the oxide layer becomes liquid. A process that may be aided by alkalis from the fuel ash, or the deliberate use of fine silica sand flux. To weld some types of iron it is necessary bring the metal very close to the point where it starts to burn in air, thus slag with very high iron oxide contents can form quickly. With bloom and billet forging not only are high temperatures required to weld up any cracks in the bloom, but the original smelting slag trapped in the raw metal will be forced out and contribution to the smithing slag.

Undiagnostic dense iron slag

These are small pieces of dense iron rich slag that are almost certainly produced as a result of an iron-working process. However, their form is such that iron smelting or any iron forging process could have produced them. These slags can be small irregular pieces and flows, or fragments from larger pieces which have broken down to the point where it is not possible to recognize their original morphology. Smithing hearth bottoms are particularly prone to this as they may contain an appreciable amount of metallic iron, which will corrode, expand and crack the slag.

Tap slag

Tap slag is a particularly distinctive characteristic product of the bloomery smelting. This slag has been run out of the furnace as a liquid to cool in distinctive flow and run morphology. Normally, a bloomery smelting site will produce much greater quantities of slag than the subsequent metal forming stages. However, when only a few small piece of slag flows are found it should not be assumed that these are tap slag, as small slag flows can be produced during forging. But as these cool in the hearth, they have a different internal morphology from the rapidly cooled tap slag. Iron smelting does not always produce tap slag as there were several periods in which various types of non-slag tapping smelting technology were used.

Metallic iron

Here metallic iron means the piece of metal that are not parts of identifiable objects. This iron comes in a number of forms

1) Mixed with slag
2) Irregularly shaped fragments
3) Smith's stock, typically fragments of billet, bar, rod or sheet
4) Partially finished or re-worked objects

Iron ore

In the lowland zone of England the iron ores that were used were hard-pan or bog ore which can form wherever the right soil conditions exist; bedded ores, typically those of the Jurassic of the Jurassic ridge or the Weald, however other geological formations may contain bands of iron rich nodules with the Bracklesham, Barton and Bagshot beds (or their equivalents) providing ores that have been of economic value in the past, specially where they have been enriched by surface weathering such as at Hengistbury Head.

Natural

A number of type of material often are included in the material first classified as metallurgical debris in particular soil cemented by calcium carbonate deposits, or cemented by deposited iron oxides called ferrocrete, and non-ore quality ironstone nodules.

X **Hammer-scale**

Although some of the iron oxide scale formed when iron is heated falls into the hearth to form smithing slag, much is shed from the metal as it is transferred to and worked on the anvil. This forms distinctive black shiny scales varying in thickness from a few tens of microns to a millimetre or so thick, small spheres varying from the just visible to about 10 mm in diameter. Initially floor of smithy

Copper-working

Most copper working processes will only produce the first three of the above classes but there also could be present where casting.

- X Crucible fragments,
- X Mould fragments,
- X Prills of spilt and splashed metal,
- X Areas of copper-glazed hearth lining and 'slag'

This is often described as copper working slag but often it is simply intermediate type slag with oxidized copper adhering or incorporated into small areas of the material. It is not a true slag in that it not an essential part of the process.

The forging of copper alloys may generate annealing scale. The working of sheet copper requires the frequent annealing of metal to soften it so that it can be worked further. This annealing will result in the formation of a surface scale of copper oxide, which is shed when the object is quenched in a water bath.