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Ancient Monuments Laboratory
Report 23/95

THE ANALYTICAL EXAMINATION OF METALWORKING DEBRIS FROM THE 1989-90 RIBCHESTER GRAVEYARD EXCAVATIONS, LANCASHIRE

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Summary

A broad-based analytical study was carried out on debris from the possible military *fabrica*. Techniques included metallography, X-ray fluorescence (XRF) analysis; X-ray diffraction (XRD) spectrometry, and scanning electron microscope (SEM) based microanalysis. 234 kg of material from the site were examined. Most derived from the smithing of iron although iron smelting and non-ferrous alloy casting debris was also present in limited quantities. Magnetic susceptibility measurement of soil samples was also used in an attempt to link the dumped debris with hearths on the site.

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1 Introduction

Excavations at Ribchester Graveyard, undertaken by the Lancaster University Archaeological Unit in 1989 and 1990 sought primarily to clarify the nature of the extra-mural settlement to the north of the Roman fort, the construction of which had been investigated by the Unit in 1980.

Provisional Phasing of the Ribchester Graveyard:

Phase 1 Construction of rampart and triple ditch of timber fort (possibly pre-Agricolan). Earliest extra-mural activity. Some silting of ditches.

Phase 2 Modification of defences: extension northwards of the rampart, recutting of inner ditch, backfilling of outer ditch and laying of road on top. Posts and pits in settlement area to north of fort.

Phase 3 Demolition of timber fort, construction of temporary 'Punic' ditch between fort and settlement. Construction of stone fort started to south of excavation area.

Phase 4 Large timber structure erected over former defences, to north of new fort. The building appears to have contained a number of 'industrial type' hearths of varied construction and is suggested to be a military *fabrica*. First stone buildings constructed within extra-mural settlement. Zone of industrial activity identified.

Phase 5.1 Buildings of Phase 4 out of use. Entire area covered with industrial debris and re-deposited clay.

Phase 5.2 Final period of Roman activity. Area falls into decay. Possible use of area as cremation cemetery.

2 Academic objectives

The post-excavation assessment of 1992 suggested *that there are indications at Ribchester of (possibly) large scale industrial activity under the direct control of the fort, as well as smaller scale activity.* Examination of the industrial debris was hoped to contribute to the following areas:

1. Understanding of the function, status and purpose of the fort in its early years as it changed from front line/frontier post to strategic staging post to garrison fort situated well behind the lines.

2. Identifying significant differences in artefact assemblages within the site. Particularly with respect to the perceived division between fort and extra-mural areas. Consideration of the nature and function of activities carried out in specific structures and areas of the site.

3. Specifically, to provide an insight into the nature of the activity associated with the *fabrica* and determine whether it can be related to a particular need of the garrison; perhaps associated with the production of something like weaponry. Implications of this for the relationship of the fort/extra-mural settlement to the wider socio-economic context. Exploring the possibility that a change from military to civilian control could be detected archaeologically.

4. Placing Ribchester within the wider trade network of the Province, possibly illustrating changes of emphasis in the flow of trade goods at various periods during the lifetime of the fort.

5. Consideration whether the debris can help to identify the type of soldier stationed at Ribchester, for instance whether material could be associated with cavalry rather than infantry.

3 Examination of the slags and metalworking debris

3.1 Introduction

A total of 234kg of material was examined. This included all the industrial debris from the earlier phases (1-4) and samples from the later phases 5.1 and 5.2. The results of the visual examination are summarised in Table 3.2, whilst full details are listed in Appendix 1.

3.2 Results of visual examination

Table 3.2 Slag weight totals

slag type	total weight (kg)
tap slag	1.45
dense ironworking slag	4.62
possible ores	0.77
smithing hearth bottoms	7.67
hammerscale (not quantified)	-
undiagnostic ironworking slag	68.98
ferruginous concretions	7.52
vitrified hearth/furnace lining	66.95
tuyère fragments	1.79
cinder	18.39
iron-rich cinder	7.03
iron objects	3.70
fuel ash slag	0.15
fired clay	44.82
charcoal	<0.01
total	234

Visual examination of metalworking debris allows the material to be categorised on criteria of morphology, density, colour and vesicularity. For certain 'classes' of materials, visual examination is able to identify the specific technological process which created them and these materials are referred to as diagnostic. Of the categories quantified above, only tap slag and smithing hearth bottoms are regarded as truly diagnostic (of iron smelting and iron smithing respectively). However, because these constitute only a small fraction of the total assemblage (about 5%)

further elemental and mineralogical analyses were undertaken to investigate whether the technological origin of the other categories of materials could be determined, hence allowing an improved interpretation of the industrial activity on the site.

It should be stressed that many 'classes' of iron working slags form part of a compositional and morphological continuum. Class names and the criteria on which they are based may vary between specialists. Those currently used by the Ancient Monuments Laboratory are defined below.

3.3 Explanation of classification

The fragments of dense, fayalitic (iron silicate) **tap slag** show a characteristic 'ropy', flowed, morphology on their upper surface and low vesicularity at their fracture surfaces. These are diagnostic of smelting (i.e. primary extraction from the ore) of iron and are typical waste products of the tapped bloomery furnace, in use during the Roman period, from which the molten slag was run out rather than collecting within its interior. The low quantities of this material probably explain why smelting was not recognised during the assessment phase of the project. The slightly greater quantities of **dense ironworking slags** may also derive from iron smelting although they do not show the flowed structure of the tap slag.

Three iron-rich stones were examined and classed as **possible ores,** although it is quite possible that their presence on the site is unconnected with any smelting activity. Given this uncertainty and their very limited presence, they provide little additional support for tying down the date and location of the smelting indicated by the smelting slag mentioned above.

Evidence for the smithing (i.e. hot working) of iron comes in two main forms; bulk slags and micro slags. Of the bulk slags produced during smithing only the **smithing hearth bottoms** are unlikely to be confused with the waste products of smelting and are therefore considered to be diagnostic of smithing. These hearth bottoms are recognisable by their characteristic plano-convex form, having a rough convex base and a smoother, vitrified, upper surface which is flat, or even slightly hollowed as a result of the downwards pressure of the air blast from the tuyère. Compositionally, smithing hearth bottoms are also predominantly fayalitic and form as a result of high temperature reactions between the iron, iron-scale and silica from either the clay furnace lining or sand used as a flux by the smith.

Table 3.3.1 Smithing hearth bottom dimensions (n=29)

	range	mean	std. dev.
weight (g)	89-938	296	203
length (mm)	65-140	95	18
width (mm)	45-110	77	15
depth (mm)	18-60	40	10

29 examples of smithing hearth bottoms were identified. As is usually the case these represented a smaller proportion of the assemblage than the non-diagnostic forms. The statistics of this group are given in Table 3.3. Although the hearth bottoms show a wide range of sizes, the mean weight and dimensions are low for the Roman period. Many were of the light, cindery, form commonly encountered in the Roman sites, others were considerably more dense. Whilst the differences in the conditions of formation of cindery and dense smithing hearth bottoms is not fully understood, it would appear that some variety of smithing work was being undertaken at Ribchester. In addition to the simple hot forging of iron, higher temperature fire-welding or bloom smithing may have been carried out.

In addition to bulk slags, iron smithing also produces micro-slags of two types. **Flake hammerscale** consists of fish-scale like fragments of the oxide/silicate skin of the iron dislodged during working. **Spheroidal hammerscale** results from the solidification of small droplets of liquid slag expelled during working, particularly when two components are being fire welded together or when a slag-rich bloom of iron is first worked into a billet or bar. Hammerscale is considered important in interpreting a site not only because it is highly diagnostic of smithing but, because it is often allowed to build up in the immediate vicinity of the smithing hearth and anvil, it may give a more precise location of the activity than the bulk slags which may be transported elsewhere for disposal (Mills and McDonnell 1992). During the visual examination of bulk slags, small quantities of hammerscale were identified in the soil attached to some of the unwashed slags. This information has been noted in the bulk slag listing in Appendix 1. However, a more systematic approach, using magnetic susceptibility to assess the hammerscale component of soil samples was also carried out. For details of the methodology and results see Section 5.

Irregularly shaped slags are produced by both iron smelting and iron smithing processes and visual examination classes these materials as **undiagnostic ironworking slags**. Like tap slag, dense slag and smithing hearth bottoms, the compositions of these fragments are predominantly fayalitic, giving a grey steak on unglazed porcelain, and they are noticeably denser than cinder.

The category of material identified as **ferruginous concretion** forms as a result of the redeposition of iron hydroxides, a process similar to the natural phenomenon of iron panning. However, on archaeological sites such material may be of relevance in identifying ironworking activities and deserves close examination. Firstly, 'bog ores' of similar appearance are known to have been used as a source of iron for smelting in antiquity. However, in the case of the material from Ribchester, it would appear to be contaminated with soil and rock fragments and therefore insufficiently rich in iron for the metal to be extracted by bloomery smelting furnaces of the Roman period. The formation of iron pan, subsequent to the occupation of the site is also likely to be enhanced by the nature of the surrounding archaeological deposits. In particular, close examination may reveal the presence of hammerscale within concretions.

Material listed as **vitrified hearth/furnace lining** may derive from either iron smelting, iron smithing or, particularly with fragments showing brightly coloured glazes, from non-ferrous metal working. It forms as a result of a high temperature reaction between the clay lining of the hearth/furnace and the alkali fuel ashes or fayalitic slag. The material may show a compositional gradient from unmodified fired clay on one surface to an irregular cindery material on the other. An associated material, classed as **cinder,** comprises only the lighter portion of this, a porous, hard and brittle slag formed as a result of high temperature reactions between the alkali fuel ashes and either fragments of clay which had spalled away from the hearth/ furnace lining or another source of silica, such as the sand used as a flux during smithing. **Iron-rich cinder** is a similar material but contains a significant content of iron not chemically combined with silicates but visible as rust-orange coloured hydrated iron oxides.

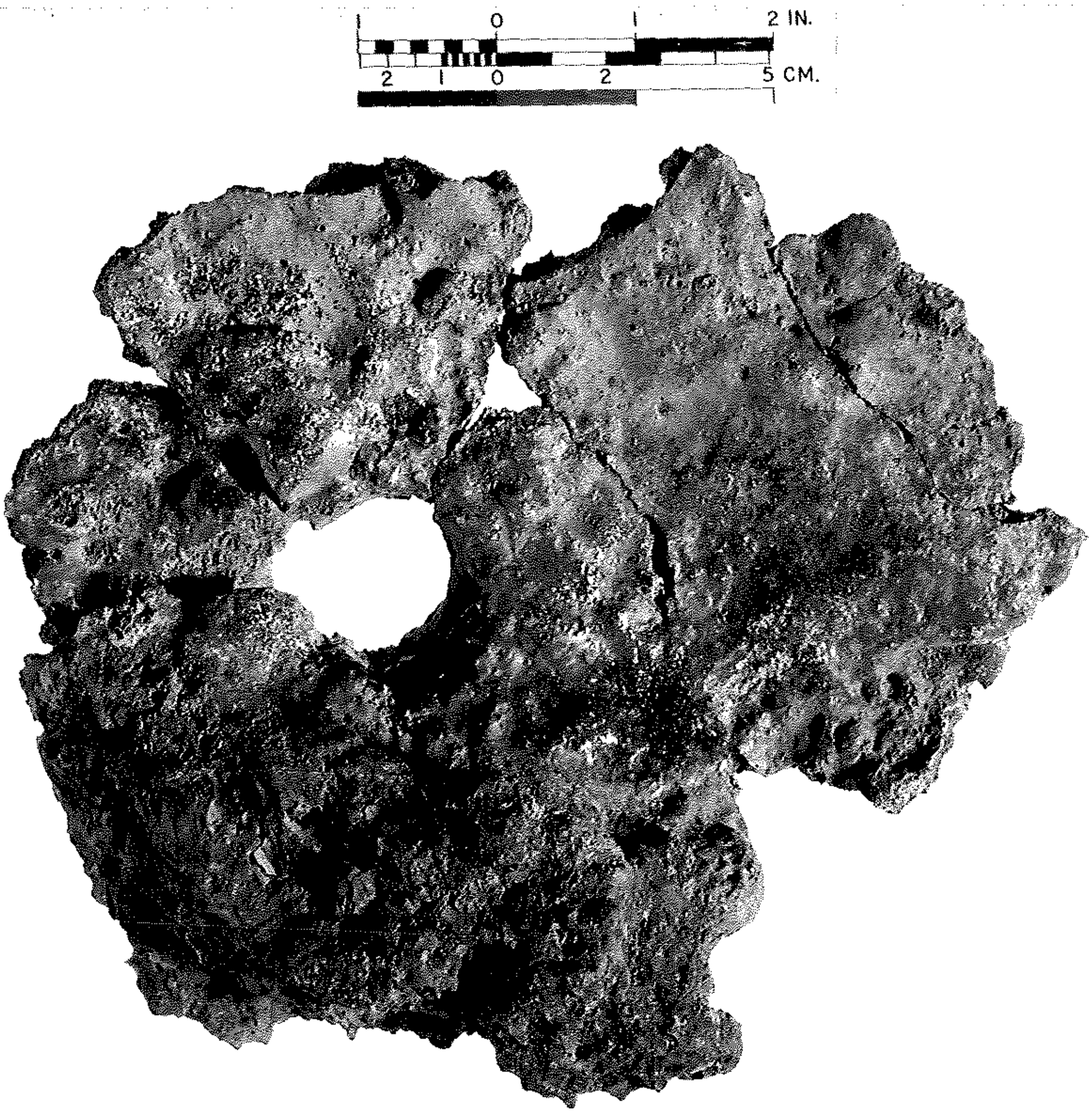

Plate 3.3 Plate tuyère

A **tuyère** is a component of a furnace or hearth through which air is forced to increase the temperature. These may exist in a number of forms and materials, of which the best known is a pre-fired, pierced, clay 'block tuyère'. However, the examples from Ribchester are of a type referred to as 'plate tuyères'. These are simply clay patches applied around the air inlet on the inside of the hearth or furnace, at the point that the heat is most intense and the clay lining is most rapidly attacked. The fabric of these resembles vitrified hearth lining, with a gradient from fired clay to a vitrified/cindery mass, but the smooth edges of the air hole are visible. Most of the tuyères from Ribchester were fragmentary and incomplete but one reconstructed example is shown in Plate 3.3.

A very small amount of material was classified as **fuel ash slag**, a lightweight, light coloured (grey-brown), highly porous material which results from the reaction between alkaline fuel ash and silicates from soil, sand or clay at elevated temperatures. The reaction is shared by many pyrotechnological processes and the slag is not diagnostic.

A number of lumps appeared to be concretions formed around **iron objects**. Survival of at least some iron was attested by their strong attraction to a magnet. Items from this category were returned to the post-excavation director to allow them to be studied with the other iron objects.

A surprisingly large amount of **fired clay** was found within the slag assemblage. Although this could have derived from structures associated with metallurgical processes it is not possible to confirm this.

The single fragment of **glassy slag,** is very reminiscent of later, post medieval, blast furnace slags. However, both experimental smelts and archaeological excavations have shown that Bloomery furnaces could, and did, occasionally produce similar material, although the conditions required would not have been suitable for producing good quality iron.

The assemblage included a piece of **coal** and a possible piece of **lignite**. It is possible that smithing could have utilised fossil fuels. However, charcoal fragments and flecks were commonly associated with the archaeological deposits and charcoal was undoubtedly the main fuel used.

A small number of sherds from **crucibles** were found in three contexts. These represent the remains of no more than three vessels and although they provide clear evidence of the casting of copper based alloys, such a limited presence suggests the activity was not of major importance at the site.

Table 3.3.2 provides details of these crucible fragments including the results of non - quantitative X-ray fluorescence analysis. The crucibles from contexts 31 and 90 were of a common Roman wheel thrown type and had been used for the casting of a copper-zinc alloy, although it is not possible to say whether the alloy contained sufficient zinc to be classified as brass. Fragments of a hand made, triangular, crucible were found in Context 205. This style of crucible originates in the iron age but is frequently found in early Romano-British contexts. A corroded metallic mass adhering to the inside surface of the sherds showed that they had been used for melting a leaded bronze alloy.

Table 3.3.2 Crucible fragments

Context	Find No.	Weight (g)	No. Frags	Min. No. vessels	Comments
31	6780	112	1	1	Wheel thrown, black/red glaze. XRF analysis Zn + Cu
90	7422	200	4	1	Wheel thrown, black/red glaze. XRF analysis Zn + Cu + (Mn)
205	7792	124	15	1	Hand made triangular vessel. XRF analysis Cu + (Pb +Sn)

3.4 Distribution of slags on site: Quantification of processes by phase
The earliest evidence of smithing in the form of diagnostic slag was found in contexts 329 and 367 of **Phase 1.2**. These two layers immediately overlay 'industrial material' (370) which, although it contained no diagnostic bulk slag, did include quantities of non-diagnostic material and hammerscale and it would be reasonable to assume that all this material derived from smithing. The quantities of material recovered are insufficient to indicate any more than very limited scale iron working at this time. The interpretation of these contexts, as dumped deposits, is significant.

The draft text for Phases 1 to 4 (Nov 1993) suggests that pit 406 contained dumped hearth debris. However, no industrial debris was found to suggest this was associated with metal-working activities (although some reasonably high magnetic susceptibility values were obtained in several of the fills). Likewise there does not appear to be any evidence of metal-working associated with the charcoal-containing layer (430) in the northern area during this phase.

No metalworking debris was found to be associated with hearth complex of **Phase 2:2** (hearths 332, 322, 290 and 295). However immediately overlying contexts classified as **Phase 3**, (285)/(565) did contain smithing slags. Also in Phase 3, a very limited quantity (51g) of undiagnostic ironworking slag in one of the debris deposits (571) may hint at the use of the nearby hearth (572) for metalworking purposes. Further metalworking debris from the fill (569) of hollow (568) was not diagnostic, but a fragment of crucible of Iron Age/early Roman type containing non-ferrous debris was recovered from the fill (205) of the Punic ditch (247).

Surprisingly little diagnostic smithing slag was associated with Phase 4, the operation of the *fabrica,* however its location is significant. **Phase 4.2** hearths (631, 440, 624 and 159) and their associated contexts within the building 722 contained no industrial debris. However very small quantities of debris were identified in pit (519) to the south of lean-to (546). Of the succeeding hearths (143, 490, 241, 142 and 494) no slag was found within the hearths but about 2kg was found within associated layers including an unusual piece of dense slag, which resembles a very dense smithing hearth bottom in (485) and some more typical undiagnostic slags in (74)/(75). These would lend some weight to arguments that the hearths were associated with some sort of smithing activity. Small amounts of slag (62g and 8g) were also found in the contemporary external features; a resurfacing layer (61) and a drain fill (83). Gully (92) contained about 7kg of assorted metallurgical debris including a large proportion of vitrified hearth/furnace lining. The presence of a smithing hearth bottom indicates that some of the debris derives from iron-smithing, though fragments of a crucible attest to non-ferrous alloy working also. Other features from Phase 4.2 including the charcoal-rich fill (149) of pit (234) were not found to contain slag.

In **Phase 5.1** very small amounts of material were associated with the redeposited rampart material (24) compared with the large sample of over 33kg of debris from the industrial deposits (18), removed as a single context. Although Context 18 contained one example of dense ironworking slag, and Context 31 included a single crucible sherd, the nature of the assemblage was overwhelmingly that associated with iron smithing. In the south-western corner of the site the interleaved deposits that constituted (18) were recorded separately. With the exception of one 'industrial layer' (28), both the industrial layers (48), (50) & (53) and the redeposited rampart clays (37), (47), (49) & (52) contained metalworking debris, apparently deriving from smithing, but with a very high proportion of vitrified hearth/furnace lining. Without knowing the relative extents of these deposits no comparison of relative concentration of debris can be made, but on the basis of the quantities examined, the 'rampart clays' might also need to be considered as industrial deposits: If the clay derived from the rampart then it must have become heavily contaminated with slag prior to deposition. (This could of course be an artefact of an uneven sampling. However, as no record of the sampling strategy was supplied for this study, this must be for the archaeologist to consider).

About 15 kg of industrial debris was associated with the infill (80), (45), (468), (460), (54), (31), (33) and (38) of the quarry (141). The debris was of similar make up to that of context (18); *ie* consistent with iron smithing but containing an unusually high proportion of vitrified hearth lining. The assumptions that the industrial debris component derived from mixing with the earlier (18) material would appear to be justified. Considering the large quantities of other material, the identification of a single crucible sherd in layer (31) should not be over-emphasised, although the possibility of some non-ferrous activity alongside predominantly iron smithing activities should be considered. Clarification of the relative importance of any non-ferrous working will require the study of metallic waste such as casting sprues, spillages *etc*. However, the lack of evidence for copper corrosion products attached to the industrial debris examined, argues against more than very limited scale copper-alloy working.

Whilst **Phase 5.2** might be thought of as a period of site decay in terms of structural evidence, metallurgical debris for this period shows a continuing emphasis on smithing and, for the first time, provides more than a hint of some iron smelting in the vicinity. The final quarry fills (3), (32), (17), (19) and (16) produced a total (sample?) of over 37kg of industrial debris. Again hearth lining was a major component of these and the assemblage is typically what would be expected from iron smithing. However, a small proportion of the large (21kg) assemblage from layer (19) shows some unusually dense material and a few grammes of tap slag which analysis confirmed most probably derived from ironsmithing. The final, undisturbed Roman layer (13) in the quarry contained a very different, although relatively small (1.3kg), assemblage. Hearth lining was a minor component, undiagnostic ironworking slags predominated with a large proportion of dense material, yet hammerscale from smithing was still present. More unusual yet was a deposit (446) to the extreme south of the site, half of a total of 3.4kg was undiagnostic ironworking slag, dense slag was a major component, 73g of distinctive tapped slag was identified and a green/blue glassy slag (though possibly later, intrusive) was also characteristic of iron smelting. By contrast very little (212g) lining material was recovered. Although these quantities of smelting slag are very small, it should be noted that only small areas of these deposits were excavated. Additionally the presence of a relatively high proportion of tap slag (15%) in the debris the sub-soil (002) is notable.

3.5 Summary of bulk slag distribution

Figure 3.5 compares the evidence for specific processes across different phases of activity on the site. Some materials and phases have been combined where evidence for individual types/phases was very limited. Hence, evidence of 'smelting' combines the diagnostic tap slag with dense ironworking slag, which on the basis of the analysis mentioned above may include a high proportion of smithing debris. Phases 1, 2 & 3 on the site have also been combined because of the paucity of ironworking evidence there, but Phase 5 has been divided (previously 5 & 6) because of the occurrence of massive quantities of debris at this time.

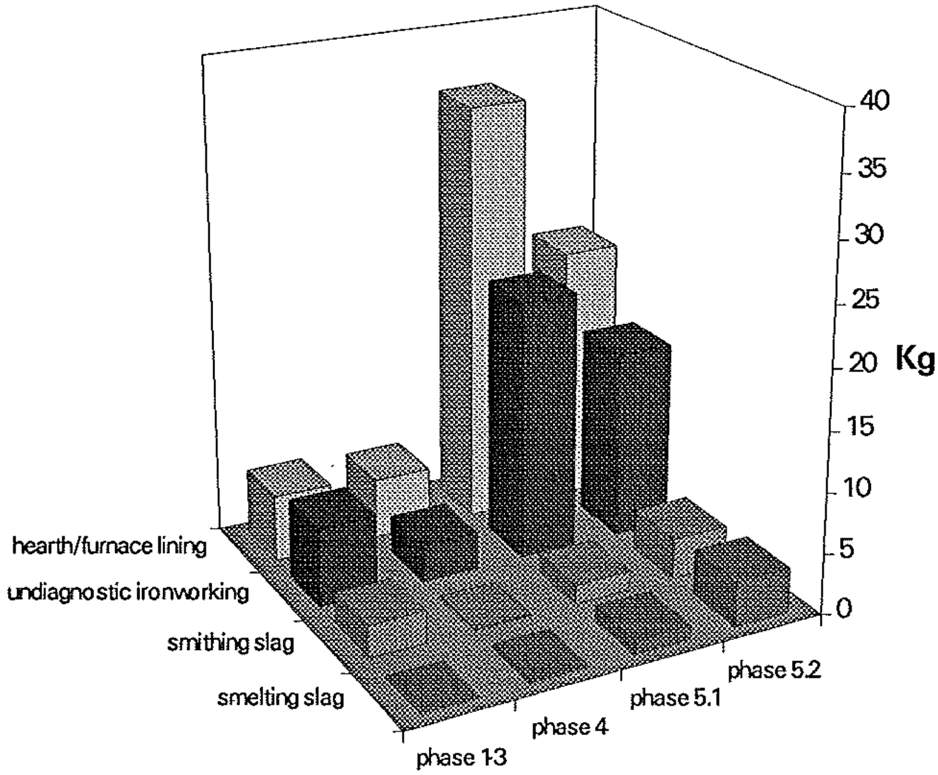

Figure 3.5 Distribution of slag by phase

The chart emphasises the relative paucity of diagnostic slags on this, as on many other, sites. However, some trends are evident. Firstly, looking at iron smelting: evidence is entirely absent from the first three phases and effectively absent in Phase 4, during the use of the *fabrica*. Limited quantities were recovered from sub-phase 5.1 and the largest total from the final occupation Phase 5.2. Thus, although there is some evidence for the smelting of iron in the vicinity of the site during last phase of occupation, it is therefore not possible to tie down the location of this activity. Indeed as the quantities of slag produced during iron smelting are generally very substantial, the site of the excavation at Ribchester is likely to have been peripheral to the focus of the iron smelting. If field walking was undertaken in the area, it might be possible to locate the actual smelting site from the greater densities of tap slag in the top soil.

The second metalworking activity identified from the debris was that of iron smithing. Very limited quantities of diagnostic bulk slags were identified within the first four phases but this evidence was supported by the identification of hammerscale in otherwise undiagnostic material. Generally, in all these first four phases good association between hearths and industrial debris, diagnostic or otherwise was not proven. For this reason it was particularly important to look for hammerscale in soil samples as described below (5.2). The overall impression given by the distribution of the slag, is that the most intense period of metalworking follows on from what, on all other forms of evidence, has been considered to be the decline of the site. Given that the material examined from these later contexts represents only a (sampled) fraction of the total present, then this trend must be even more pronounced in reality.

A third metalworking activity, the casting of copper alloys may have taken place on a limited scale, but the importance of this activity should not be over-estimated.

4 The physico-chemical analysis of bulk slags

4.1 Introduction

As set out in the project proposal, a wide range of pieces of slag were selected and analysed. This was intended to clarify the nature (and morphological interpretation) of the debris and to chemically characterise it, so as to provide data against which future assemblage analyses could be compared.

In order to determine the usefulness of analysis four different techniques were applied to samples of material:

- Metallography (reflected light microscopy) to determine the proportions of phases and estimate the vesicularity.
- Semi-quantitative X-ray fluorescence (XRF) analysis (for elements above fluorine in the periodic table).
- Qualitative X-ray diffraction (XRD) analysis (identification of crystalline mineral phases).
- Quantitative scanning electron microscope (SEM) based energy-dispersive X-ray analysis (EDXA) (microanalysis of slag samples and constituent phases).

Sample preparation for metallography and SEM microanalysis involved standard metallurgical procedures: Cutting slices from the slag lumps with a diamond saw, mounting part of the slice in conductive thermosetting resin, grinding on abrasive paper and finally polishing with 1μm diamond paste. The samples were drawn at actual size, then examined under an optical microscope, with the structure recorded by sketch and on 35mm print film. Unmounted, cut fragments of slag were examined in the XRF analyser, and further fragments were pulverised in a mortar for XRD.

The results of the XRF, XRD and metallographic studies are listed in Appendix 2. A summary of the mean bulk SEM analyses, ordered by slag type, is given in Appendix 4 whilst details of the area analyses of phases within the slag structures, and the replicate area analyses used to determine the bulk mean figures are listed in Appendix 3. Whilst attempts were made to select 'typical' areas of each slag lump for analysis, because three different samples were removed (from a frequently heterogeneous material) for metallography and SEM analysis, XRF analysis and XRD analysis, some variation in determined composition might be expected.

4.2 Metallography

Under a metallurgical (reflected light) microscope distinct phases can be identified within the structure of a polished sample. The proportions of these phases, and of the porosity within the sample are given in Appendix 2, whist example micrographs of structures are shown in Plates 4.2.1 and 4.2,2. Within the Ribchester slags a limited number of phases were identified:

Quartz grains, often in a partly dissolved condition (sketchy, sub-round particles).
Wüstite, generally present as dendrites (white).
Fayalite laths (mid-grey).
Glassy matrix (dark grey-black)
Metallic iron particles
In addition, occasional white angular grains or 'skeletons' were probably magnetite and small areas of "eutectic" phase could have been leucite.

N.B., as can be seen from the SEM/EDX microanalyses in Appendix 3, compositions of these phases do not necessarily conform to the pure minerals quartz, wüstite and fayalite as elements may be substituted.

Many slags, including all the tap slags and dense slags comprised wüstite (FeO) and fayalite ($2FeO.SiO_2$) in a background of glassy phase. The presence of high proportions of fayalite in tap and dense slags is to be expected. The compound fayalite has the minimum liquidus temperature of the FeO-SiO_2 system (c1150C), thereby giving the slag great fluidity at the temperatures of furnace/hearth operation and allowing it to either flow from the furnace or to form a more consolidated mass of low porosity. Similar balances of phases were found in numerous other samples including undiagnostic ironworking slag, iron-rich cinder and smithing hearth bottoms. However, the latter were found to be quite heterogeneous even within very localised areas.

The other commonly occurring combination of phases comprised a matrix of glassy phase enclosing quartz particles, the quartz often appearing to be partly dissolved. This structure was found in all vitrified hearth/furnace lining and all cinder samples together with about half the undiagnostic slag, one iron-rich cinder sample and areas of several smithing hearth bottoms. Of these, a couple of samples were found to contain quartz, glassy phase and wüstite, but in no instance was quartz found in proximity to fayalite.

Reference to the SEM analyses in Appendix 3 and metallographic data in Appendix 2 shows that the metallographic structures are dictated by the elemental composition: Samples containing above 36% FeO show the full range of wüstite, fayalite and glassy phase, those below this figure tend to contain quartz and glassy phase only.

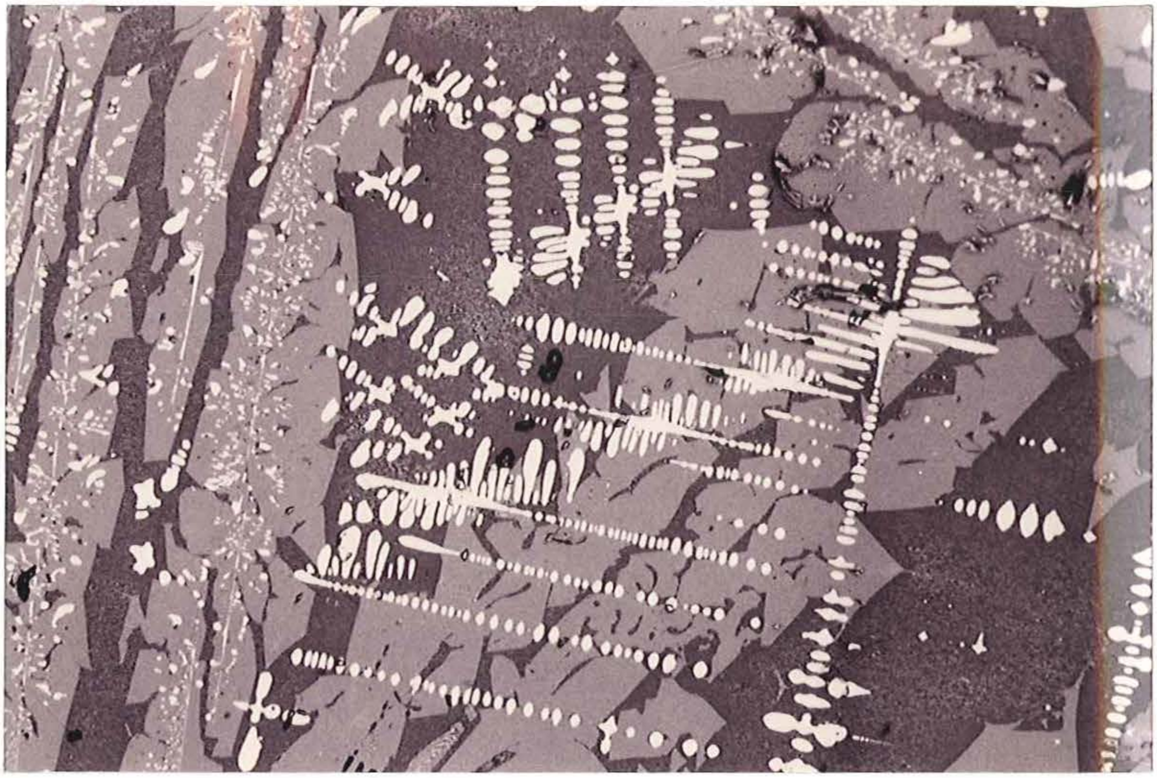

Plate 4.2.1 Micrograph showing wüstite dendrites (white) and ferrite laths (grey) in a glassy matrix (dark grey)

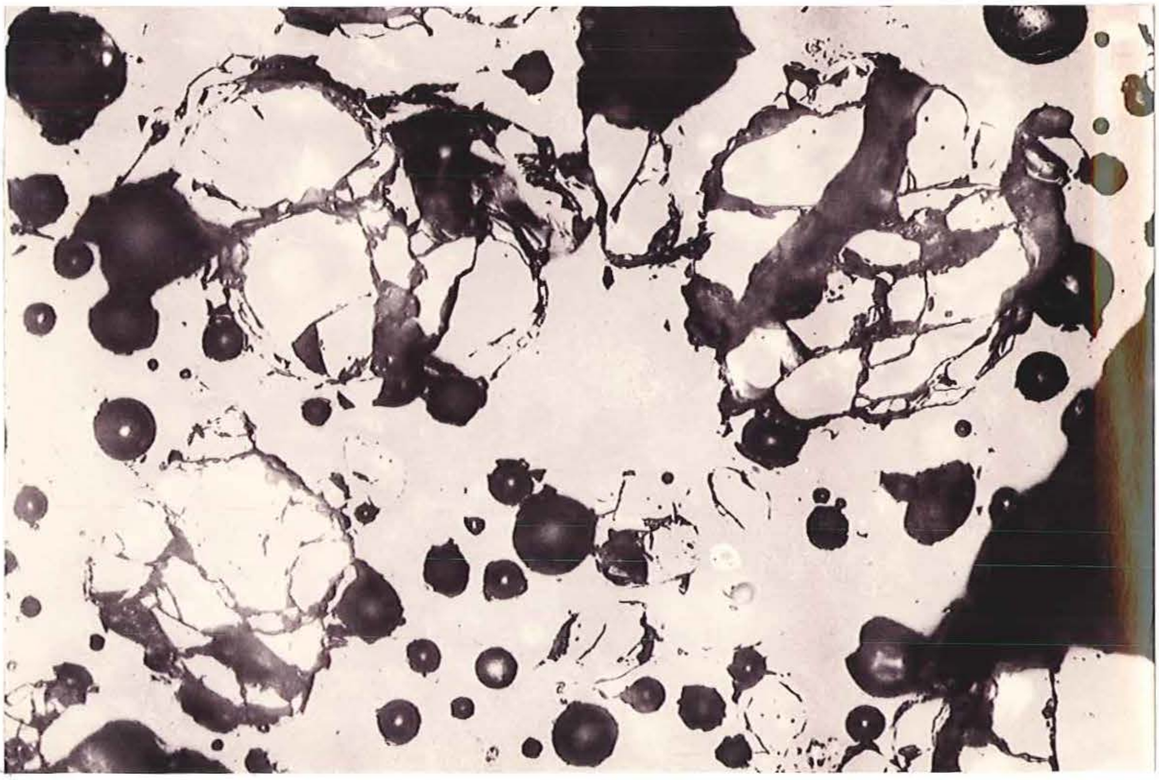

Plate 4.2.2 Micrograph showing quartz inclusions (large fractured grains) in a glassy matrix of high porosity (black, spheroidal voids)

4.3 X-ray fluorescence results

Analyses are quoted only as 'strong', 'weak' and 'detected' on the basis of peak height. As no standards were compared it was not possible to be more precise on composition because peak height is also dependent on a number of factors other than composition. In particular, the choice of incident x-ray voltage will determine which elements will tend to be excited to a greater or lesser degree. In these analyses an excitation voltage of 15kV was chosen. This gave a strong response from the transition elements of interest, *ie* iron, manganese and titanium but the sensitivity to lighter elements dropped off with decreasing atomic number. This effect can be seen by comparing the results in appendix 2 to the calibrated SEM/EDXA data in Appendix 4.

All samples provided a strong peak for iron, even for the glassy sample (94037) which contained less than 20% FeO. More usefully, the technique was sensitive to titanium and manganese, detecting these elements down to trace levels, which could prove of assistance in diagnosing technological origins. Potassium and calcium were generally found at 'detected' or 'weak' level, very approximately corresponding to below 1% or between 1% and 5% respectively. Elements lower in the periodic table were increasingly poorly detected; it was unfortunate that the potentially diagnostic element, phosphorus was not always detected when between 1% and 2%. Aluminium and silicon were generally detected, but only because of the abundance of these elements in the sample. Sodium and magnesium were not detected, even at concentrations of 2-3%.

In conclusion in can be said that the relatively rapid technique of non-quantitative XRF analysis does have some value in detecting certain **elements** in slag samples, particularly Al, Ca, Ti, Mn, Ti and K, but much more informative data can be obtained from quantitative techniques such as analytical SEM. It must be stressed that the equipment used was unable to detect oxygen, and therefore the content of this element was not determined. XRF analysis enabled the slag to be checked for the presence of non-ferrous metals. If present these would indicate that the debris derived from a process which produced, alloyed or worked these metals, although the latter might be carried out in a hearth also used for the working of iron.

4.4 X-ray diffraction analysis

An important advantage of the x-ray diffractometer is its ability to identify specific compounds, rather than only listing the constituent elements. The technique relies on the existence of uniquely different spacing of crystal planes within crystalline minerals. For the analysis of slags the technique has two inherent weaknesses. Firstly, the minerals must be in a crystalline state. As many slags contain at least some glassy phases, or largely glassy phases, these will not produce a diffraction pattern. Secondly, many minerals can exist over a range of composition with one element substituting for another, which may prevent the mineral being identified.

Most samples gave 'strong' diffraction patterns for the minerals which had been recognised by metallography, particularly, wüstite, fayalite and quartz. Other minerals recognised included high temperature modifications of these, such as cristobalite (SiO_2) and alternative oxides of iron including haematite(Fe_2O_3) and magnetite (Fe_3O_4), together with hydrated forms such as opal, goethite and silicon oxide hydrate. As expected, recognition of the glassy alkali silicates was poor. No positive identification of the 'very common constituent of slag' (Bachmann 1982), anorthite, was made although a few alkali silicates were suggested. Other suggested minerals, such as dolomite and sodium aluminium sulphate should be disregarded because the requisite elements were not detected by elemental analysis.

4.5 SEM based microanalysis

The advantages of SEM based EDX analysis lie in the ability of the technique to undertake analysis at high magnifications on selected small areas such as specific phases or mixtures of phases. The method is therefore highly suitable for heterogeneous archaeological materials. The sample may be viewed in back-scattered mode prior to analysis. This mode enhances atomic number contrast, rather than topography, allowing phases in the flat, polished specimen to be differentiated. It should be noted that the tones of a back-scattered image are likely to be different from those of the optical microscope; Phases containing elements with higher atomic numbers, such as the iron in wüstite, appear darker than low atomic number phases, such as glasses, with fayalite appearing as an intermediate mid-grey.

Like XRF analysis, the technique can only be used to detect elements. The quoted figures, which refer to the weight percentage of oxide are derived from assumptions about the stoichiometry (*ie* the combining tendency) of each element. Minimum detectable levels vary from element to element: for oxides of Na, Mg, Al, Si, P, S, K, Ca and, Ti these would be approximately 0.1%, Mn about 0.15% and Co, Ni and Cu between 0.15 and 2.5%. Due to instrumentation problems, samples 94003 to 94017 recorded sodium and magnesium contents of zero and these have been removed from the data.

Analyses of the supposed quartz inclusions, confirmed their identity, and showed impurity elements to be, with very few exceptions, below the minimum detection limits of the instrument. Wüstite, seen as a black on the SEM back-scattered image, was found to be reasonably pure, typically with only 2 or 3% of other oxides present. The fayalite laths showed much greater diversity. Although approximating to 70% Fe0, 30% SiO_2, it was clear that in samples containing high levels of manganese and magnesium, most of these elements concentrated in the fayalitic phase, where they would be expected to substitute for iron. The glassy matrix analyses also contained a high proportion of silica, typically 30 to 50%, combined with the bulk of the sodium, aluminium, phosphorus, calcium, sodium and sulphur. The glassy phases were also found to contain significant quantities of iron oxide; 20-30% was not unusual.

As a general observation, it was found that duplicate analyses of a phase within the same sample indicated very similar compositions, whilst a series of area analyses (mixed phases) within a single sample showed considerable variation. The bulk analyses quoted in Appendix 4, therefore, are mean figures derived from at least five area analyses. The figures give a far more useful characterisation of the sample than was achievable by XRF. For instance it is possible to compare iron oxide contents; tap slag and dense slags have very similar levels, of 47 to 59%, iron-rich cinder tends to contain more, up to 76%, whereas hearth lining and cinder are generally below 10%. By contrast, iron oxide contents in smithing hearth bottoms and undiagnostic slag vary greatly. From a technological point of view, the 18% iron oxide in the glassy slag from Context 446 is of interest as this suggests that it is not an intrusive post-medieval blast furnace slag which should not contain such a large quantity of iron.

In studying the origins of the different elements comprising slag it should be noted that whilst some may originate from a number of sources (silicon for example may derive from the ore, furnace lining, sand fluxes or fuel ash), the possible origins of other elements are more limited. For example, with the possible exception of certain, specific fuel ashes, the main source of manganese must be the ore. At the temperatures of the bloomery furnace, this element is not significantly reduced into the metal but passes into the slag. The element may therefore be regarded as an indicator of smelting slag, assuming of course that the source of ore contains some manganese. Of the three highest manganese contents one was the glassy slag and the other two were from the samples identified morphologically as tap slag. Although this result would appear obvious, recent experimental work (Peter Crew pers. comm.) has highlighted the danger of confusing small slag runs from smithing hearths with true tap (*ie* smelting) slag. Manganese contents can also shed some light on whether the dense slag also derives from smelting. Of the four samples chosen for analysis, only the sample from context 485 (Phase 4.2) contains a manganese content comparable to that of the tap slag, to suggest that it too is a smelting slag. It is conceivable that the other three derive from the smelting of manganese-free ore. However, as two are matched by contemporary manganese-rich tap slags (from the same context), this must be considered unlikely.

The element phosphorus is also of interest. The extent to which this element passes into the slag, rather than metal, on smelting depends largely on the operating conditions of the furnace. However, the element does appear to be very mobile, migrating from metal to slag or slag to metal when conditions are favourable. It is of little surprise to find it in the two tap slags and the probable smelting dense slag. Its absence in the glassy slag would be explained by unusually reducing conditions which removed both phosphorus and most of the iron from the slag. More difficult to explain is the high concentrations of the element in some of the other slag types. In some of these samples the distribution was very uneven, but in others phosphorus was found throughout the sample, the sample of fuel ash slag, for instance contained over 4% of phosphorus pentoxide.

A few fragments of coal found within the assemblage may have been associated with the smithing of iron, though charcoal was more commonly present. The coal was returned to the post-excavation manager without being analysed. In retrospect it would have been interesting to determine the sulphur content of the coal, to find whether this would be detectable in smithing slags using coal as fuel. In fact no significant levels of sulphur were found in any of the bulk mean figures. However, one sample (the possibly smelted dense slag from Context 485) gave values of 0.5, 0.6 and 0.7% for sulphur monoxide in its glassy phase.

Contents of those oxides which combine with silica to form glassy phases vary considerably and it is difficult to detect patterns in these. Groups such as the vitrified linings and cinder do tend to have high concentrations of Na, Mg, Al and K, possibly deriving from fuel ash, though most could originate from clay minerals within the lining material. However, all the major categories show occasional high concentrations of these elements. Calcium is also very unpredictable, not surprisingly as sources of this element are likely to include the ore, fuel ash and the accidental or deliberate addition of calcium-rich minerals. The latter case should be considered for the single fragment of glassy slag from Context 446. The historical and modern blast furnace process utilises high temperatures, highly reducing conditions and the deliberate addition of limestone. As a result, calcium is substituted for iron in the slag and the yield of iron is considerably increased. The drawback of this mode of production is that the high carbon alloy, cast iron, is the product. Examples of this material are known from Roman sites (Tylecote 1986) but there is no reason to think that its production was intentional.

Some care must be taken in the interpretation of the data in Appendix 3 due to the very low compositional totals obtained during analysis, as mentioned the detector was giving poor resolution, particularly for light elements for the earlier samples analysed. Another cause may be due to elements combining with more oxygen than had been predicted for instance magnetite (Fe_3O_4) rather than wüstite (FeO), or as hydroxides rather than oxides, as might be expected in some of the weathered-looking iron rich cinder. additionally many of the samples were porous and the surfaces analysed were not perfectly flat.

5 The Determination of hammerscale

5.1 Introduction

As mentioned above (3.3), hammerscale is considered to be of importance in identifying the existence, location and nature of smithing activity. Because the slag from Ribchester had been packed uncleaned, hammerscale was often inadvertently included in the sample and this is noted, but not quantified, in Appendix 1.

A more objective methodology for the determination of hammerscale has been set out by Mills and McDonnell (1992). Although hammerscale can be extracted using a magnet, cleaned and weighed, this requires a great deal of time. Mills and McDonnell's method relies on the high magnetic susceptibility (an expression of the magnetic moment induced in a material when it is placed in a magnetic field) of hammerscale, due primarily to its magnetite content. Their study showed that in samples containing hammerscale, the value of magnetic susceptibility was effectively proportional to the content of hammerscale in the sample. As magnetic susceptibility can be relatively easily determined, this provides a far more rapid means of quantifying the hammerscale component. It should be noted that although non-industrial materials (and post-depositional environments) can give enhanced magnetic susceptibility readings, these are likely to be minimal in comparison to the very high values given by hammerscale.

5.2.1 Methodology: Single frequency, large samples

Soil samples from contexts across the site were dried at room temperature, crushed and sieved (2mm sieve) to remove small stones etc. Magnetic susceptibility measurements were made using a Bartington Meter Model MS2, large samples of approximately 100cm^3 were used to give a single reading. In all cases the sample was accurately weighed so that the mass specific magnetic susceptibility could be calculated (Given as m^{2}kg^{-1}).

To determine the causes of the enhanced susceptibility, a sub-group of 17 samples had its magnetic fraction removed with a magnet and this was examined under a binocular microscope, to determine the relative proportions of fired clay, flake hammerscale and spheroidal hammerscale.

5.2.2 Results

Enormous variation in mass specific magnetic susceptibility was found to occur between samples. A sample of "natural" gave a value of 4 x10^{-8}m^2 kg^{-1} whilst figures of up to 50 x10^{-8}m^2 kg^{-1} were typical for disturbed top soil. Compared with these, values in the region of several hundreds to thousands x10^{-8}m^2 kg^{-1} stand out as exceptional and must derive from some combination of high temperatures applied to materials with a significant ferrous component.

The earliest significantly enhanced material was the Phase 1.2 fill (396) of pit (406), recorded as containing possible hearth debris (though this had not been matched by metalworking debris). In the second phase, several putative hearth debris contexts gave very low magnetic susceptibility readings but a layer (334) in hearth (332) gave a much more positive signal of 484 $x10^{-8}m^2\ kg^{-1}$. Unfortunately it is not possible to tell whether these high values were due to hammerscale or the presence of burnt or fired clay. Three contexts in Phase 3 gave similarly high mass specific values; hearth debris (564) (from the hearth (572) with which a small quantity of bulk slag, (571), is possibly associated) and two layers (545) and (800).

Samples from a large number of Phase 4 contexts were examined, including many associated with hearths within the *fabrica*. Again, many of the readings were so low as to preclude the presence of hammerscale but several others, including (698), (223), (485), (542) and (589) gave mass specific magnetic susceptibility values in excess of 400 $x10^{-8}m^2\ kg^{-1}$. Three of these contexts (223), (485) and (542) are associated with the later series of hearths for which bulk slags also provided some evidence of possible smithing. By chance all three of the samples from these contexts were chosen (as examples of high values) for visual examination of their magnetic fractions. In these three cases large proportions of fired clay were present, and it was this that provided most of the magnetic susceptibility enhancement. However, all three samples also contained small quantities of flake hammerscale and the former two included examples of spheroïdal hammerscale.

Phase 5.1 and 5.2 samples were found to give surprisingly low mass specific magnetic susceptibility readings, suggesting that the high component of bulk slags in some of these contexts was not matched by hammerscale content.

5.3.1 Dual frequency susceptibility measurement

An attempt to refine the methodology of Mills and McDonnell was made by repeating the magnetic susceptibility measurements on $10cm^3$ samples using a Bartington Dual Frequency MS2B36 instrument, which measured susceptibility at low (0.43 kHz) and high frequency (4.3kHz) cycles. It is known that fine grained materials exhibit frequency dependent susceptibility and it was hoped that differences in these values might help to indicate the nature of the magnetic materials and hence help to diagnose the process being undertaken. From the readings it was possible to calculate the coefficient of frequency dependency, as follows:

$$\text{frequency dependence, } X_{FD} = \frac{(\text{mag. sus.}_{\text{high freq}} - \text{mag sus.}_{\text{low freq}}) \times 100\%}{\text{mag. sus.}_{\text{high freq}}}$$

5.3.2 Results

Occasional negative values for the frequency dependency were obtained, where the high frequency value exceeded the low. This should not occur. However, it is evident that the erroneous values derive from samples giving very low readings, and the discrepancy is due to experimental errors.

No patterns in frequency dependency with respect to types of archaeological features were observed in the data.

Again it was impossible to draw any conclusions on the relative contribution of the different types of magnetic particles within the soil, due to the very small quantities of hammerscale present. As a comparison, small quantities of hammerscale were extracted from another site assemblage and these gave the following results:

Table 5.3.2 Comparative magnetic susceptibility data for hammerscale

	Mass (g)	High freq. ($x10^{-5}$)	Low freq. ($x10^{-5}$)	Mass spec. high freq. (m^2kg^{-1} $x10^{-8}$)	Mass spec. low freq. (m^2kg^{-1} $x10^{-8}$)	Frequency dependence
Spheroidal hammerscale	0.1	108	105	10800	10500	-2.9
Flake hammerscale	0.4	275	273	6875	6825	-0.7
Mixed magnetic residue	2.6	2359	2353	9073	9050	-0.3

It should be noted that the actual quantities of hammerscale tested were very small, and it was necessary to repeat and average the measurements to produce reliable figures. The higher mass specific magnetic susceptibility values for spheroidal, rather than flake, hammerscale may be significant, although, in future more samples need to be tested to confirm this. Coefficients of frequency dependence are all negative, but close enough to zero to suggest that there is no significant difference between the figures derived at high, and low frequency.

6 Conclusions

The choice of Ribchester, Graveyard as the subject for in-depth analysis of metalworking debris was due both to the importance of the archaeological site, particularly in understanding the role of the military occupation of Britain, but also because it provided an excellent opportunity to investigate innovative archaeometallurgical techniques. Two unusual features of the fort, its continuity of occupation beyond the initial period of invasion, and the presence of an extramural settlement with evidence of large scale crafts/industries may be linked. Together with the working of leather, iron metallurgy was therefore thought to have been of particular importance for the function of the settlement.

From the archaeometallurgical perspective Ribchester is intriguing because, despite the considerable quantity of metalworking debris on site and the large number of apparently industrial hearths excavated, there was very little cause to link these two forms of evidence together. In particular, there was no record of significant quantities of residues within the hearths. Ribchester was therefore seen as an appropriate test site on which to follow new methodologies for identifying metalworking sites, especially the use of magnetic susceptibility, which had recently been undertaken with remarkable success at a medieval smithy at Burton Dassett Mills and McDonnell 1992).

Further to this it was decided to follow a very broad-based analytical program to look at the range of metalworking debris on the site. Ordinarily, metalworking debris is examined visually only, yet there are still some differences of opinion between archaeometallurgists regarding the origins of some classes of material. It was hoped, therefore, that the analytical program would help not only to interpret the material from Ribchester, but to investigate procedures for the (visual and analytical) identification of material in future studies. The data produced would also provide a useful reference base, against which future analyses could be compared.

The primary means of assessing the nature of the metalworking activity at Ribchester was the classification of slag types visually. The assemblage was found to be predominantly from the smithing of iron. Additionally, a limited amount of evidence for the smelting of iron was identified. Evidence of non-ferrous metal working was on a scale which did not suggest that this was a significant activity on the site.

Examination of a range of prepared samples of debris using an optical microscope emphasised the similarities of structure between the different classes of slag. "Vitrified hearth/furnace linings" and "cinder" both exhibited a structure of quartz particles in a matrix of glassy phase. By contrast, "tap slag", "dense slag" and most "undiagnostic ironworking slags" comprised wüstite, and fayalite in a glassy matrix. Some categories, particularly "smithing hearth bottoms" proved to be exceedingly heterogeneous.

The microstructural similarities between "tap slags" and "dense slags" do not necessarily imply similar technological origins. Although SEM based microanalysis showed broadly similar compositional ranges (an impure fayalite which would have remained fluid at relatively low temperatures), trace levels of manganese were used to distinguish between smelting and smithing slags. All the analysed "tap slags" and one of the four "dense slags" were thereby confirmed as smelting debris. Identifying the origin of "dense slag" without time consuming analysis remains problematic. However, results from the much more rapid X-ray fluorescence (XRF) analysis suggested that this technique may be sufficiently sensitive to distinguish between the two types providing, as at Ribchester, sufficiently high contents of manganese are present.

Analysis of the slags by X-ray diffraction (XRD) confirmed the major mineral phases identified by metallography and also showed some modification of these. The inability of the technique to recognise non-crystalline materials prevented the glassy phases from being identified.

Recent research has emphasised the importance of hammerscale in locating the site of iron smithing. Attempts to quantify hammerscale in Ribchester soil samples, using magnetic susceptibility, were less successful than had been hoped. Many of the samples which gave considerably enhanced values were examined and found to contain burnt clay but no hammerscale. However, some limited success in linking hammerscale with hearths was achieved. An attempted extension of the methodology to include dual frequency measurement failed to reach meaningful conclusions because of the very low levels of hammerscale.

As mentioned above, a considerable problem encountered in interpreting the scale, nature and timing of the metalworking activity at Ribchester was the physical separation of the debris from the hearths on the site. Very rarely was any debris discovered *in situ* and only occasionally was material found in immediate proximity to the hearths. For many of these structures there is no reliable evidence to prove that they relate to metalworking. Their apparent variation in size and construction would also suggest a variety of uses. However, in a number of cases small amounts of bulk slags and, more convincingly, hammerscale provided evidence for smithing activity in some of the hearths, or at least close to them. The latter case might be explained by the use of waist-height smithing hearths. These would leave little structural trace and the bulk slags may well have been removed from the site, though some hammerscale would be expected in the vicinity. Quantification of slag totals showed that whilst bulk slag is generally not found in contexts near hearths within the same phase, often larger amounts of debris occur in the following phase. For instance slag in Phase 3 layers lay directly above the Phase 2.2 hearth complex. The pattern is repeated to an even greater extent for the industrial deposits of 5.1 above the Phase 4 hearths of building complex 722.

The reason for this tendency is not clear. An immediate interpretation, that the choice of phasing has effectively divorced the building of hearths from their operation, would ignore the sub-phases of hearth construction. A number of other possibilities should be considered: Iron could have been smithed within the building, the slag dumped elsewhere then at a later stage some could have been redeposited in the immediate area; an explanation which would fit the limited quantities in Phase3. Alternatively iron could have been worked at the site, the debris dumped elsewhere, then at a later date when the focus of smithing had moved to an adjacent site the old hearth site became the new dumping zone for debris. Of course if other functions are assigned to the hearths, then the spatial and temporal origins of the ironworking debris becomes very unclear.

Bearing in mind the above difficulty in linking the smithing debris to the hearths, it is still possible to address the academic objectives of the project. The first aim was to understand the function, status and purpose of the fort though time. No metalworking debris was identified from the pre-Roman contexts or from the construction of the fort. It is only during Phase 1.2, with the establishment of the extra-mural settlement, that limited quantities of smithing debris show that iron was worked. However, at this date there is insufficient material to suggest that this was more than a short term activity. The hearths of Phase 2.2 again present difficulties in interpretation due to their lack of bulk debris, and unconvincing magnetic susceptibility values. The interim archaeological report stresses the proximity of the Phase 3 debris to the underlying Phase 2.2 hearths, but as outlined above, several alternative sets of circumstances could have led to this stratigraphic relationship. A deposit associated with a separate hearth within Phase 3 did yield a very small amount of undiagnostic ironworking slag, amongst other debris. Again this is meagre evidence for a significant metalworking activity on the site at this time.

The majority of the hearths found on the site were within building 722, constructed in Phase 4, for which a mid-Hadrianic date is suggested. No slag was found in any of these hearths but deposits associated with some of them contained both small quantities of bulk ironsmithing slags, hammerscale and a fragment of a crucible containing non-ferrous debris. It would therefore appear likely that some iron smithing was being carried out at this time. However, given the difficulty in ascribing a metalworking function to the hearths, very little can be said of the scale or nature of this activity during this period.

It is during Phase 5 that evidence of large scale metalworking, producing beyond the needs of the immediate settlement and its occupants, first becomes clear. Diagnostic slags within Phase 5.1 show the debris to derive almost entirely from iron smithing. Clarification of the nature of the objects being worked may be achieved by the examination of associated iron artefacts and scrap. However, the slags do appear to be of a light and cindery nature, probably indicating relatively low temperature forging to shape iron, rather than high temperature work required for either the consolidation of iron blooms or the welding of composite objects.

To some extent slag from 5.2 shows a continued emphasis on iron smithing. This still constitutes the overwhelming majority of the diagnostic material. However, there does seem to be some shift in the make-up of this assemblage, with higher proportion of dense ironworking slags, indicating perhaps a diversification in the range of ironworking processes being carried out. Further to this, small amounts of tap slag, deriving from the primary smelting of iron from ore, were found to be concentrated in some of the latest contexts. It is therefore possible to suggest that, in the latest phase of occupation of the site, some diversification in the working of iron took place, with the actual smelting of some of the metal occurring within the vicinity of the enclosure rather than it all being brought in from an exterior source.

To summarise, and address some of the initial academic objectives of the work, it can be argued that changes in the scale and nature of metalworking can be seen throughout the occupation of the site. None of this activity appears to have taken place within the fort but was concentrated in the extra-mural enclosure. The limited scale of operation in the first three phases may imply that the smithing, of imported iron, was carried out only to serve the immediate locality *ie* the fort and its garrison. At a later time which may date from Phase 4, but certainly during phase 5, a wider range of iron working, perhaps associated with local iron smelting, was carried out. The greatly expanded scale of this appears to imply that the products of this phase were destined for use beyond the immediate environs of Ribchester.

The exact location of the smithing activity is open to some doubt, as few of the hearths can be proved to have been used for this purpose. However, the localised dumping does imply that the focus of the activity was in the immediate vicinity. From the debris alone it is not possible to determine the exact identity of the product, or whether the objects relate to specific types of soldier, and thus no transition from military to civilian control could be detected. Trade links may be implied by the need for the supply of raw iron for smithing in the earlier phases. It is tempting to compare the writing tablet evidence from Vindolanda which shows that the military did sometimes purchase iron locally (Bowman and Thomas 1994). Some iron was smelted close-by in the latest phase of the occupation, although whether this supplied a significant proportion of the demand cannot be said.

7 Storage of slag

Ironworking slag, being predominantly fayalitic, is not prone to deterioration and requires no special storage treatment. It is recommended that at least representative samples of the slag and other technological debris should be saved.

8 Bibliography

Bachmann, H-G (1982) *The Identification of slags from Archaeological Sites.* University of London, Institute of Archaeology Occasional Publication **6** 11, London.

Bowman, A.K. & Thomas, J.D. (1994) *Tabulae Vindolandenses II*, British Museum Press, 131-135, London.

Mills, A. and McDonnell, J G (1992) *The Identification and Analysis of the Hammerscale from Burton Dassett, Warwickshire.* Ancient Monuments Laboratory Report **47/92**.

Tylecote, R F (1986) *The Prehistory of Metallurgy in the British Isles*, Institute of Metals, 167, London.

Appendix 1 Classification & weight of Ribchester ironworking debris

Context	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
1	5.2	5039	2	coke/fuel ash slag	?	topsoil
1	5.2	5039	52	dense ironworking slag	?	topsoil
2	5.2	5051	490	cinder	?	subsoil
2	5.2	5051	1296	dense ironworking slag	?	subsoil
2	5.2	5051	98	iron obj.	?	subsoil
2	5.2	5051	1756	undiagnostic ironworking slag	?	subsoil
2	5.2	5051	381	smithing hearth bottom (dense)	?	subsoil
2	5.2	5051	664	tap slag (small runs only)	?	subsoil
2	5.2	5051	171	ferruginous concretion	?	subsoil
2	5.2	5051	982	vitrified hearth/furnace lining	?	subsoil
2	5.2	5428	23	ceramic (Pb rich glaze internally)	?	subsoil
2/3	5.2	8480	9	fuel ash slag	?/layer	subsoil/horizon: fill of hollows below 02
2/3	5.2	8480	13	cinder	?/layer	subsoil/horizon: fill of hollows below 02
2/24	5.1/5.2	8474	23	cinder	?/layer	subsoil/clay: redeposited rampart material
2/24	5.1/5.2	8474	548	dense ironworking slag	?/layer	subsoil/clay: redeposited rampart material
2/24	5.1/5.2	8474	1625	undiagnostic ironworking slag	?/layer	subsoil/clay: redeposited rampart material
2/24	5.1/5.2	8474	178	iron-rich cinder	?/layer	subsoil/clay: redeposited rampart material
2/24	5.1/5.2	8474	324	tap slag	?/layer	subsoil/clay: redeposited rampart material
3	5.2	6301	33	iron obj.	layer	horizon: fill of hollows below 02
3	5.2	6301	933	iron obj.	layer	horizon: fill of hollows below 02
3	5.2	6301	980	fired clay	layer	horizon: fill of hollows below 02
3	5.2	6301	3269	undiagnostic ironworking slag (cindery)	layer	horizon: fill of hollows below 02
3	5.2	6301	895	smithing hearth bottom	layer	horizon: fill of hollows below 02
3	5.2	6301	1244	ferruginous concretion	layer	horizon: fill of hollows below 02
3	5.2	6301	6368	vitrified hearth/furnace lining	layer	horizon: fill of hollows below 02
3/19	5.2	6517	15	bone	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/19	5.2	6517	13	cinder	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/19	5.2	6517	<1	flake hammerscale	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/19	5.2	6517	500	undiagnostic ironworking slag	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/19	5.2	6517	245	lignite?	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/19	5.2	6517	366	iron-rich cinder	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/19	5.2	6517	211	ferruginous concretion	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/19	5.2	6517	2003	vitrified hearth/furnace lining	layer	horizon: fill of hollows below 02/mixed horizon. Below 05 above 03 & 18
3/31	5.1/5.2	6303	156	cinder	layer	horizon: fill of hollows below 02/grey sandy layer below 03 above 18
3/31	5.1/5.2	6303	32	iron obj.	layer	horizon: fill of hollows below 02/grey sandy layer below 03 above 18
3/31	5.1/5.2	6303	118	undiagnostic ironworking slag (cindery)	layer	horizon: fill of hollows below 02/grey sandy layer below 03 above 18
3/31	5.1/5.2	6303	278	stone (poss. worked)	layer	horizon: fill of hollows below 02/grey sandy layer below 03 above 18
3/31	5.1/5.2	6303	146	ferruginous concretion	layer	horizon: fill of hollows below 02/grey sandy layer below 03 above 18
3/33	5.1/5.2	6510	12	cinder	layer	horizon: fill of hollows below 02/upper organic layer in W baulk below 03 & 19
3/33	5.1/5.2	6510	245	undiagnostic ironworking slag	layer	horizon: fill of hollows below 02/upper organic layer in W baulk below 03 & 19
3/33	5.1/5.2	6510	304	ferruginous concretion	layer	horizon: fill of hollows below 02/upper organic layer in W baulk below 03 & 19

Con-text	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
3/33	5.1/5.2	6510	719	vitrified hearth/furnace lining	layer	horizon: fill of hollows below 02/upper organic layer in W baulk below 03 & 19
4	5.2	5161	5	vitrified hearth/furnace lining	layer	horizon: fill of hollows below 02 = 05
4	5.2	5162	69	cinder (hard brittle white=high Ca)	layer	horizon: fill of hollows below 02 = 05
4	5.2	5162	36	dense ironworking slag	layer	horizon: fill of hollows below 02 = 05
4	5.2	5162	38	iron obj.	layer	horizon: fill of hollows below 02 = 05
4	5.2	5162	397	undiagnostic ironworking slag	layer	horizon: fill of hollows below 02 = 05
4	5.2	5162	45	ferruginous concretion	layer	horizon: fill of hollows below 02 = 05
4	5.2	5162	44	vitrified hearth/furnace lining	layer	horizon: fill of hollows below 02 = 05
5	5.2	5698	51	fuel ash slag	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	380	cinder	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	70	dense ironworking slag	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	377	iron obj.	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	641	undiagnostic ironworking slag	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	298	smithing hearth bottom	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	26	iron-rich cinder	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	8	stone	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	12	tap slag	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	35	ferruginous concretion	layer	horizon: fill of hollows below 02 = 04
5	5.2	5698	859	vitrified hearth/furnace lining	layer	horizon: fill of hollows below 02 = 04
5	5.2	5709	5	iron obj.	layer	horizon: fill of hollows below 02 = 04
5	5.2	5709	201	fired clay	layer	horizon: fill of hollows below 02 = 04
5	5.2	5709	117	vitrified hearth/furnace lining (heavily slagged)	layer	horizon: fill of hollows below 02 = 04
5	5.2	5709	25	vitrified hearth/furnace lining (thin black glaze)	layer	horizon: fill of hollows below 02 = 04
6	5.2	5631	20	cinder	layer	horizon: fill of hollows below 02 = ?05
6	5.2	5631	40	dense ironworking slag	layer	horizon: fill of hollows below 02 = ?05
6	5.2	5631	68	iron obj.	layer	horizon: fill of hollows below 02 = ?05
6	5.2	5631	296	undiagnostic ironworking slag	layer	horizon: fill of hollows below 02 = ?05
6	5.2	5631	12	ferruginous concretion	layer	horizon: fill of hollows below 02 = ?05
6	5.2	5631	29	vitrified hearth/furnace lining	layer	horizon: fill of hollows below 02 = ?05
10	5.2	7307	276	iron-rich cinder	road surface	pebble spread overlying cobble (road) area
11	5.2	5438	26	fired clay	layer	horizon: equivalent to 04
11	5.2	5438	58	vitrified hearth/furnace lining	layer	horizon: equivalent to 04
11	5.2	5439	10	fuel ash slag	layer	horizon: equivalent to 04
11	5.2	5439	264	iron obj.	layer	horizon: equivalent to 04
13	5.2	6407	<1	spheroidal hammerscale	layer	horizon: equivalent to 03
13	5.2	6739	184	cinder (very light)	layer	horizon: equivalent to 03
13	5.2	6739	147	dense ironworking slag (inc. dribbles)	layer	horizon: equivalent to 03
13	5.2	6739	63	iron obj.	layer	horizon: equivalent to 03
13	5.2	6739	66	fired clay	layer	horizon: equivalent to 03
13	5.2	6739	728	undiagnostic ironworking slag (dense fayalitic)	layer	horizon: equivalent to 03
13	5.2	6739	32	lignite?	layer	horizon: equivalent to 03
13	5.2	6739	27	stone	layer	horizon: equivalent to 03
13	5.2	6739	196	vitrified hearth/furnace lining (dense fayalitic slag adhering)	layer	horizon: equivalent to 03
14	5.2	6807	81	vitrified hearth/furnace lining	layer	horizon: between 05 and 13
16	5.2	6529	51	cinder	layer	stony area within 03/13
16	5.2	6529	14	ferruginous concretion	layer	stony area within 03/13
16	5.2	6529	72	vitrified hearth/furnace lining (black glaze)	layer	stony area within 03/13
17	5.2	6812	51	cinder	layer	sand horizons below 13
17	5.2	6812	334	iron obj.	layer	sand horizons below 13
17	5.2	6812	20	fired clay	layer	sand horizons below 13
17	5.2	6812	142	undiagnostic ironworking slag	layer	sand horizons below 13
17	5.2	6812	4	ferruginous concretion	layer	sand horizons below 13
17	5.2	6812	50	vitrified hearth/furnace lining	layer	sand horizons below 13

Con-text	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
18	5.1	6526	5	fuel ash slag	industrial layer	very black deposits, industrial debris?
18	5.1	6526	6423	cinder	industrial layer	very black deposits, industrial debris?
18	5.1	6526	34	dense ironworking slag	industrial layer	very black deposits, industrial debris?
18	5.1	6526	210	iron obj.	industrial layer	very black deposits, industrial debris?
18	5.1	6526		flake hammerscale	industrial layer	very black deposits, industrial debris?
18	5.1	6526	60	fired clay	industrial layer	very black deposits, industrial debris?
18	5.1	6526	11216	undiagnostic ironworking slag (some cindery)	industrial layer	very black deposits, industrial debris?
18	5.1	6526	389	fired clay	industrial layer	very black deposits, industrial debris?
18	5.1	6526	1385	smithing hearth bottom	industrial layer	very black deposits, industrial debris?
18	5.1	6526	762	iron-rich cinder	industrial layer	very black deposits, industrial debris?
18	5.1	6526	145	stone	industrial layer	very black deposits, industrial debris?
18	5.1	6526	56	stones	industrial layer	very black deposits, industrial debris?
18	5.1	6526	195	tuyere	industrial layer	very black deposits, industrial debris?
18	5.1	6526	742	ferruginous concretion	industrial layer	very black deposits, industrial debris?
18	5.1	6526	11898	vitrified hearth/furnace lining	industrial layer	very black deposits, industrial debris?
18/80	5.1	7429	60	undiagnostic ironworking slag (cindery)	industrial layer/?	v. black deposit. Industrial debris/grey gritty layer above 18 cuts/butts 81
19	5.2	5705	33	bone	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	3465	cinder	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	637	dense ironworking slag	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	259	iron obj.	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705		flake hammerscale	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	5073	undiagnostic ironworking slag	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	1220	smithing hearth bottom	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	1515	iron-rich cinder	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	42	tap slag	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	235	ferruginous concretion	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	2200	vitrified hearth/furnace lining	layer	mixed horizon. below 5, above 3 and 18
19	5.2	5705	7	vitrified hearth/furnace lining (green glaze)	layer	mixed horizon. below 5, above 3 and 18
19	5.2	7506	7253	vitrified hearth/furnace lining	layer	mixed horizon. below 5, above 3 and 18
19/32	5.2	6524	618	undiagnostic ironworking slag	layer	mixed horizon. Below 5 above 3 & 18/black area: matrix of 16 ? similar deposit to 18
19/32	5.2	6524	290	ferruginous concretion	layer	mixed horizon. Below 5 above 3 & 18/black area: matrix of 16 ? similar deposit to 18
19/32	5.2	6524	737	vitrified hearth/furnace lining	layer	mixed horizon. Below 5 above 3 & 18/black area: matrix of 16 ? similar deposit to 18
24	5.1	6995	28	cinder	rampart/layer	clay: redeposited rampart material
24	5.1	6995	5	fired clay	rampart/layer	clay: redeposited rampart material
24	5.1	6995	26	undiagnostic ironworking slag	rampart/layer	clay: redeposited rampart material
24	5.1	6995	3	fired clay	rampart/layer	clay: redeposited rampart material
24	5.1	6995	10	vitrified hearth/furnace lining	rampart/layer	clay: redeposited rampart material
24	5.1	6995	67	vitrified hearth/furnace lining	rampart/layer	clay: redeposited rampart material
25	5.1	6314	141	cinder	layer	gritty horizon below 19, above 18
25	5.1	6314	10	coal	layer	gritty horizon below 19, above 18
25	5.1	6314	24	iron obj.	layer	gritty horizon below 19, above 18
25	5.1	6314	544	undiagnostic ironworking slag	layer	gritty horizon below 19, above 18
25	5.1	6314	2	bone	layer	gritty horizon below 19, above 18
25	5.1	6314	676	stone (poss. ore?)	layer	gritty horizon below 19, above 18
25	5.1	6314	562	ferruginous concretion	layer	gritty horizon below 19, above 18
25	5.1	6314	323	vitrified hearth/furnace lining	layer	gritty horizon below 19, above 18
25/54	5.1	9053	47	bone	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow
25/54	5.1	9053	52	cinder	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow
25/54	5.1	9053	170	undiagnostic ironworking slag	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow
25/54	5.1	9053	15	fired clay	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow

Con-text	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
25/54	5.1	9053	408	vitrified hearth/furnace lining	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow
31	5.1	6780	162	cinder	layer	grey sandy layer, below 03 above 18
31	5.1	6780	112	crucible fragment.	layer	grey sandy layer, below 03 above 18
31	5.1	6780	140	iron obj.	layer	grey sandy layer, below 03 above 18
31	5.1	6780	25	fired clay	layer	grey sandy layer, below 03 above 18
31	5.1	6780	371	undiagnostic ironworking slag (cindery)	layer	grey sandy layer, below 03 above 18
31	5.1	6780	75	poss. ore (box stone)	layer	grey sandy layer, below 03 above 18
31	5.1	6780	955	iron-rich cinder	layer	grey sandy layer, below 03 above 18
31	5.1	6780	174	ferruginous concretion	layer	grey sandy layer, below 03 above 18
31	5.1	6780	1137	vitrified hearth/furnace lining	layer	grey sandy layer, below 03 above 18
31/54	5.1	6427	5	fuel ash slag	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow
31/54	5.1	6427	150	cinder	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow
31/54	5.1	6427	1168	vitrified hearth/furnace lining	layer/industrial layer	gritty horizon below 19 above 18/mottled sandy layers/lens , poss. a slump into a large pit/hollow
33	5.1	6545	262	cinder	layer	upper organic layer in W baulk. Below 3 &19
33	5.1	6545	47	fired clay	layer	upper organic layer in W baulk. Below 3 &19
33	5.1	6545	466	ferruginous concretion	layer	upper organic layer in W baulk. Below 3 &19
33	5.1	6545	938	vitrified hearth/furnace lining	layer	upper organic layer in W baulk. Below 3 &19
37	5.1	7309	245	cinder	layer	redeposited clay above 18
37	5.1	7309	460	undiagnostic ironworking slag	layer	redeposited clay above 18
37	5.1	7309	234	iron-rich cinder	layer	redeposited clay above 18
37	5.1	7309	1368	vitrified hearth/furnace lining	layer	redeposited clay above 18
38	5.1	7360	42	cinder	layer	hearth? debris? mixed red clay below 03
38	5.1	7360	303	vitrified hearth/furnace lining	layer	hearth? debris? mixed red clay below 03
40	5.1	7323	123	vitrified hearth/furnace lining	layer	dark grey/black gritty layer below 33 above 31
45	5.1	7329	48	iron-rich cinder	industrial layer	substantial deposit of mixed red clay
47	5.2	7342	42	cinder	industrial layer	grey clay layer below 18 above 48. Separates two layers of industrial debris
48	5.1	7338	55	cinder	industrial layer	black industrial layer. Below 47 above 49
48	5.1	7338	33	undiagnostic ironworking slag	industrial layer	black industrial layer. Below 47 above 49
48	5.1	7338	257	iron-rich cinder	industrial layer	black industrial layer. Below 47 above 49
48	5.1	7338	635	vitrified hearth/furnace lining	industrial layer	black industrial layer. Below 47 above 49
49	5.2	7343	2252	vitrified hearth/furnace lining (lightly slagged)	industrial layer	grey clay layer/lens, possibly a slump into a large pit/hollow
50	5.1	6977	82	cinder	industrial layer	black industrial layer. Below 49 above 52
50	5.1	6977	19	tuyere fragment.	industrial layer	black industrial layer. Below 49 above 52
50	5.1	6977	500	vitrified hearth/furnace lining	industrial layer	black industrial layer. Below 49 above 52
51/52	5.1	7376	65	cinder	fill of Punic ditch/industrial layer	grey clay below 54/grey clay below 50 above 53
51/52	5.1	7376	122	iron-rich cinder	fill of Punic ditch/industrial layer	grey clay below 54/grey clay below 50 above 53
51/52	5.1	7376	661	vitrified hearth/furnace lining	fill of Punic ditch /industrial layer	grey clay below 54/grey clay below 50 above 53
52	5.1	7353	173	cinder	industrial layer	grey clay layer below 50 above 53
52	5.1	7353	11	fired clay	industrial layer	grey clay layer below 50 above 53
52	5.1	7353	442	undiagnostic ironworking slag	industrial layer	grey clay layer below 50 above 53
52	5.1	7353	62	iron-rich cinder	industrial layer	grey clay layer below 50 above 53
52	5.1	7353	703	vitrified hearth/furnace lining	industrial layer	grey clay layer below 50 above 53
53	5.1	7369	880	cinder	industrial layer	black industrial layer below 52 above 60
53	5.1	7369	233	fired clay	industrial layer	black industrial layer below 52 above 60
53	5.1	7369	1980	undiagnostic ironworking slag (cindery)	industrial layer	black industrial layer below 52 above 60
53	5.1	7369	138	iron-rich cinder	industrial layer	black industrial layer below 52 above 60
53	5.1	7369	231	ferruginous concretion	industrial layer	black industrial layer below 52 above 60
53	5.1	7369	4430	vitrified hearth/furnace lining	industrial layer	black industrial layer below 52 above 60
54	5.1	6427	32	undiagnostic ironworking slag	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow

Con-text	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
54	5.1	6894	411	cinder	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow
54	5.1	6894	135	iron obj.	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow
54	5.1	6894	1337	undiagnostic ironworking slag	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow
54	5.1	6894	1434	fired clay	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow
54	5.1	6894	115	stone (crinoidal limestone)	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow
54	5.1	6894	63	unknown (not metallurgical)	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow
54	5.1	6894	3961	vitrified hearth/furnace lining	industrial layer	mottled sandy layers/lens, poss. a slump into a large pit/hollow
55	4.1	1646	13	stone	layer	brown clay loam below 18 & 24
55	4.1	1646	8	ferruginous concretion	layer	brown clay loam below 18 & 24
56/64	5.1	7385	130	vitrified hearth/furnace lining	other/industrial layer	fill of shallow linear slot/clay mixed component of 54 below 03
60	3	7407	6	fuel ash slag	layer	grey clay below 53 (demolition of early fort?)
60	3	7407	61	fired clay	layer	grey clay below 53 (demolition of early fort?)
60	3	7407	893	undiagnostic ironworking slag (cindery)	layer	grey clay below 53 (demolition of early fort?)
60	3	7407	103	undiagnostic ironworking slag	layer	grey clay below 53 (demolition of early fort?)
60	3	7407	388	vitrified hearth/furnace lining	layer	grey clay below 53 (demolition of early fort?)
61	4.2	9577	62	undiagnostic ironworking slag (cindery)	other	pebble surface below 46. E of timber building 722
65	3	7367	76	cinder	fill of Punic ditch	organic material below 51 & 54. Fill of ditch 247
74	4.2	7358	167	cinder	layer	layer below 18 in section 11. S + above 78
74	4.2	7358	466	undiagnostic ironworking slag	layer	layer below 18 in section 11. S + above 78
74	4.2	7358	36	vitrified hearth/furnace lining	layer	layer below 18 in section 11. S + above 78
74	4.2	9057	4	bone	layer	layer below 18 in section 11. S + above 78
75	4.2	9058	17	cinder	layer	layer below 18 in section 11. N + above 78
75	4.2	9058	93	fired clay	layer	layer below 18 in section 11. N + above 78
75	4.2	9058	708	undiagnostic ironworking slag (many stony inclusions)	layer	layer below 18 in section 11. N + above 78
75	4.2	9058	45	vitrified hearth/furnace lining	layer	layer below 18 in section 11. N + above 78
76	5.1	7488	266	iron-rich cinder	other	base of furnace shaft
80	5.1	7475	273	undiagnostic ironworking slag	?	grey gritty layer above 18
83	4.2	7444	8	undiagnostic ironworking slag	linear feature	fill of slot 82
87/112		7481	317	undiagnostic ironworking slag	layer/other	grey gritty layer over stones 88 in slump/machine clearance of stone horizon
90	4.2	7422	409	cinder	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	207	crucible	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	12	iron obj.	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	1256	undiagnostic ironworking slag	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	86	fired clay	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	105	smithing hearth bottom	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	243	iron-rich cinder	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	33	ferruginous concretion	linear feature	brown organic fill of gully 92 below 89 above 91
90	4.2	7422	2035	vitrified hearth/furnace lining(some black glaze)	linear feature	black organic fill of gully 92 "below 91"
91	4.2	7432	242	cinder	linear feature	brown organic fill of gully 92 below 89 above 91
91	4.2	7432	90	fired c lay	linear feature	brown organic fill of gully 92 below 89 above 91
91	4.2	7432	555	undiagnostic ironworking slag (cindery)	linear feature	brown organic fill of gully 92 below 89 above 91
91	4.2	7432	1792	vitrified hearth/furnace lining	linear feature	brown organic fill of gully 92 below 89 above 91
102	5.2	7103	471	undiagnostic ironworking slag	other	machine clearance of 03, 13, 14, 17, 19 & 54
102	5.2	7103	223	smithing hearth bottom	other	machine clearance of 03, 13, 14, 17, 19 & 54
102	5.2	7103	128	ferruginous concretion	other	machine clearance of 03, 13, 14, 17, 19 & 54
102	5.2	7103	12	vitrified hearth/furnace lining	other	machine clearance of 03, 13, 14, 17, 19 & 54
104	4.2	7417	1	bone	hearth within building	beige/grey sandy loam below 96,95 & 100

Con-text	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
104	4.2	7417	26	cinder	hearth within building	beige/grey sandy loam below 96,95 & 100
104	4.2	7417	21	vitrified hearth/furnace lining	hearth within building	beige/grey sandy loam below 96,95 & 100
120	5.1	7493	137	cinder	other	machine removal of industrial and clay layers
120	5.1	7493	1711	undiagnostic ironworking slag	other	machine removal of industrial and clay layers
120	5.1	7493	567	iron-rich cinder	other	machine removal of industrial and clay layers
120	5.1	7493	432	vitrified hearth/furnace lining	other	machine removal of industrial and clay layers
175	5.1	7748	107	undiagnostic ironworking slag		grey silty loam above 174
175	5.1	7748	133	vitrified hearth/furnace lining		grey silty loam above 174
201	5.1	7944	5	copper corrosion lump	other	machine clearance of stones
201	5.1	7944	60	iron obj.	other	machine clearance of stones
201	5.1	7944	107	fired clay	other	machine clearance of stones
201	5.1	7944	340	undiagnostic ironworking slag	other	machine clearance of stones
201	5.1	7944		spheroidal hammerscale	other	machine clearance of stones
201	5.1	7944	113	vitrified hearth/furnace lining	other	machine clearance of stones
205	3	7792	122	crucible frags.	fill of Punic ditch	organic ditch fill of 247
205	3	7792	585	ferruginous concretion	fill of Punic ditch	organic ditch fill of 247
209	3	7581	37	vitrified hearth/furnace lining (black glaze)	fill of Punic ditch	sandy organic ?ditch fill below 203
212	5.1	7907	10	vitrified hearth/furnace lining		sandy layer below pebble surface 190
224	4.2	7919	21	fired clay		industrial debris abutting the rampart
224	4.2	7919	35	vitrified hearth/furnace lining		industrial debris abutting the rampart
224	4.2	9918	38	vitrified hearth/furnace lining		industrial debris abutting the rampart
229	4.2	7923	52	fuel ash slag	rectangular pit	orange brown sandy grit below 228
261	3	7970	140	cinder		cleaning layer of entire site 55/60. After removal of 120
261	3	7970	52	fired clay		cleaning layer of entire site 55/60. After removal of 120
261	3	7970	197	undiagnostic ironworking slag		cleaning layer of entire site 55/60. After removal of 120
274	4.2	8008	22	cinder (grey glaze)		grey layer below 201 machine clearance
274	4.2	8008	12	undiagnostic ironworking slag		grey layer below 201 machine clearance
285	3	8031	15	fuel ash slag	layer	mixed brown clay loam
285	3	8031	11	fired clay	layer	mixed brown clay loam
285	3	8031	47	undiagnostic ironworking slag	layer	mixed brown clay loam
285	3	8031	115	vitrified hearth/furnace lining	layer	mixed brown clay loam
285	3	9981	11	cinder	layer	mixed brown clay loam
285	3	9981	309	undiagnostic ironworking slag	layer	mixed brown clay loam
285	3	9981	167	smithing hearth bottom	layer	mixed brown clay loam
286	1.2	8087	10	cinder	layer	black/mixed material below 285
329	1.2	8421	3	bone	layer	industrial residue below 285 above 286
329	1.2	8421	255	cinder	layer	industrial residue below 285 above 286
329	1.2	8421	31	undiagnostic ironworking slag	layer	industrial residue below 285 above 286
329	1.2	8421	1625	smithing hearth bottom	layer	industrial residue below 285 above 286
329	1.2	8421	103	iron-rich cinder	layer	industrial residue below 285 above 286
329	1.2	8421	<1	spheroidal hammerscale	layer	industrial residue below 285 above 286
329	1.2	8421	98	vitrified hearth/furnace lining	layer	industrial residue below 285 above 286
330	1.2	8090	9	cinder	layer	orange? redeposited natural in hollow above 286
330	1.2	8090	10	undiagnostic ironworking slag	layer	orange? redeposited natural in hollow above 286
330	1.2	8090	25	vitrified hearth/furnace lining	layer	orange? redeposited natural in hollow above 286
343	1.2	8414	5	bone	layer	black/orange material containing slag, within 329
343	1.2	8414	904	cinder	layer	black/orange material containing slag, within 329
343	1.2	8414	<1	flake hammerscale	layer	black/orange material containing slag, within 329
343	1.2	8414	1923	undiagnostic ironworking slag	layer	black/orange material containing slag, within 329

Con-text	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
343	1.2	8414	55	iron-rich cinder	layer	black/orange material containing slag, within 329
343	1.2	8414	1304	vitrified hearth/furnace lining	layer	black/orange material containing slag, within 329
366	1.2	8446	112	undiagnostic ironworking slag	layer	mixed horizon above 345 & 366, below 274?
366	1.2	8446	122	vitrified hearth/furnace lining	layer	mixed horizon above 345 & 366, below 274?
367	1.2	8467	23	cinder	other/layer	brown sandy area below 345 & 366
367	1.2	8467	52	fired clay	other/layer	brown sandy area below 345 & 366
367	1.2	8467	185	undiagnostic ironworking slag	other/layer	brown sandy area below 345 & 366
367	1.2	8467	556	smithing hearth bottom	other/layer	brown sandy area below 345 & 366
368	1.2	8447	5	cinder	layer	charcoal layer below 366 above 369
370	1.2	9046	895	cinder	layer	charcoal layer below 369
370	1.2	9046	4	charcoal	layer	charcoal layer below 369
370	1.2	9046		flake & spheroidal hammerscale	layer	charcoal layer below 369
370	1.2	9046	1398	undiagnostic ironworking slag (cindery)	layer	charcoal layer below 369
370	1.2	9046	115	fired clay	layer	charcoal layer below 369
370	1.2	9046	920	tuyere	layer	charcoal layer below 369
370	1.2	9046	56	tuyere	layer	charcoal layer below 369
370	1.2	9046	545	ferruginous concretion	layer	charcoal layer below 369
370	1.2	9046	491	vitrified hearth/furnace lining	layer	charcoal layer below 369
420	2.2	9951	128	iron obj.	?	mottled clay below 286
431	4.2	9595	20	vitrified hearth/furnace lining	layer	clay below 221, east of stake line 148
435	5.1	9016	157	dense ironworking slag (smooth both sides)	?	black industrial residue (removed by machine) =18
435	5.1	9016	1378	undiagnostic ironworking slag	?	black industrial residue (removed by machine) =18
435	5.1	9016	53	fired clay	?	black industrial residue (removed by machine) =18
435	5.1	9016	458	ferruginous concretion	?	black industrial residue (removed by machine) =18
435	5.1	9016	69	vitrified hearth/furnace lining	?	black industrial residue (removed by machine) =18
437	5.1	9002	6	undiagnostic ironworking slag	road surface	second phase of machine clearance below 12
437	5.1	9002	11	vitrified hearth/furnace lining	road surface	second phase of machine clearance below 12
445	5.1	9007	333	tap slag	?	cleaning layer in southern extension
445	5.1	9907	74	cinder	?	cleaning layer in southern extension
445	5.1	9907	659	dense ironworking slag	?	cleaning layer in southern extension
445	5.1	9907	527	undiagnostic ironworking slag	?	cleaning layer in southern extension
446	5.2	9022	147	cinder	?	grey-black material
446	5.2	9022	580	dense ironworking slag	?	grey-black material
446	5.2	9022	11	iron obj.	?	grey-black material
446	5.2	9022	1624	undiagnostic ironworking slag	?	grey-black material
446	5.2	9022	661	iron-rich cinder	?	grey-black material
446	5.2	9022	73	tap slag	?	grey-black material
446	5.2	9022	25	unknown slag (green blue glassy)	?	grey-black material
446	5.2	9022	212	vitrified hearth/furnace lining	?	grey-black material
446	5.2		51	undiagnostic ironworking slag	?	grey-black material
448	5.1	9014	75	cinder	?	brown clay loam above 24, below 445. Redeposited ?ramp
448	5.1	9014	10	undiagnostic ironworking slag	?	brown clay loam above 24, below 445. Redeposited ?ramp
448	5.1	9014	50	iron-rich cinder	?	brown clay loam above 24, below 445. Redeposited ?ramp
453	5.2	9906	27	cinder	?	machine removal of 446
453	5.2	9906	77	dense ironworking slag	?	machine removal of 446
453	5.2	9906	345	smithing hearth bottom (dense)	?	machine removal of 446
458	4.2	9076	22	stone (poss. ore)	road surface	road surfaces, machined to the N of 457
458	4.2	9076	107	ferruginous concretion	road surface	road surfaces, machined to the N of 457
458	4.2	9076	12	vitrified hearth/furnace lining	road surface	road surfaces, machined to the N of 457

Con-text	Phase	Find No.	Wt. (g)	Slag interpretation	Context type	Context description
460	5.1	9973	29	bone	?	area similar to but below 54
460	5.1	9973	57	cinder	?	area similar to but below 54
460	5.1	9973	87	undiagnostic ironworking slag	?	area similar to but below 54
460	5.1	9973	43	ferruginous concretion	?	area similar to but below 54
460	5.1	9973	382	vitrified hearth/furnace lining	?	area similar to but below 54
468	5.1	9526	204	cinder	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	6	ceramic	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	436	undiagnostic ironworking slag	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	61	fired clay	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	182	smithing hearth bottom	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	137	iron-rich cinder	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	604	tuyere	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	93	ferruginous concretion	?	grey mixed clay loam with flecks, above 18
468	5.1	9526	2898	vitrified hearth/furnace lining	?	grey mixed clay loam with flecks, above 18
474	1.1	9954	174	vitrified hearth/furnace lining	?	rampart clay ?= to 96 & 100
477	5.2	9940	4	iron obj.	layer	black patch within rampart 145
478	5.2	9968	15	vitrified hearth/furnace lining	layer	bottom fill of slot 82
485	4.2	9902	290	dense ironworking slag	hearth	orange hearth debris above 78. Hearth 490
489		9530	33	cinder	general layer	orange clay below 311
489		9530	6	fired clay	general layer	orange clay below 311
497	4.2	9093	15	fired clay	other	white clay W of 311. Another foundation
504	4.2	9541	777	vitrified hearth/furnace lining	layer	baulk removal of E extension 74, 75, 18 & 468
506		9564	57	cinder	?	Machining W baulk. ?18+industrial debris
506		9564	41	fired clay	?	Machining W baulk. ?18+industrial debris
506		9564	433	ferruginous concretion (inc. coal frags	?	Machining W baulk. ?18+industrial debris
506		9564	353	vitrified hearth/furnace lining	?	Machining W baulk. ?18+industrial debris
508		9086	3	ferruginous concretion	?	Machining W baulk. ? fill of ditch 122
509	4.2	9914	88	fired clay	layer	buff clay to W of slot 82
509	4.2	9914	75	vitrified hearth/furnace lining	layer	buff clay to W of slot 82
518	4.2	9096	3	cinder	other	layer fill of pit, below 517. Fill of 519
518	4.2	9096	12	undiagnostic ironworking slag	other	layer fill of pit, below 517. Fill of 519
518	4.2	9096	9	iron-rich cinder	other	layer fill of pit, below 517. Fill of 519
518	4.2	9096	54	vitrified hearth/furnace lining	other	layer fill of pit, below 517. Fill of 519
532		9004	5	iron obj.	?	cleaning layer outside E extension
532		9004	13	undiagnostic ironworking slag	?	cleaning below 534, 544/545 mix
537	3	1610	27	cinder	general layer	cleaning layer outside E extension
537	3	1610	177	undiagnostic ironworking slag	general layer	cleaning layer outside E extension
537	3	1610	8	ferruginous concretion	general layer	cleaning layer outside E extension
555	3	9943	223	iron obj.	general layer	layer below 534 & above 544
562	3	1555	1130	vitrified hearth/furnace lining	general layer	pink clay NE corner below 555
565	3	9937	3	bone	general layer	orange brown crunchy, below 562
565	3	9937	225	undiagnostic ironworking slag	general layer	orange brown crunchy, below 562
565	3	9937	287	smithing hearth bottom	general layer	orange brown crunchy, below 562
565	3	9937	521	vitrified hearth/furnace lining	general layer	orange brown crunchy, below 562
569	3	1628	96	cinder	other	fill of 568 (linear slot)
569	3	1628	807	undiagnostic ironworking slag	other	fill of 568 (linear slot)
569	3	1628	15	fired clay	other	fill of 568 (linear slot)
569	3	1628	186	ferruginous concretion	other	fill of 568 (linear slot)
569	3	1628	28	vitrified hearth/furnace lining	other	fill of 568 (linear slot)
571	3	1549	51	undiagnostic ironworking slag	hearth	burnt mottled layer below 570. Hearth 572
637	4.2	1506	22	vitrified hearth/furnace lining	other assoc. feature	gritty material in S room of 722. Same as 618 & 637
700	4.1	1642	21	cinder	other assoc. feature	fill of N end of N/S trench of 722. Trench 387
3999		1548	80	vitrified hearth/furnace lining		
3999		8486	248	iron obj.		
3999		8768	4	spill (Cu, Pb, Sn)		

Con text	Find No.	Slag Type	XRF Analysis (**strong** weak *detected*)	XRD Analysis (**strong**, clear, *uncertain*)	Sample No.	Metallographic structure
3	6301	undiagnostic	**Fe** Si Ca *Na Al*	**wüstite, fayalite,** magnetite, goethite	94003	10% Porosity, 45% wüstite dendrites, 35% fayalite laths, 10% glassy matrix
3	6301	smithing hearth bottom	**Si Fe** K Ca Ti *Al Mn*	**quartz, fayalite**, cristobalite	94004	Very varied 20% porosity. Some quartz in mid-grey matrix, some fayalite laths in glassy matrix. Some metallic iron
5	5698	tap slag	**Mn Fe** Ca	**wüstite, fayalite**	94005	2% porosity. 8% wüstite dendrites, 45% fayalite laths, 45% glassy matrix. Some metallic iron
5	5698	undiagnostic	**Si Fe** Ca *Ti*	**quartz,** fayalite, cristobalite, *potassium aluminium silicate*	94006	20% porosity. 20% quartz grains, occasional iron particles, 60% glassy matrix. Some metallic iron
5	5698	cinder	**Si** Fe K Ca Ti *Mn*	**quartz**, magnetite, cristobalite	94007	10% porosity. Very varied. 5-10% quartz grains in glassy matrix. Some zones 10% wüstite dendrites/magnetie grains
5	5698	vitrified hearth/ furnace lining	**Si Fe** K Ca Ti *Al Mn*	**quartz**, magnetite, cristobalite	94008	20% porosity. 15% quartz, 65% glassy phase with occasional wüstite precipitate
5	5698	dense	**Fe** K Ca *Si Ti Mn*	**fayalite**, galaxite, quartz	94009	5% Porosity. 10% wüstite dendrites, 20% fayalite laths, 65% glassy matrix
5	5698	fuel ash slag	**Si Fe** K Ca *P Ti Mn*	**quartz,** augite, cristobalite,	94010	40% Porosity. 10% quartz, 35% acicular grey phase, 15% mid-grey matrix
5	5698	iron-rich cinder	**Fe** Si K Ca *Ti Mn*	**wüstite, fayalite,** quartz, *leucite*	94011	30% Porosity. 5% wüstite dendrites, 35% fayalite laths, 15% glassy matrix, 15% leucite
5	5698	smithing hearth bottom	**Fe** Si K Ca *Ti*	**fayalite,** leucite, honquite, *ferro gadrite*	94012	2% Porosity. 15% fine wüstite dendrites, 50% fayalite laths, 35% glassy matrix
18	6526	dense	**Fe** Si *K Ca Ti*	**fayalite,** maghemite, potassium aluminium silicate, quartz, leucite	94013	5% Porosity. 10% angularmagnetite? skeletons, 55% fayalite laths, 30% glassy matrix
18	6526	cinder	**Fe Si** K Ca Ti	**quartz**, silicon oxide	94014	10% Porosity. Very variable proportions of: mid grey (fayalite?), orange (iron hydroxide?), white/orange dapple phase, quartz. Occasional metallic iron
18	6526	smithing hearth bottom	**Fe** Si *Al K Ca Ti*	**fayalite**	94015	20% Porosity. 20% wüstite dendrites, 30% fayalite laths, 30% glassy matrix

Con text	Find No.	Slag Type	XRF Analysis (**strong** weak *detected*)	XRD Analysis (**strong**, clear, *uncertain*)	Sample No.	Metallographic structure
18	6526	undiagnostic less cindery	**Fe Si** K Ca Ti *Al Mn*	**quartz,** fayalite, silicon oxide	94016	20% Porosity. Varies 0-45% quartz, remainder mid grey phase with light grey sub round and angular precipitates
18	6526	undiagnostic more cindery	**Fe Si** K Ca Ti *Al Mn*	**quartz**, fayalite, cristobalite	94017	25% Porosity. 35% quartz grains, 40% glassy matrix
18	6526	iron-rich cinder	**Fe** Si *Al K Ca Ti*	**fayalite, goethite,** quartz	94018	40% Porosity. 30% quartz grains, 30% glassy matrix
18	6526	vitrified hearth/ furnace lining	**Fe Si** *Al K Ca Ti Mn*	**magnetite,** quartz, calcium aluminium oxide, silicon oxide	94019	(Slagged surface) 30% Porosity. 20% fine wüstite dendrites, 10% quartz grains, 40% glassy matrix
19	5705	smithing hearth bottom	**Fe Si** K Ca *Ti*	**fayalite, quartz**, calcium silicate hydrate, magnetite, cristobalite	94020	20% Porosity. Very variable structure: Some glassy with quartz grains, some fayalite laths and glassy matrix with fine wüstite dendrites.
19	5705	iron-rich cinder	**Fe** Si *K Ca*	**wüstite, magnetite,** fayalite, quartz	94021	10% Porosity. 50% wüstite dendrites, 45% fayalite laths, 5% glassy matrix
19	5705	undiagnostic	**Fe Si** K Ca Ti *Al*	**quartz, fayalite**	94022	2 zones 1) dark area: 25% Porosity,.20% quartz, 2% wüstite dendrites, 53% glassy matrix. 2) light area: 50% wüstite dendrites, 50% glassy matrix
19	5705	vitrified hearth/ furnace lining	**Fe Si** K Ca Ti Mn	**quartz**, *opal*	94023	25% Porosity. Variable structure 10-25% quartz, 65-50% glassy matrix
19	5705	cinder	**Fe Si** K Ca Ti Mn	**quartz**, *opal*	94024	30% Porosity. 15% part dissolved quartz grains, 55% glassy matrix
19	5705	tap slag	**Mn Fe** Si K Ca *Al Ti*	**fayalite**	94025	2% Porosity. 5% very fine wüstite dendrites, 35% fayalite laths, 58% glassy matrix
19	5705	dense	**Fe** Si K Ca *Al Ti Mn*	**fayalite,** *quartz*	94026	5% Porosity. 2% very fine wüstite dendrites, 45% fayalite laths, 48% glassy matrix
76	7488	iron-rich cinder	**Fe** Si K Ca Ti	**fayalite**, galaxite, iron silicate, wüstite	94027	40% Porosity. 2% wüstite dendrites, 40% fayalite laths, 18% glassy matrix. some metallic iron
37	7309	undiagnostic	**Fe Si** K Ti *Ca*	**quartz, cristobalite,** fayalite, maghemite	94028	2 zones: 1) dense dark; 1% Porosity, 2) light porous; 30% porosity. Both variable quantity of quartz in glassy matrix

Con text	Find No.	Slag Type	XRF Analysis (**strong** weak *detected*)	XRD Analysis (**strong**, clear, *uncertain*)	Sample No.	Metallographic structure
37	7309	iron-rich cinder	**Fe** Al Si Ca Ti *K Mn*	**wüstite, fayalite**, quartz, goethite, *lime*	94029	2 zones 1) Fe corrosion, 2) 30% Porosity. 10% wüstite dendrites, 40% fayalite laths, 20% glassy matrix
90	7422	vitrified hearth/ furnace lining	**Fe Si** K Ca Ti Mn *Al*	**quartz**, magnetite, silicon oxide, potassium aluminium silicate	94030	Slagged layer 15% Porosity. 35% quartz grains, 5% fine white (?wüstite) particles, 45% glassy matrix
90	7422	smithing hearth bottom	**Fe** Si K Ca	**wüstite**, fayalite, maghemite	94031	5% Porosity. 30% wüstite dendrites, 25% fayalite laths, 30% glassy matrix
90	7422	undiagnostic (cindery)	**Fe Si** Al K Ca Ti	**quartz**, cristobalite, *silicon oxide hydrate*	94032	20% Porosity. 30% quartz grains, 50% glassy matrix
90	7422	undiagnostic (less cindery)	**Fe Si** K Ca Ti *Al Mn*	**quartz, fayalite,** sodium aluminium silicate hydrate	94033	5% Porosity. 25% wüstite dendrites, 30% fayalite laths, 45% glassy matrix. Possibly magnetite in some zones
90	7422	cinder	**Fe Si** K Ca Ti *Al*	**quartz**, cristobalite, *iron*	94034	30% Porosity. 35% quartz grains, 35% glassy matrix
90	7422	iron-rich cinder	**Fe** Si K Ca Ti *Al P*	**wüstite,** maghemite, quartz, fayalite	94035	2 zones: 1) hard dark region; 15% Porosity. 35% wüstite dendrites, 50% mid grey matrix, 2) soft mottled region; light particles against mottled background/matrix
104	7417	cinder	**Fe Si** K Ca Ti *Al*	**quartz, maghemite,** silicon oxide	94036	Most of sample very porous, small dense region comprises 2 zones: 1) (bulk) 10% Porosity. 2 acicular phases 2) 10% Porosity. 20% quartz grains, 70% glassy matrix
285	9981	smithing hearth bottom	**Fe Si** K Ca Ti *Al*	**quartz, cristobalite,** fayalite	94039	15% Porosity. 0-35% quartz grains, 85-50% glassy matrix, occasional (max. 1%) fine angular precipitate
285	9981	undiagnostic	**Fe** Si K Ca *Al Ti*	**fayalite**, silicon oxide, quartz	94040	10% Porosity. 50% coarse fayalite laths, 39% glassy matrix, approx 1% iron particles with graphite flakes
446	9022	glassy	**Si Ca Mn Fe** K *Al Ti*	*iron, iron manganese oxide hydrate, carbon*	94037	Green/blue glassy matrix with spheroidal cast iron inclusions. etching in 2% Nital showed these to comprise 49% pearlite dendrites, 49% ledeburite with approx 2% graphite flakes.
485	9902	dense	**Fe** Si K Ca Mn *Al Ti*	**fayalite**, leucite	94038	10% Porosity. 2% very fine wüstite dendrites, 50% fayalite laths, 38% glassy matrix . Occasional leucite? in parts

Appendix 3 SEM microanalyses of phases within samples

Con-text	Sampl No.	Slag "type"	Area analysed	Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
				EDX Analysis % Oxide															
3	94003	undiagnostic	bulk (platy)	---	---	1.0	0.2	0.3	0.0	0.0	0.1	0.0	0.0	45.7	0.0	0.0	0.2	8.1	55.8
3	94003	undiagnostic	bulk (platy)	---	---	0.5	0.0	0.3	0.1	0.0	0.3	0.0	0.0	72.1	0.1	0.0	0.2	10.4	84.1
3	94003	undiagnostic	bulk (platy)	---	---	0.2	0.1	0.2	0.0	0.0	0.3	0.2	0.1	65.8	0.1	0.0	0.2	3.3	70.5
3	94003	undiagnostic	bulk (platy)	---	---	0.3	0.0	0.5	0.0	0.0	0.2	0.0	0.1	69.1	0.0	0.0	0.2	3.6	73.9
3	94003	undiagnostic	bulk (platy)	---	---	0.4	0.0	0.3	0.0	0.0	0.0	0.1	0.2	63.3	0.0	0.0	0.2	7.3	72.0
3	94004	smithing hearth bottom	bulk (flat)	---	---	3.1	0.0	0.9	1.1	0.2	0.0	0.0	0.0	7.9	3.4	0.1	0.0	44.9	61.8
3	94004	smithing hearth bottom	bulk(rough)	---	---	0.5	0.0	1.5	0.3	0.0	0.0	0.0	0.0	10.1	0.6	0.0	0.1	13.6	26.6
3	94004	smithing hearth bottom	bulk (mixed)	---	---	0.8	0.0	0.3	0.5	0.1	0.0	0.0	0.0	3.4	1.9	0.0	0.0	50.7	57.7
3	94004	smithing hearth bottom	bulk (flat)	---	---	1.6	0.0	2.3	0.5	0.0	0.2	0.0	0.0	21.8	3.2	0.1	0.0	47.6	77.4
3	94004	smithing hearth bottom	bulk (rough)	---	---	1.1	0.0	0.1	0.3	0.0	0.0	0.0	0.2	1.3	1.9	0.1	0.0	52.9	57.9
5	94005	tap slag	bulk	---	---	1.1	1.1	4.6	0.5	4.1	0.1	0.0	0.2	51.7	2.2	0.0	0.1	22.2	88.0
5	94005	tap slag	bulk	---	---	1.2	1.1	4.5	0.4	4.4	0.0	0.0	0.0	51.1	2.1	0.0	0.2	22.2	87.4
5	94005	tap slag	bulk	---	---	1.0	1.4	4.6	0.5	4.3	0.0	0.1	0.0	52.5	2.1	0.0	0.1	22.5	89.2
5	94005	tap slag	bulk	---	---	1.3	0.9	5.0	0.5	4.2	0.4	0.0	0.0	52.5	2.4	0.0	0.2	23.1	90.5
5	94005	tap slag	bulk	---	---	1.2	1.6	4.9	0.7	4.4	0.2	0.0	0.0	52.4	2.2	0.0	0.1	22.9	90.4
5	94005	tap slag	dendrites	---	---	0.3	0.0	0.5	0.8	1.9	0.5	0.0	0.2	93.5	0.3	0.0	0.0	1.4	99.4
5	94005	tap slag	matrix	---	---	2.6	3.1	12.5	1.2	1.8	0.0	0.2	0.2	24.1	5.9	0.0	0.4	26.0	77.9
5	94005	tap slag	laths	---	---	0.1	0.1	2.0	0.2	6.7	0.4	0.0	0.0	61.9	0.1	0.0	0.0	24.6	96.1
5	94005	tap slag	dendrites	---	---	0.3	0.0	0.2	0.8	1.9	0.3	0.2	0.0	95.8	0.2	0.1	0.1	0.9	100.8
5	94005	tap slag	matrix	---	---	1.3	1.1	4.8	0.3	0.6	0.0	0.0	0.0	23.5	6.4	0.0	0.3	27.0	78.7
5	94005	tap slag	laths	---	---	0.0	0.3	2.1	0.0	6.6	0.1	0.0	0.2	62.0	0.0	0.1	0.0	25.6	97.1
5	94005	tap slag	bulk	---	---	1.2	1.2	5.2	0.6	4.5	0.1	0.0	0.1	53.3	2.4	0.0	0.1	23.4	92.0
5	94005	tap slag	bulk	---	---	1.1	1.3	4.8	0.5	4.5	0.3	0.1	0.0	54.7	2.3	0.0	0.1	23.7	93.9
5	94005	tap slag	bulk	---	---	0.8	0.8	4.1	0.4	5.1	0.0	0.0	0.0	55.4	1.7	0.0	0.1	23.4	91.7
5	94006	undiagnostic	bulk	---	---	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	3.4	0.4	0.0	0.0	70.3	74.5
5	94006	undiagnostic	bulk	---	---	1.6	0.0	1.8	0.8	0.1	0.0	0.1	0.1	12.4	1.8	0.0	0.0	48.2	66.8
5	94006	undiagnostic	bulk	---	---	1.2	0.0	1.3	0.4	0.0	0.0	0.0	0.0	10.1	3.0	0.0	0.0	54.3	70.3
5	94006	undiagnostic	bulk	---	---	1.6	0.0	0.8	0.7	0.0	0.1	0.0	0.0	10.6	2.5	0.1	0.0	48.6	65.1
5	94006	undiagnostic	bulk	---	---	1.4	0.0	2.4	0.5	0.0	0.2	0.0	0.0	14.2	1.9	0.0	0.0	44.7	65.2
5	94006	undiagnostic	bulk	---	---	2.5	0.0	2.0	0.9	0.1	0.2	0.0	0.0	14.0	3.1	0.0	0.1	44.4	67.2
5	94006	undiagnostic	matrix	---	---	2.2	0.0	3.3	1.0	0.1	0.0	0.1	0.2	26.3	2.4	0.0	0.0	43.1	78.6
5	94006	undiagnostic	quartz grain?	---	---	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	88.0	88.4
5	94006	undiagnostic	matrix	---	---	2.5	0.0	2.9	0.7	0.2	0.0	0.2	0.0	18.5	3.7	0.3	0.0	47.0	76.1
5	94006	undiagnostic	quartz grain?	---	---	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.4	0.0	0.0	0.0	82.9	83.5
5	94007	cinder	bulk	---	---	1.6	0.0	0.2	0.7	0.0	0.0	0.2	0.0	1.6	2.1	0.0	0.0	62.1	68.4
5	94007	cinder	bulk	---	---	1.3	0.0	0.1	0.8	0.1	0.0	0.0	0.1	1.7	1.5	0.0	0.0	59.3	65.1
5	94007	cinder	bulk	---	---	1.6	0.0	2.6	0.9	0.0	0.0	0.0	0.1	12.6	3.6	0.1	0.0	58.8	80.3
5	94007	cinder	bulk	---	---	2.5	0.0	0.6	1.4	0.0	0.0	0.1	0.0	1.7	2.9	0.1	0.0	54.4	63.7
5	94007	cinder	bulk	---	---	1.8	0.0	2.1	0.7	0.1	0.0	0.0	0.3	10.3	3.0	0.1	0.0	55.8	74.4
5	94007	cinder	matrix	---	---	3.1	0.0	2.9	1.5	0.1	0.1	0.3	0.0	8.6	3.7	0.1	0.0	52.4	72.7
5	94007	cinder	quartz grain?	---	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	86.1	86.5
5	94007	cinder	matrix	---	---	3.1	0.3	6.6	1.5	0.5	0.0	0.0	0.1	10.4	3.4	0.1	0.0	54.3	80.3
5	94007	cinder	quartz grain?	---	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	90.3	90.6
5	94008	vitrified hearth lining	bulk	---	---	2.2	0.0	1.8	0.9	0.0	0.0	0.0	0.2	2.7	5.1	0.1	0.0	49.6	62.7
5	94008	vitrified hearth lining	bulk	---	---	2.7	0.0	0.6	0.7	0.0	0.0	0.0	0.0	4.8	3.9	0.0	0.0	45.6	58.4
5	94008	vitrified hearth lining	bulk	---	---	2.8	0.0	0.5	0.9	0.1	0.0	0.0	0.0	5.6	3.7	0.1	0.0	45.8	59.5
5	94008	vitrified hearth lining	bulk	---	---	1.9	0.2	0.3	1.1	0.0	0.1	0.0	0.9	4.0	0.0	0.0	0.0	43.0	51.5
5	94008	vitrified hearth lining	bulk	---	---	1.9	0.0	1.7	1.0	0.0	0.2	0.0	0.0	2.6	4.1	0.0	0.0	50.2	61.7
5	94008	vitrified hearth lining	matrix	---	---	2.2	0.0	5.9	1.2	0.1	0.1	0.0	0.1	7.7	5.8	0.0	0.0	45.4	68.6
5	94008	vitrified hearth lining	matrix	---	---	2.1	0.2	5.6	0.8	0.0	0.0	0.0	0.1	8.4	4.4	0.0	0.0	47.4	69.1
5	94008	vitrified hearth lining	quartz grain?	---	---	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	75.4	75.5
5	94008	vitrified hearth lining	quartz grain?	---	---	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	1.3	0.0	0.0	71.4	73.8
5	94009	dense	bulk	---	---	1.3	0.0	0.2	0.3	0.2	0.0	0.0	0.0	54.2	0.1	0.0	0.0	18.1	74.5
5	94009	dense	bulk	---	---	1.1	0.5	0.6	0.1	0.2	0.1	0.0	0.1	56.6	0.5	0.0	0.2	17.9	77.7
5	94009	dense	bulk	---	---	1.9	0.0	0.7	0.2	0.1	0.1	0.0	0.0	57.1	0.4	0.1	0.1	16.9	77.8
5	94009	dense	bulk	---	---	1.5	0.1	0.6	0.2	0.1	0.4	0.0	0.1	55.6	0.4	0.1	0.1	18.1	77.3
5	94009	dense	bulk	---	---	1.5	0.3	0.3	0.3	0.4	0.0	0.0	0.0	55.7	0.2	0.0	0.1	17.6	76.4
5	94009	dense	dendrites	---	---	0.2	0.2	0.0	1.9	0.0	0.2	0.0	0.2	89.9	0.0	0.0	0.0	0.9	93.5
5	94009	dense	dendrites	---	---	0.2	0.0	0.0	0.9	0.0	0.5	0.0	0.1	91.7	0.0	0.0	0.0	0.7	94.1
5	94009	dense	laths	---	---	0.0	0.0	0.5	0.0	0.2	0.3	0.0	0.1	63.6	0.0	0.0	0.0	24.1	89.0

Con-text	Sampl No.	Slag "type"	Area analysed	EDX Analysis % Oxide Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
5	94009	dense	laths	---	---	0.0	0.0	0.5	0.0	0.2	0.0	0.0	0.0	69.1	0.1	0.1	0.0	24.9	94.8
5	94009	dense	matrix	---	---	2.5	2.9	4.6	0.5	0.0	0.0	0.0	0.0	28.1	5.0	0.0	0.6	26.1	70.3
5	94009	dense	matrix	---	---	2.8	1.1	1.4	0.0	0.1	0.0	0.0	0.0	13.0	0.2	0.0	0.4	36.5	55.6
5	94009	dense	polygonal grey	---	---	10.7	0.0	0.0	0.5	0.2	0.1	0.0	0.0	45.8	0.0	0.2	0.0	0.2	57.8
5	94009	dense	polygonal grey	---	---	10.8	0.1	0.1	1.0	0.1	0.5	0.0	0.0	50.8	0.0	0.0	0.0	0.0	63.4
5	94009	dense	bulk	---	---	1.1	0.5	0.9	0.5	0.2	0.4	0.0	0.0	63.4	0.6	0.0	0.1	17.1	84.7
5	94009	dense	bulk	---	---	1.4	0.0	0.3	0.5	0.4	0.5	0.0	0.0	61.7	0.1	0.0	0.0	16.3	81.1
5	94010	fuel ash slag	bulk	---	---	0.6	5.0	9.5	0.5	0.2	0.0	0.0	0.0	2.6	3.4	0.1	0.0	28.3	50.7
5	94010	fuel ash slag	bulk	---	---	0.7	6.1	13.0	0.4	0.6	0.0	0.0	0.0	2.3	1.7	0.0	0.0	24.1	49.0
5	94010	fuel ash slag	bulk	---	---	0.8	6.4	10.5	0.5	0.2	0.0	0.0	0.0	3.4	4.7	0.0	0.0	35.9	62.2
5	94010	fuel ash slag	bulk	---	---	0.8	1.0	2.8	0.4	0.2	0.0	0.0	0.0	1.4	3.3	0.1	0.1	30.1	40.1
5	94010	fuel ash slag	bulk	---	---	1.1	2.6	4.0	0.3	0.1	0.2	0.0	0.0	2.4	3.7	0.0	0.0	34.4	48.9
5	94010	fuel ash slag	needles	---	---	0.2	1.2	16.9	0.4	0.2	0.0	0.0	0.0	2.6	0.5	0.0	0.0	38.2	60.5
5	94010	fuel ash slag	needles	---	---	0.6	16.2	24.0	0.3	0.1	0.0	0.0	0.1	2.0	1.7	0.0	0.0	27.0	72.1
5	94010	fuel ash slag	matrix	---	---	1.8	2.5	8.0	0.8	0.0	0.2	0.1	0.0	3.0	3.9	0.2	0.0	33.8	54.1
5	94010	fuel ash slag	matrix	---	---	2.1	2.6	4.1	1.2	0.0	0.2	0.1	0.0	3.0	6.1	0.0	0.0	41.8	61.3
5	94010	fuel ash slag	bulk	---	---	0.5	5.7	12.4	0.5	0.2	0.0	0.0	0.1	3.5	4.9	0.0	0.0	32.7	60.5
5	94010	fuel ash slag	bulk	---	---	0.3	5.2	16.1	0.4	0.3	0.0	0.0	0.1	3.6	2.9	0.0	0.0	30.9	59.8
5	94011	iron-rich cinder	bulk (laths etc)	---	---	1.1	0.0	1.7	0.4	0.0	0.1	0.0	0.0	53.2	1.5	0.0	0.0	23.0	81.0
5	94011	iron-rich cinder	bulk (laths etc)	---	---	0.7	0.0	1.5	0.3	0.1	0.4	0.1	0.1	59.0	0.4	0.0	0.0	22.8	85.4
5	94011	iron-rich cinder	bulk (laths etc)	---	---	1.2	0.0	1.6	0.3	0.0	0.1	0.0	0.1	56.3	1.7	0.0	0.0	24.4	85.6
5	94011	iron-rich cinder	bulk (laths etc)	---	---	0.7	0.0	1.2	0.3	0.0	0.1	0.0	0.0	65.1	0.7	0.1	0.0	25.3	93.5
5	94011	iron-rich cinder	bulk (laths etc)	---	---	1.0	0.1	0.9	0.3	0.0	0.6	0.0	0.0	59.1	0.8	0.0	0.0	25.9	88.7
5	94011	iron-rich cinder	dendrites	---	---	0.1	0.1	0.0	1.4	0.0	0.2	0.0	0.0	86.4	0.1	0.0	0.0	0.6	89.0
5	94011	iron-rich cinder	laths	---	---	0.0	0.0	0.4	0.2	0.2	0.4	0.0	0.0	61.7	0.1	0.1	0.0	20.3	83.4
5	94011	iron-rich cinder	matrix	---	---	2.9	0.0	0.2	0.0	0.2	0.2	0.0	0.1	6.3	14.1	0.0	0.0	32.8	56.8
5	94011	iron-rich cinder	mid grey phase	---	---	0.1	0.0	0.2	0.0	0.0	0.3	0.1	0.1	64.3	0.0	0.0	0.1	4.3	69.6
5	94011	iron-rich cinder	bulk(mixed)	---	---	0.4	0.2	1.0	0.2	0.0	0.3	0.0	0.2	61.2	0.1	0.1	0.0	17.5	81.1
5	94011	iron-rich cinder	bulk(mixed)	---	---	0.3	0.2	0.4	0.3	0.0	0.4	0.0	0.0	66.6	0.3	0.0	0.0	14.6	83.1
5	94011	iron-rich cinder	bulk(mixed)	---	---	2.5	1.1	1.1	0.7	0.0	0.0	0.0	0.0	31.6	6.8	0.1	0.0	21.6	65.4
5	94011	iron-rich cinder	bulk(mixed)	---	---	1.4	3.8	1.5	0.4	0.0	0.4	0.0	0.1	59.0	0.4	0.0	0.0	12.2	79.1
5	94011	iron-rich cinder	bulk(mixed)	---	---	0.7	5.6	1.7	0.3	0.0	0.5	0.1	0.2	52.5	0.0	0.1	0.0	9.2	70.8
5	94011	iron-rich cinder	bulk(laths etc)	---	---	0.2	0.1	4.5	0.0	0.1	0.3	0.0	0.0	52.7	2.8	0.1	0.0	14.2	74.9
5	94011	iron-rich cinder	bulk(laths etc)	---	---	0.2	0.0	2.5	0.0	0.0	0.4	0.0	0.1	57.6	2.7	0.0	0.0	12.8	76.3
5	94012	smithing hearth bottom	dendrites	---	---	0.2	0.0	0.1	0.4	0.0	0.2	0.0	0.0	91.3	0.1	0.0	0.0	0.9	93.4
5	94012	smithing hearth bottom	laths	---	---	0.0	0.0	1.6	0.1	0.1	0.0	0.0	0.1	65.0	0.1	0.1	0.0	25.7	92.6
5	94012	smithing hearth bottom	matrix	---	---	4.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	8.6	16.8	0.1	0.0	42.1	73.2
5	94012	smithing hearth bottom	dendrites	---	---	0.1	0.0	0.0	0.4	0.0	0.3	0.0	0.0	100.0	0.1	0.0	0.1	0.9	102.0
5	94012	smithing hearth bottom	laths	---	---	0.0	0.1	2.4	0.0	0.1	0.3	0.0	0.0	70.1	0.1	0.1	0.0	28.1	101.4
5	94012	smithing hearth bottom	matrix	---	---	5.4	0.0	0.3	0.0	0.0	0.1	0.0	0.0	4.4	18.7	0.1	0.1	44.2	73.4
5	94012	smithing hearth bottom	bulk	---	---	1.7	0.4	2.4	0.3	0.0	0.1	0.0	0.1	63.3	3.3	0.0	0.0	24.2	95.9
5	94012	smithing hearth bottom	bulk	---	---	1.4	0.1	3.8	0.0	0.0	0.2	0.0	0.0	63.2	2.1	0.2	0.0	26.4	97.4
5	94012	smithing hearth bottom	bulk	---	---	1.0	0.0	1.9	0.1	0.2	0.5	0.0	0.3	72.1	1.9	0.0	0.1	20.6	98.7
5	94012	smithing hearth bottom	bulk	---	---	1.7	0.7	2.6	0.0	0.2	0.0	0.0	0.3	54.5	4.2	0.0	0.0	30.7	94.8
5	94012	smithing hearth bottom	bulk	---	---	1.9	0.0	2.5	0.2	0.0	0.0	0.0	0.0	62.2	3.7	0.0	0.0	25.6	96.2
5	94012	smithing hearth bottom	laths	---	---	0.0	0.0	1.5	0.1	0.3	0.5	0.0	0.1	73.2	0.0	0.0	0.0	24.4	100.2
18	94013	dense	ang.incs.	---	---	1.5	0.0	0.1	3.6	0.1	0.3	0.0	0.0	93.3	0.0	0.0	0.0	0.9	99.7
18	94013	dense	matrix	---	---	2.4	0.0	5.1	0.4	0.0	0.2	0.0	0.0	14.8	8.0	0.1	0.1	37.0	68.0
18	94013	dense	laths	---	---	0.0	0.0	1.7	0.1	0.0	0.5	0.0	0.5	74.8	0.0	0.0	0.0	24.3	100.5
18	94013	dense	ang incs.	---	---	0.6	0.0	0.1	1.5	0.0	0.3	0.0	0.0	97.5	0.1	0.1	0.0	0.8	100.8
18	94013	dense	matrix	---	---	1.8	0.0	5.2	0.1	0.0	0.2	0.0	0.0	23.5	4.1	0.0	0.1	39.6	74.7
18	94013	dense	laths	---	---	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	77.0	0.0	0.1	0.0	25.3	102.9
18	94013	dense	bulk	---	---	0.7	0.0	1.2	0.3	0.0	0.1	0.0	0.0	57.2	1.5	0.1	0.0	23.6	84.7
18	94013	dense	bulk	---	---	0.9	0.0	1.7	0.2	0.0	0.1	0.0	0.1	51.0	2.0	0.0	0.0	25.8	81.9
18	94013	dense	bulk	---	---	0.8	0.0	1.1	0.4	0.0	0.0	0.0	0.1	58.2	1.4	0.0	0.0	21.4	83.5
18	94013	dense	bulk	---	---	0.4	0.0	0.7	0.3	0.1	0.7	0.0	0.0	66.4	0.5	0.0	0.0	21.0	90.1
18	94013	dense	bulk	---	---	0.8	0.1	1.0	0.3	0.0	0.3	0.0	0.0	62.4	2.4	0.0	0.0	21.1	88.4
18	94014	cinder	bulk (hard black)	---	---	1.1	0.0	2.8	0.7	0.0	0.1	0.0	0.1	33.0	3.1	0.0	0.0	34.4	75.3
18	94014	cinder	bulk (hard black)	---	---	1.0	0.0	2.9	0.6	0.2	0.3	0.0	0.0	36.9	2.0	0.0	0.0	31.1	74.8
18	94014	cinder	bulk (hard black)	---	---	1.2	0.0	2.7	0.7	0.0	0.0	0.0	0.0	32.9	2.8	0.0	0.0	35.1	75.4
18	94014	cinder	bulk (hard black)	---	---	0.9	0.0	2.8	0.6	0.0	0.1	0.0	0.0	41.1	1.8	0.1	0.0	31.0	78.4
18	94014	cinder	bulk (hard black)	---	---	1.0	0.0	2.9	0.4	0.0	0.0	0.0	0.1	39.3	2.0	0.0	0.0	31.2	76.9
18	94014	cinder	bulk (crumbly)	---	---	0.0	2.6	1.0	0.1	0.2	0.7	0.0	0.1	60.0	0.0	0.0	0.1	2.6	65.1

Con-text	Sampl No.	Slag "type"	Area analysed	Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
				EDX Analysis % Oxide															
18	94014	cinder	bulk (crumbly)	---	---	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.2	45.6	0.0	0.0	0.1	1.7	48.3
18	94014	cinder	bulk (crumbly)	---	---	0.1	0.0	0.8	0.0	0.0	0.0	0.0	0.2	42.8	0.0	0.0	0.1	2.5	46.5
18	94014	cinder	bulk (crumbly)	---	---	0.3	0.8	0.7	0.1	0.0	0.3	0.0	0.2	61.0	0.0	0.1	0.2	3.7	67.4
18	94015	smithing hearth bottom	bulk	---	---	1.1	0.5	0.9	0.5	0.2	0.4	0.0	0.0	63.4	0.6	0.0	0.1	17.1	84.7
18	94015	smithing hearth bottom	bulk	---	---	1.4	0.0	0.3	0.5	0.4	0.5	0.0	0.0	61.7	0.1	0.0	0.1	16.3	81.2
18	94015	smithing hearth bottom	bulk	---	---	0.6	5.7	12.4	0.5	0.2	0.0	0.0	0.1	3.5	4.9	0.0	0.0	32.7	60.5
18	94015	smithing hearth bottom	bulk	---	---	0.3	5.2	16.1	0.4	0.3	0.0	0.0	0.1	3.6	2.9	0.0	0.1	30.9	59.8
18	94015	smithing hearth bottom	bulk	---	---	0.9	0.0	2.5	0.4	0.0	0.1	0.0	0.1	50.2	2.6	0.0	0.1	21.6	78.4
18	94015	smithing hearth bottom	dendrites	---	---	0.8	0.0	1.1	0.5	0.0	0.3	0.0	0.1	52.9	2.5	0.1	0.0	21.8	80.2
18	94015	smithing hearth bottom	laths	---	---	0.5	0.0	1.4	0.0	0.0	0.4	0.0	0.0	64.3	1.1	0.1	0.1	19.2	87.1
18	94015	smithing hearth bottom	matrix	---	---	0.8	0.0	1.3	0.3	0.0	0.4	0.0	0.3	67.0	1.4	0.0	0.0	17.4	89.0
18	94015	smithing hearth bottom	small laths	---	---	0.7	0.0	1.1	0.1	0.0	0.0	0.1	0.0	64.0	1.1	0.1	0.0	20.5	87.7
18	94015	smithing hearth bottom	dendrites	---	---	0.1	0.0	0.6	0.2	0.0	0.5	0.0	0.1	70.1	0.1	0.1	0.1	19.3	91.2
18	94015	smithing hearth bottom	laths	---	---	0.5	0.1	1.2	0.2	0.0	0.2	0.0	0.2	67.3	0.6	0.1	0.0	21.8	92.2
18	94015	smithing hearth bottom	matrix	---	---	0.2	0.0	0.0	0.7	0.0	0.3	0.0	0.3	97.6	0.0	0.0	0.0	0.5	99.6
18	94016	undiagnostic<cinder	bulk	---	---	0.7	0.0	0.2	0.6	0.0	0.0	0.0	0.1	3.1	2.2	0.0	0.0	38.1	45.0
18	94016	undiagnostic<cinder	bulk	---	---	0.8	0.0	0.9	0.6	0.0	0.0	0.0	0.0	3.1	2.4	0.0	0.0	38.7	46.4
18	94016	undiagnostic<cinder	bulk	---	---	0.8	0.0	0.4	1.4	0.1	0.1	0.0	0.1	4.4	2.7	0.0	0.0	35.5	45.5
18	94016	undiagnostic<cinder	bulk	---	---	0.8	0.0	0.9	0.8	0.2	0.0	0.1	0.0	10.6	2.3	0.0	0.0	39.1	54.8
18	94016	undiagnostic<cinder	bulk	---	---	0.9	0.0	0.4	1.3	0.0	0.1	0.2	0.0	5.6	3.4	0.2	0.0	37.5	49.4
18	94016	undiagnostic<cinder	dark matrix	---	---	1.2	0.0	0.4	1.5	0.1	0.0	0.0	0.1	8.3	3.6	0.0	0.0	44.3	59.5
18	94016	undiagnostic<cinder	quartz grain?	---	---	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	68.0	68.5
18	94016	undiagnostic<cinder	dark matrix	---	---	1.0	0.0	3.5	0.8	0.1	0.1	0.0	0.0	11.6	3.5	0.0	0.0	44.0	64.8
18	94016	undiagnostic<cinder	quartz grain?	---	---	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	67.3	67.7
18	94016	undiagnostic<cinder	dark matrix	---	---	1.7	0.0	0.4	0.8	0.1	0.2	0.0	0.0	6.0	2.9	0.2	0.0	38.4	50.7
18	94017	undiagnostic>cinder	bulk	---	---	0.6	0.0	0.6	0.7	0.0	0.2	0.0	0.0	5.2	2.3	0.1	0.0	40.7	50.5
18	94017	undiagnostic>cinder	bulk	---	---	0.5	0.0	0.3	0.3	0.0	0.0	0.0	0.2	3.5	1.9	0.1	0.2	46.9	53.9
18	94017	undiagnostic>cinder	bulk	---	---	0.8	0.0	1.8	0.6	0.1	0.0	0.1	0.1	2.1	3.5	0.0	0.0	40.5	49.7
18	94017	undiagnostic>cinder	bulk	---	---	0.4	0.0	1.1	0.4	0.1	0.0	0.0	0.0	0.9	2.3	0.0	0.1	39.2	44.4
18	94017	undiagnostic>cinder	bulk	---	---	1.2	0.0	0.9	0.8	0.0	0.0	0.0	0.1	2.3	3.1	0.1	0.0	34.1	42.6
18	94017	undiagnostic>cinder	matrix (black)	---	---	1.7	0.0	2.0	1.4	0.1	0.0	0.0	0.0	10.7	2.9	0.1	0.0	37.7	56.5
18	94017	undiagnostic>cinder	matrix (black)	---	---	2.0	0.0	0.4	1.2	0.1	0.1	0.1	0.0	12.0	3.3	0.0	0.0	38.4	57.5
18	94017	undiagnostic>cinder	quartz grain?	---	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	67.8	68.0
18	94017	undiagnostic>cinder	quartz grain?	---	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	68.9	69.1
18	94018	iron-rich cinder	bulk	1.2	1.3	10.7	0.0	0.5	1.4	0.1	0.2	0.0	0.0	5.7	2.9	0.0	0.0	76.0	99.8
18	94018	iron-rich cinder	bulk	0.7	0.8	8.5	0.0	0.2	0.7	0.1	0.0	0.1	0.0	3.5	2.3	0.1	0.0	69.3	86.4
18	94018	iron-rich cinder	bulk	0.7	0.7	10.5	0.0	0.4	0.9	0.0	0.6	0.0	0.1	5.1	2.5	0.1	0.0	64.6	85.7
18	94018	iron-rich cinder	bulk	0.6	0.5	11.0	0.0	0.1	0.5	0.1	0.0	0.0	0.1	4.9	2.8	0.0	0.0	69.8	90.2
18	94018	iron-rich cinder	bulk	1.2	0.9	8.8	0.0	0.1	0.6	0.0	0.1	0.0	0.1	3.9	2.4	0.0	0.0	69.2	87.4
18	94018	iron-rich cinder	matrix	2.0	2.3	12.0	0.0	2.0	1.0	0.2	0.0	0.2	0.0	17.5	2.6	0.0	0.0	58.6	98.4
18	94018	iron-rich cinder	matrix	1.7	1.6	18.3	0.0	0.4	1.1	0.0	0.1	0.0	0.0	8.4	4.6	0.0	0.0	63.0	99.2
18	94018	iron-rich cinder	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.4	101.5
18	94018	iron-rich cinder	quartz grain?	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	101.5	102.0
18	94019	vitrified hearth lining	bulk	1.0	1.6	7.9	0.2	4.6	0.5	0.2	0.0	0.0	0.1	28.7	2.5	0.1	0.0	52.1	99.4
18	94019	vitrified hearth lining	bulk	1.5	2.1	9.1	0.6	3.5	0.6	0.0	0.0	0.0	0.1	29.6	2.7	0.1	0.0	57.2	107.3
18	94019	vitrified hearth lining	bulk	1.8	0.8	7.5	0.0	4.2	0.5	0.2	0.1	0.0	0.0	35.5	3.3	0.1	0.0	43.0	97.3
18	94019	vitrified hearth lining	bulk	1.7	1.1	5.7	0.4	6.4	0.6	0.1	0.0	0.0	0.1	38.2	2.3	0.0	0.1	44.4	101.1
18	94019	vitrified hearth lining	bulk	1.5	0.4	5.0	0.2	3.9	0.3	0.0	0.3	0.0	0.0	44.9	2.1	0.2	0.0	37.5	96.2
18	94019	vitrified hearth lining	matrix	0.8	0.9	6.4	0.2	5.5	0.4	0.2	0.1	0.0	0.0	18.1	2.5	0.1	0.0	59.4	94.5
18	94019	vitrified hearth lining	matrix	1.1	1.0	9.1	0.1	4.4	0.6	0.1	0.0	0.0	0.0	15.2	3.2	0.0	0.0	61.2	96.1
18	94019	vitrified hearth lining	black cuboid	0.0	1.0	2.3	0.0	0.1	0.3	0.1	0.3	0.0	0.2	85.8	0.1	0.0	0.0	0.5	90.9
18	94019	vitrified hearth lining	black cuboid	0.2	1.0	2.4	0.0	0.0	0.5	0.0	0.2	0.0	0.0	85.9	0.0	0.0	0.1	0.3	90.5
18	94019	vitrified hearth lining	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.2	0.0	0.1	0.0	97.2	97.8
18	94019	vitrified hearth lining	quartz grain?	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	99.7	100.2
19	94020	smithing hearth bottom	bulk(laths etc)	1.6	0.3	6.5	0.0	2.1	0.5	0.0	0.1	0.0	0.3	49.7	2.2	0.2	0.0	39.6	103.0
19	94020	smithing hearth bottom	bulk(laths etc)	1.1	0.0	4.8	0.0	1.7	0.2	0.0	0.0	0.0	0.1	52.4	2.0	0.0	0.0	34.4	96.5
19	94020	smithing hearth bottom	bulk(laths etc)	1.3	0.1	6.0	0.0	1.9	0.2	0.0	0.5	0.1	0.0	54.1	2.2	0.0	0.0	35.7	101.9
19	94020	smithing hearth bottom	bulk(laths etc)	1.8	0.1	6.2	0.0	1.9	0.4	0.0	0.4	0.0	0.0	46.6	2.4	0.0	0.0	36.6	96.5
19	94020	smithing hearth bottom	bulk(laths etc)	1.5	0.1	3.9	0.1	0.5	0.2	0.0	0.2	0.0	0.0	56.4	0.4	0.0	0.0	28.5	91.7
19	94020	smithing hearth bottom	laths	0.2	1.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	70.6	0.0	0.0	0.0	31.7	103.9
19	94020	smithing hearth bottom	laths	0.1	0.9	0.0	0.0	0.4		0.0	0.4	0.0	0.1	70.7	0.0	0.0	0.0	32.3	105.1
19	94020	smithing hearth bottom	matrix	1.6	0.0	11.6	0.1	6.0	1.3	0.0	0.0	0.0	0.0	26.6	4.6	0.0	0.0	50.3	102.3
19	94020	smithing hearth bottom	matrix	1.2	0.7	9.6	0.1	0.5	0.7	0.0	0.0	0.1	0.0	5.3	3.9	0.0	0.0	77.7	99.9

Con-text	Sampl No.	Slag "type"	Area analysed	Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
				EDX Analysis % Oxide															
19	94020	smithing hearth bottom	bulk(quartzy)	2.4	0.0	15.4	0.7	5.0	1.3	0.0	0.0	0.0	0.2	18.3	5.5	0.1	0.0	55.0	103.7
19	94020	smithing hearth bottom	bulk(quartzy)	2.2	0.8	7.8	0.0	1.6	0.7	0.1	0.1	0.0	0.0	12.3	2.9	0.0	0.0	70.4	98.8
19	94020	smithing hearth bottom	matrix(quartzy)	0.9	1.4	13.8	0.2	0.6	1.1	0.0	0.1	0.0	0.0	7.4	4.7	0.0	0.0	66.2	96.4
19	94020	smithing hearth bottom	matrix(quartzy)	1.7	1.0	11.4	0.3	0.4	0.9	0.0	0.0	0.0	0.1	8.6	6.7	0.0	0.0	71.4	102.4
19	94020	smithing hearth bottom	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.1	0.0	101.1	101.6
19	94020	smithing hearth bottom	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.0	103.1	103.7
19	94021	iron-rich cinder	bulk	0.5	0.2	0.5	0.0	0.1	0.1	0.1	0.5	0.0	0.0	79.8	0.0	0.1	0.1	14.3	96.1
19	94021	iron-rich cinder	bulk	0.6	0.4	0.6	0.2	0.2	0.1	0.0	0.1	0.0	0.0	85.4	0.0	0.0	0.0	11.4	99.1
19	94021	iron-rich cinder	bulk	0.6	0.3	1.4	0.0	0.3	0.2	0.1	0.3	0.1	0.2	74.4	0.1	0.1	0.0	18.3	96.4
19	94021	iron-rich cinder	bulk	0.8	0.3	3.1	0.3	0.6	0.2	0.0	0.1	0.0	0.2	67.7	0.4	0.0	0.1	20.3	94.0
19	94021	iron-rich cinder	bulk	0.3	0.4	0.5	0.0	0.5	0.1	0.0	0.1	0.0	0.3	73.3	0.0	0.1	0.0	13.4	89.0
19	94021	iron-rich cinder	dendrites	0.4	0.1	0.8	0.2	0.1	0.2	0.0	0.2	0.0	0.0	100.0	0.1	0.1	0.1	0.7	102.8
19	94021	iron-rich cinder	dendrites	0.5	0.4	0.5	0.0	0.1	0.2	0.0	0.2	0.0	0.0	100.5	0.0	0.0	0.0	0.6	102.9
19	94021	iron-rich cinder	laths	0.0	0.5	0.0	0.0	0.4	0.1	0.0	0.1	0.0	0.0	71.4	0.1	0.0	0.0	32.0	104.6
19	94021	iron-rich cinder	laths	0.2	0.5	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.1	72.6	0.0	0.1	0.0	32.8	106.7
19	94021	iron-rich cinder	matrix	3.4	0.0	19.6	0.5	5.3	0.1	0.0	0.0	0.0	0.1	26.7	7.5	0.0	0.1	42.3	105.6
19	94021	iron-rich cinder	matrix	3.2	0.1	18.1	0.4	6.9	0.3	0.1	0.0	0.0	0.0	30.5	6.3	0.0	0.2	40.8	106.9
19	94022	undiagnostic	bulk (dk area)	1.6	3.9	14.4	0.1	0.7	0.9	0.0	0.0	0.0	0.1	23.9	2.7	0.1	0.0	54.9	103.2
19	94022	undiagnostic	bulk (dk area)	1.1	2.3	9.2	0.1	3.5	0.8	0.0	0.0	0.0	0.0	8.6	2.4	0.1	0.0	70.1	98.3
19	94022	undiagnostic	bulk (dk area)	1.5	2.6	11.7	0.0	1.0	0.7	0.0	0.1	0.2	0.0	16.6	3.0	0.0	0.0	65.7	103.0
19	94022	undiagnostic	bulk (dk area)	0.9	3.5	12.3	0.4	5.8	1.0	0.2	0.0	0.0	0.2	15.9	3.0	0.1	0.0	57.5	100.8
19	94022	undiagnostic	bulk (dk area)	0.7	1.1	6.5	0.5	1.3	0.4	0.1	0.0	0.0	0.0	5.7	3.9	0.0	0.0	69.1	89.4
19	94022	undiagnostic	matrix	1.0	3.2	12.4	0.2	1.8	1.0	0.0	0.0	0.0	0.0	24.4	2.4	0.0	0.0	52.5	98.9
19	94022	undiagnostic	matrix	1.3	3.2	17.1	0.2	0.8	1.1	0.1	0.2	0.0	0.1	18.0	3.4	0.0	0.0	58.6	104.0
19	94022	undiagnostic	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.7	99.8
19	94022	undiagnostic	dendrites	0.5	2.1	10.9	0.0	0.0	1.7	0.0	0.2	0.0	0.1	78.4	0.1	0.1	0.0	0.4	94.5
19	94022	undiagnostic	dendrites	0.5	3.7	9.0	0.0	0.1	2.0	0.0	0.3	0.0	0.0	78.1	0.2	0.4	0.0	1.9	96.2
19	94022	undiagnostic	bulk(light area)	1.5	2.5	12.3	0.1	0.8	0.9	0.1	0.0	0.1	0.2	4.3	3.9	0.1	0.0	62.2	88.9
19	94022	undiagnostic	bulk(light area)	1.0	1.9	10.8	0.1	0.1	0.6	0.0	0.2	0.1	0.0	5.0	3.1	0.0	0.0	70.8	93.7
19	94022	undiagnostic	bulk(light area)	1.5	2.3	14.7	0.2	0.3	1.1	0.0	0.0	0.0	0.0	4.4	3.6	0.0	0.0	71.8	99.9
19	94022	undiagnostic	bulk(light area)	1.5	2.1	11.9	0.1	0.3	0.6	0.0	0.2	0.0	0.1	3.8	4.8	0.1	0.0	72.3	97.9
19	94022	undiagnostic	bulk(light area)	0.9	1.7	11.4	0.1	0.5	0.7	0.0	0.1	0.0	0.0	3.8	4.0	0.0	0.0	70.2	93.5
19	94022	undiagnostic	matrix(light area)	1.8	3.8	17.4	0.0	0.4	0.9	0.0	0.0	0.0	0.0	7.5	4.3	0.0	0.0	68.6	104.8
19	94022	undiagnostic	matrix(light area)	1.8	3.8	20.4	0.4	0.6	1.3	0.2	0.1	0.1	0.0	8.0	5.8	0.0	0.0	67.5	109.9
19	94022	undiagnostic	quartz grain? (light	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.2	0.3	0.2	0.0	0.0	0.0	107.0	107.9
19	94022	undiagnostic	bulk(mid grey	1.2	1.3	5.7	0.3	1.2	0.2	0.0	0.0	0.0	0.0	62.3	1.7	0.0	0.0	38.1	111.9
19	94022	undiagnostic	bulk(mid grey	0.7	1.3	4.8	0.0	1.2	0.1	0.0	0.1	0.0	0.0	60.9	1.7	0.1	0.0	36.3	107.1
19	94022	undiagnostic	black acic(mid	0.1	0.7	2.9	0.0	0.1	0.4	0.0	0.4	0.0	0.0	92.6	0.1	0.1	0.0	0.9	98.3
19	94022	undiagnostic	black acic(mid	0.7	0.9	3.8	0.1	0.0	0.7	0.1	0.7	0.0	0.0	91.9	0.0	0.0	0.0	0.7	99.5
19	94022	undiagnostic	white matrix(mid	1.3	1.9	7.8	0.0	1.7	0.2	0.0	0.0	0.0	0.1	31.4	3.0	0.0	0.0	60.9	108.4
19	94022	undiagnostic	white matrix(mid	1.3	1.9	6.6	0.2	3.0	0.2	0.0	0.1	0.0	0.1	28.5	3.4	0.1	0.0	64.7	110.2
19	94023	vitrified hearth lining	bulk(slagged)	1.8	1.3	12.0	0.5	3.6	0.7	0.1	0.1	0.2	0.1	4.4	4.8	0.0	0.0	68.7	98.3
19	94023	vitrified hearth lining	bulk(slagged)	1.4	1.3	12.8	0.4	1.1	0.9	0.2	0.0	0.0	0.0	4.8	4.7	0.0	0.0	65.3	92.9
19	94023	vitrified hearth lining	bulk(slagged)	1.7	2.1	15.2	0.3	1.5	1.3	0.1	0.0	0.1	0.0	8.5	3.8	0.0	0.0	72.4	106.8
19	94023	vitrified hearth lining	bulk(slagged)	1.4	2.7	16.3	0.5	1.6	1.1	0.1	0.0	0.1	0.1	11.9	2.6	0.2	0.0	62.8	101.4
19	94023	vitrified hearth lining	bulk(slagged)	0.9	1.3	9.1	0.3	1.4	0.6	0.0	0.0	0.0	0.0	4.9	2.0	0.1	0.0	75.1	95.7
19	94023	vitrified hearth lining	matrix	1.6	2.5	14.3	0.0	7.1	1.0	0.2	0.2	0.0	0.0	12.4	3.9	0.1	0.0	59.5	102.8
19	94023	vitrified hearth lining	matrix	0.9	3.6	12.8	1.0	10.0	1.0	0.5	0.0	0.0	0.1	20.0	1.8	0.1	0.0	57.6	109.5
19	94023	vitrified hearth lining	quartz grain?	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	107.3	107.9
19	94023	vitrified hearth lining	bulk (ceramic)	0.4	0.9	10.8	0.5	1.6	0.5	0.1	0.1	0.2	0.1	3.3	1.5	0.0	0.2	45.1	65.3
19	94023	vitrified hearth lining	bulk (ceramic)	0.5	2.3	7.6	0.5	1.2	0.9	0.0	0.1	0.0	0.0	11.6	2.7	0.0	0.0	54.9	92.5
19	94023	vitrified hearth lining	bulk (ceramic)	0.6	0.9	8.7	0.3	1.1	0.5	0.0	0.0	0.1	0.0	3.9	1.3	0.0	0.1	26.9	44.5
19	94024	cinder	bulk	2.8	2.0	9.3	0.1	0.4	0.7	0.1	0.0	0.0	0.0	5.3	2.2	0.0	0.0	75.4	98.5
19	94024	cinder	bulk	2.5	2.4	10.7	0.7	0.1	0.8	0.0	0.5	0.0	0.0	6.5	2.5	0.0	0.0	73.7	100.2
19	94024	cinder	bulk	2.3	2.0	9.8	0.6	0.3	0.7	0.1	0.1	0.0	0.2	6.0	2.3	0.2	0.0	73.4	98.1
19	94024	cinder	bulk	1.6	8.5	0.1	0.1	0.1	0.6	0.0	0.1	0.0	0.0	4.4	2.1	0.0	0.0	80.2	99.8
19	94024	cinder	bulk	1.8	0.9	6.2	0.3	0.1	0.5	0.0	0.1	0.0	0.2	4.3	2.0	0.1	0.0	78.5	95.0
19	94024	cinder	matrix	3.9	4.1	15.1	0.0	0.3	1.1	0.0	0.1	0.0	0.0	9.2	2.4	0.1	0.0	62.8	99.0
19	94024	cinder	matrix	3.6	4.1	13.1	0.6	0.7	1.5	0.2	0.0	0.0	0.0	6.9	2.3	0.0	0.0	66.5	99.5
19	94024	cinder	residual phase	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.0	0.2	0.0	102.2	102.9
19	94024	cinder	residual phase	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.0	0.0	0.0	102.0	102.6
19	94025	tap slag	bulk	1.3	0.4	5.8	0.6	2.9	0.4	6.3	0.0	0.0	0.1	49.1	2.2	0.1	0.1	34.4	103.7
19	94025	tap slag	bulk	1.1	0.7	5.7	0.9	2.7	0.6	5.7	0.2	0.0	0.2	50.3	2.9	0.0	0.1	35.1	106.1
19	94025	tap slag	bulk	1.0	1.0	4.0	0.7	1.8	0.2	7.5	0.0	0.0	0.2	53.7	1.9	0.0	0.0	34.9	106.7

Con-text	Sampl No.	Slag "type"	Area analysed	EDX Analysis % Oxide															
				Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
19	94025	tap slag	bulk	0.4	0.1	5.8	1.0	3.3	0.4	8.1	0.7	0.1	0.1	39.1	2.8	0.0	0.0	42.2	104.0
19	94025	tap slag	bulk	1.3	0.5	5.2	0.4	3.5	0.5	9.4	0.0	0.0	0.0	43.2	2.5	0.0	0.1	38.5	105.2
19	94025	tap slag	dendrites	0.1	0.1	1.1	0.2	0.6	0.7	2.2	0.1	0.0	0.0	87.3	0.4	0.1	0.0	5.5	98.3
19	94025	tap slag	dendrites	1.2	0.4	3.1	0.3	2.3	0.6	2.7	0.2	0.0	0.1	72.4	1.9	0.0	0.0	14.8	100.1
19	94025	tap slag	laths	0.1	0.6	0.3	0.3	1.3	0.2	8.6	0.3	0.0	0.1	57.3	0.3	0.0	0.1	30.9	100.4
19	94025	tap slag	laths	0.0	1.1	0.0	0.1	0.6	0.0	8.9	0.3	0.0	0.0	58.4	0.1	0.1	0.0	30.9	100.5
19	94025	tap slag	matrix	1.9	0.0	12.6	3.1	8.2	0.9	3.0	0.1	0.0	0.0	27.4	7.0	0.0	0.4	35.9	100.5
19	94025	tap slag	matrix	0.9	0.1	7.3	3.0	3.2	0.4	0.9	0.0	0.0	0.0	37.2	2.4	0.0	0.2	34.7	90.4
19	94026	dense	bulk	1.8	0.3	4.7	0.7	4.6	0.3	0.0	0.0	0.0	0.0	52.3	3.1	0.0	0.0	38.3	106.2
19	94026	dense	bulk	1.0	0.4	3.5	0.2	2.9	0.2	0.1	0.0	0.0	0.2	58.4	1.8	0.0	0.0	37.7	106.3
19	94026	dense	bulk	1.7	0.4	4.6	0.2	4.6	0.4	0.1	0.1	0.0	0.0	51.4	2.8	0.0	0.0	37.9	104.2
19	94026	dense	bulk	1.2	0.8	2.7	0.3	2.4	0.0	0.1	0.0	0.0	0.1	59.2	1.4	0.0	0.1	34.0	102.3
19	94026	dense	bulk	0.6	0.2	2.7	0.2	2.4	0.2	0.0	0.5	0.0	0.1	57.8	1.5	0.1	0.0	34.8	101.0
19	94026	dense	laths	0.0	1.1	0.0	0.2	0.4	0.0	0.0	0.2	0.0	0.0	68.5	0.0	0.0	0.0	32.1	102.6
19	94026	dense	laths	0.7	0.5	0.0	0.0	0.8	0.2	0.0	0.2	0.0	0.1	69.2	0.1	0.0	0.0	31.9	103.7
19	94026	dense	matrix	1.4	0.0	7.5	1.3	12.4	0.4	0.1	0.2	0.0	0.0	27.1	4.8	0.0	0.2	45.7	101.0
19	94026	dense	matrix	2.3	0.0	7.7	1.7	12.3	0.3	0.0	0.1	0.0	0.1	27.1	5.1	0.1	0.3	43.9	101.0
76	94027	iron-rich cinder	bulk	0.0	0.7	1.5	0.1	0.3	0.1	0.0	0.0	0.0	0.0	66.6	0.4	0.0	0.0	29.5	99.1
76	94027	iron-rich cinder	bulk	0.7	1.0	3.2	0.2	0.5	0.2	0.0	0.2	0.0	0.2	65.8	0.9	0.0	0.1	30.6	103.6
76	94027	iron-rich cinder	bulk	1.5	1.0	1.6	0.0	0.7	0.2	0.0	0.3	0.0	0.0	63.4	0.5	0.0	0.0	27.9	97.2
76	94027	iron-rich cinder	bulk	1.0	0.2	5.3	0.0	1.4	0.5	0.1	0.1	0.0	0.0	59.4	1.2	0.0	0.1	33.7	103.0
76	94027	iron-rich cinder	bulk	0.8	0.8	5.1	0.1	0.5	0.2	0.0	0.0	0.0	0.1	66.1	0.1	0.0	0.0	29.4	103.0
76	94027	iron-rich cinder	laths	0.7	1.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	70.6	0.1	0.0	0.0	32.7	105.5
76	94027	iron-rich cinder	dendrites	0.5	0.0	0.9	0.0	0.0	1.4	0.0	0.5	0.0	0.2	95.7	0.1	0.0	0.0	0.8	100.2
76	94027	iron-rich cinder	dendrites	0.3	0.0	0.8	0.0	0.1	2.2	0.0	0.1	0.0	0.1	96.2	0.1	0.1	0.0	0.9	100.8
76	94027	iron-rich cinder	matrix (white)	6.9	0.0	18.3	1.0	6.7	0.4	0.0	0.0	0.0	0.0	17.4	7.1	0.0	0.1	44.4	102.3
76	94027	iron-rich cinder	matrix(white)	1.0	0.1	21.5	0.0	0.2	0.1	0.0	0.1	0.0	0.0	1.0	21.3	0.0	0.0	58.9	104.2
76	94027	iron-rich cinder	Fe inc	0.5	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	107.7	0.0	0.0	0.0	0.0	108.7
76	94027	iron-rich cinder	Fe inc	0.5	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.2	98.8	0.1	0.1	0.0	0.1	100.2
37	94028	undiagnostic	bulk("light ends")	2.7	2.7	10.5	0.0	0.2	0.9	0.0	0.0	0.2	0.2	6.9	2.5	0.2	0.0	67.9	95.0
37	94028	undiagnostic	bulk("light ends")	1.5	1.6	6.4	0.0	0.4	0.6	0.1	0.0	0.0	0.0	5.7	1.6	0.0	0.1	72.4	90.5
37	94028	undiagnostic	bulk("light ends")	2.6	1.8	9.6	0.0	0.3	0.5	0.0	0.0	0.0	0.0	6.4	2.3	0.0	0.0	64.3	87.8
37	94028	undiagnostic	bulk("dark mid")	1.0	0.4	5.2	0.0	0.3	0.6	0.0	0.0	0.0	0.0	6.3	2.3	0.0	0.0	78.0	94.1
37	94028	undiagnostic	bulk("dark mid")	1.3	1.0	9.4	0.0	1.3	0.8	0.0	0.0	0.0	0.1	30.5	2.7	0.0	0.0	51.6	98.7
37	94028	undiagnostic	bulk("light mid")	0.3	0.2	3.0	0.0	0.4	0.4	0.0	0.0	0.0	0.2	11.5	0.8	0.1	0.0	76.0	93.0
37	94028	undiagnostic	bulk("light mid")	0.1	0.0	2.2	0.2	0.2	0.3	0.0	0.1	0.1	0.0	7.8	0.5	0.0	0.1	70.9	82.5
37	94028	undiagnostic	bulk("light mid")	0.0	0.0	2.1	0.2	0.2	0.2	0.0	0.0	0.0	0.1	14.4	0.4	0.0	0.0	75.4	93.0
37	94028	undiagnostic	matrix(dk)"light	0.3	0.2	2.6	0.0	0.2	0.3	0.0	0.0	0.0	0.2	7.1	0.5	0.0	0.0	70.6	82.1
37	94028	undiagnostic	matrix(dk)"light	0.4	0.3	2.7	0.0	0.2	0.2	0.0	0.2	0.0	0.1	12.0	0.6	0.1	0.1	60.4	77.1
37	94028	undiagnostic	resid(dk)"light reg"	2.7	4.3	11.4	0.0	0.3	2.5	0.0	0.0	0.0	0.1	9.4	2.8	0.1	0.0	59.7	93.5
37	94028	undiagnostic	resid(dk)"light reg"	3.6	4.8	16.2	0.0	0.4	2.1	0.0	0.1	0.0	0.0	9.9	3.0	0.2	0.0	59.5	99.6
37	94028	undiagnostic	bulk("dense black	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	97.3	97.8
37	94028	undiagnostic	bulk("dense black	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	95.3	95.6
37	94028	undiagnostic	bulk("dense black	1.1	1.0	5.4	0.0	0.6	0.7	0.1	0.1	0.0	0.1	26.7	1.6	0.0	0.0	60.3	97.5
37	94028	undiagnostic	bulk("dense black	0.7	0.0	2.6	0.0	0.2	0.6	0.1	0.0	0.2	0.1	8.3	0.8	0.0	0.0	79.4	93.0
37	94028	undiagnostic	bulk("dense black	0.5	0.5	3.6	0.2	0.1	0.5	0.0	0.2	0.0	0.0	12.3	1.0	0.1	0.0	75.2	94.2
37	94028	undiagnostic	bulk("Fe	1.3	1.6	5.1	0.0	0.2	0.4	0.0	0.0	0.0	0.2	4.2	1.6	0.0	0.0	77.0	91.6
37	94028	undiagnostic	bulk("Fe	2.8	1.1	10.8	0.0	0.3	0.3	0.0	0.0	0.1	0.2	4.1	3.0	0.2	0.0	67.1	90.0
37	94029	iron-rich cinder	bulk("Fe	0.9	0.0	0.3	0.2	1.0	0.1	0.1	0.0	0.0	0.0	30.3	0.0	0.0	0.2	2.6	35.7
37	94029	iron-rich cinder	bulk("Fe	0.5	0.3	2.4	2.0	0.8	0.3	0.2	0.1	0.0	0.1	52.7	0.1	0.1	0.1	5.6	65.4
37	94029	iron-rich cinder	bulk("Fe	0.4	0.0	6.6	0.9	0.7	0.3	0.0	0.2	0.0	0.1	46.0	0.0	0.0	0.1	17.3	72.6
37	94029	iron-rich cinder	bulk("Fe	0.6	0.3	1.2	0.5	1.1	0.0	0.0	0.1	0.0	0.0	53.8	0.0	0.1	0.2	7.3	65.1
37	94029	iron-rich cinder	bulk("Fe	0.8	0.5	4.8	0.3	1.3	0.3	0.2	0.0	0.0	0.0	28.5	0.0	0.1	0.2	10.1	46.9
37	94029	iron-rich cinder	bulk("dense	0.5	0.6	3.9	0.0	0.4	0.4	0.0	0.0	0.0	0.1	65.7	0.2	0.0	0.1	22.3	94.2
37	94029	iron-rich cinder	bulk("dense	0.3	0.4	3.9	0.0	0.8	0.2	0.0	0.4	0.0	0.0	65.3	1.0	0.2	0.0	24.9	97.3
37	94029	iron-rich cinder	bulk("dense	0.6	0.4	3.1	0.0	0.4	0.3	0.0	0.6	0.0	0.2	61.4	0.0	0.1	0.1	14.4	81.5
37	94029	iron-rich cinder	bulk("dense	0.7	0.0	0.1	0.1	0.1	0.0	0.0	0.3	0.0	0.0	72.3	0.1	0.0	0.1	6.7	80.4
37	94029	iron-rich cinder	bulk("dense	0.7	0.5	0.0	0.6	0.2	0.0	0.0	0.3	0.0	0.1	68.3	0.0	0.0	0.1	6.4	77.1
37	94029	iron-rich cinder	dendrites"dense	0.0	0.0	1.9	0.0	0.0	1.0	0.0	0.5	0.0	0.0	95.6	0.0	0.0	0.1	0.7	99.8
37	94029	iron-rich cinder	dendrites"dense	1.0	0.2	0.8	0.0	0.0	0.6	0.1	0.3	0.0	0.2	95.4	0.0	0.1	0.0	0.7	99.2
37	94029	iron-rich cinder	laths"dense reg"	0.2	0.7	0.0	0.0	0.3	0.2	0.1	0.3	0.0	0.0	68.7	0.0	0.0	0.1	31.4	101.9
37	94029	iron-rich cinder	laths"dense reg"	0.5	1.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	69.0	0.0	0.0	0.0	31.4	102.4
37	94029	iron-rich cinder	white matrix	1.7	0.2	24.9	0.2	2.5	0.2	0.0	0.0	0.1	0.0	14.5	3.3	0.0	0.0	42.9	90.4
37	94029	iron-rich cinder	white matrix	0.3	0.3	17.3	0.5	0.6	0.4	0.0	0.0	0.0	0.1	27.0	0.0	0.0	0.1	36.1	82.7

Con-	Sampl	Slag "type"	Area analysed					EDX	Analysis			%	Oxide						
text	No.			Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
90	94030	vitrified hearth lining	bulk"dk.region"	1.8	1.1	12.6	0.0	2.4	0.9	0.4	0.0	0.0	0.1	7.6	9.4	0.0	0.0	61.6	97.8
90	94030	vitrified hearth lining	bulk"dk.region"	1.0	1.8	14.5	0.0	0.3	0.9	0.0	0.0	0.0	0.1	3.4	2.8	0.0	0.0	67.9	92.8
90	94030	vitrified hearth lining	bulk"dk.region"	1.1	1.8	16.0	0.2	0.9	1.0	0.2	0.0	0.1	0.1	3.1	3.2	0.0	0.0	65.1	92.8
90	94030	vitrified hearth lining	bulk"dk.region"	1.6	1.4	14.1	0.0	1.7	1.0	0.0	0.0	0.0	0.0	6.6	3.1	0.0	0.0	65.8	95.4
90	94030	vitrified hearth lining	bulk"dk.region"	1.0	0.9	10.5	0.0	0.4	0.6	0.0	0.1	0.0	0.0	3.1	3.1	0.0	0.0	64.9	84.5
90	94030	vitrified hearth lining	bulk"fired clay"	1.3	1.3	12.7	0.0	0.8	0.7	0.0	0.0	0.0	0.0	5.4	2.7	0.0	0.1	55.9	80.9
90	94030	vitrified hearth lining	bulk"fired clay"	0.9	0.9	7.4	0.1	1.0	0.6	0.1	0.0	0.1	0.0	4.4	1.5	0.0	0.4	21.3	38.7
90	94030	vitrified hearth lining	bulk"fired clay"	0.6	0.4	3.3	0.2	0.6	0.2	0.1	0.0	0.0	0.1	3.2	0.7	0.0	0.2	14.4	24.0
90	94030	vitrified hearth lining	black particle	0.6	0.0	0.0	40.1	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	38.8	80.1
90	94030	vitrified hearth lining	black particle	0.5	0.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	91.3	0.0	0.0	0.0	0.3	93.8
90	94030	vitrified hearth lining	large black	0.1	0.2	1.9	0.1	0.1	0.0	0.0	0.2	0.0	0.0	74.7	0.1	0.1	0.0	18.0	95.5
90	94030	vitrified hearth lining	small black	0.9	5.4	4.1	0.3	0.2	1.4	0.7	0.6	0.1	0.0	80.7	0.1	0.3	0.0	1.1	96.2
90	94030	vitrified hearth lining	quartz"dk.region"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	103.1	103.6
90	94030	vitrified hearth lining	quartz"dk.region"	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.3	0.1	0.0	0.0	103.3	104.1
90	94030	vitrified hearth lining	matrix "dk.region"	2.0	1.5	14.3	0.0	1.3	0.9	0.2	0.0	0.0	0.1	5.9	4.2	0.0	0.0	69.2	99.4
90	94030	vitrified hearth lining	matrix "dk.region"	2.0	2.8	13.1	0.6	5.6	1.0	0.1	0.0	0.1	0.1	10.9	2.9	0.0	0.0	63.5	102.6
90	94031	smithing hearth bottom	bulk	1.1	0.6	7.3	0.3	1.7	0.2	0.0	0.2	0.0	0.0	63.4	1.8	0.1	0.0	28.9	105.4
90	94031	smithing hearth bottom	bulk	1.2	0.2	5.8	0.2	1.3	0.2	0.0	0.0	0.0	0.0	74.1	1.4	0.1	0.0	22.4	107.0
90	94031	smithing hearth bottom	bulk	0.7	0.2	5.1	0.0	1.4	0.2	0.0	0.5	0.0	0.0	71.7	1.3	0.0	0.0	23.7	104.9
90	94031	smithing hearth bottom	bulk	1.1	1.0	4.8	0.1	1.3	0.2	0.0	0.3	0.0	0.0	70.8	0.9	0.0	0.1	22.9	103.3
90	94031	smithing hearth bottom	bulk	1.2	0.9	4.4	0.0	1.1	0.2	0.1	0.1	0.0	0.1	72.7	1.0	0.0	0.0	20.9	102.8
90	94031	smithing hearth bottom	dendrites	0.4	0.2	1.1	0.0	0.1	0.4	0.0	0.1	0.0	0.2	97.9	0.0	0.0	0.1	0.5	101.0
90	94031	smithing hearth bottom	dendrites	0.1	0.4	0.8	0.0	0.0	0.2	0.2	0.3	0.0	0.0	98.5	0.0	0.0	0.0	0.7	101.2
90	94031	smithing hearth bottom	laths	0.4	1.2	0.0	0.9	0.4	0.1	0.0	0.1	0.0	0.1	68.0	0.1	0.1	0.1	30.9	101.5
90	94031	smithing hearth bottom	laths	0.4	1.4	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.0	68.6	0.0	0.0	0.0	31.8	102.7
90	94031	smithing hearth bottom	matrix	2.6	0.2	18.5	0.3	6.5	0.1	0.0	0.0	0.0	0.1	26.2	6.2	0.0	0.2	38.7	99.6
90	94031	smithing hearth bottom	matrix	2.3	0.0	18.9	0.4	6.0	0.2	0.1	0.2	0.0	0.1	27.3	5.7	0.0	0.1	37.2	98.6
90	94032	undiagnostic (cindery)	bulk	1.0	1.0	8.4	0.0	0.4	0.6	0.0	0.0	0.0	0.1	3.4	2.0	0.1	0.0	59.5	76.5
90	94032	undiagnostic (cindery)	bulk	0.9	1.1	10.3	0.0	0.1	0.7	0.1	0.0	0.1	0.0	4.2	2.8	0.0	0.0	67.1	87.5
90	94032	undiagnostic (cindery)	bulk	0.8	1.1	10.3	0.0	0.3	0.5	0.1	0.0	0.1	0.0	5.2	3.1	0.0	0.0	70.4	92.0
90	94032	undiagnostic (cindery)	bulk	1.2	0.9	9.3	0.0	0.3	0.3	0.0	0.0	0.1	0.0	3.6	2.3	0.1	0.0	67.4	85.6
90	94032	undiagnostic (cindery)	bulk	0.7	1.0	7.6	0.0	0.3	0.3	0.0	0.0	0.1	0.0	3.3	2.3	0.0	0.0	74.7	90.1
90	94032	undiagnostic (cindery)	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	102.2	102.3
90	94032	undiagnostic (cindery)	quartz grain?	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1	103.9	104.4
90	94032	undiagnostic (cindery)	matrix	2.8	1.4	15.2	0.0	0.5	0.2	0.0	0.0	0.0	0.0	2.3	5.4	0.0	0.0	64.4	92.2
90	94032	undiagnostic (cindery)	matrix	6.0	0.0	17.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	1.4	3.9	0.1	0.0	70.2	99.9
90	94033	undiagnostic (<cinder)	bulk	0.7	0.5	7.6	0.2	3.2	0.3	0.2	0.0	0.0	0.0	51.3	2.1	0.2	0.0	36.2	102.6
90	94033	undiagnostic (<cinder)	bulk	1.2	1.3	6.4	0.3	3.0	0.3	0.3	0.1	0.0	0.0	55.2	1.8	0.0	0.0	34.4	104.3
90	94033	undiagnostic (<cinder)	bulk	0.9	0.5	8.9	0.2	2.6	0.4	0.2	0.1	0.0	0.0	51.7	2.2	0.1	0.0	36.6	104.6
90	94033	undiagnostic (<cinder)	bulk	1.1	1.2	9.1	0.0	4.2	0.4	0.3	0.0	0.0	0.1	15.4	3.0	0.0	0.0	54.6	89.6
90	94033	undiagnostic (<cinder)	bulk	1.1	0.6	8.2	0.0	2.5	0.4	0.1	0.1	0.0	0.0	55.3	1.7	0.1	0.0	36.9	107.0
90	94033	undiagnostic (<cinder)	dendrites	0.3	0.2	1.6	0.0	0.0	0.6	0.0	0.4	0.0	0.0	93.2	0.0	0.0	0.0	1.0	97.5
90	94033	undiagnostic (<cinder)	dendrites	0.0	0.4	1.2	0.0	0.2	0.2	0.1	0.5	0.0	0.1	94.0	0.1	0.1	0.0	0.8	97.5
90	94033	undiagnostic (<cinder)	matrix	1.9	0.3	13.4	1.7	11.5	0.2	0.1	0.2	0.0	0.0	26.2	5.9	0.0	0.1	42.4	103.8
90	94033	undiagnostic (<cinder)	matrix	1.2	0.0	13.9	0.5	7.6	0.3	0.1	0.5	0.1	0.0	24.3	4.4	0.0	0.0	46.7	99.7
90	94033	undiagnostic (<cinder)	laths	0.0	1.0	0.0	0.0	0.5	0.0	0.7	0.6	0.0	0.0	62.2	0.0	0.0	0.0	29.6	94.7
90	94033	undiagnostic (<cinder)	laths	0.4	1.1	0.0	0.0	0.7	0.0	0.5	1.6	0.0	0.0	57.1	0.0	0.1	0.0	28.4	90.0
90	94034	cinder	bulk	1.1	1.6	10.7	0.0	0.4	0.8	0.1	0.0	0.2	0.0	4.7	3.4	0.0	0.0	68.8	91.7
90	94034	cinder	bulk	1.2	2.5	18.8	0.0	0.3	1.2	0.1	0.2	0.0	0.0	9.7	3.4	0.0	0.0	59.9	97.2
90	94034	cinder	bulk	1.0	2.1	15.2	0.0	0.7	1.0	0.0	0.0	0.0	0.1	9.0	3.9	0.0	0.0	65.0	98.0
90	94034	cinder	bulk	1.5	1.7	10.9	0.0	0.3	0.8	0.0	0.0	0.0	0.0	7.4	3.7	0.0	0.0	71.2	97.5
90	94034	cinder	bulk	1.0	1.3	10.8	0.0	0.5	0.8	0.0	0.0	0.0	0.0	9.8	3.4	0.1	0.0	57.7	85.4
90	94034	cinder	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.1	0.2	0.0	0.0	0.0	105.3	105.9
90	94034	cinder	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	102.5	102.9
90	94034	cinder	matrix	0.8	3.1	18.5	0.0	0.3	1.2	0.0	0.0	0.8	0.0	13.5	2.7	0.0	0.0	58.6	98.9
90	94034	cinder	matrix	1.1	1.9	18.7	0.1	0.5	2.1	0.0	0.0	0.0	0.0	6.4	4.0	0.0	0.0	66.0	101.0
90	94035	iron-rich cinder	bulk"dense	0.8	0.2	6.7	1.7	0.7	0.4	0.0	0.1	0.0	0.0	50.9	0.2	0.0	0.1	20.7	82.5
90	94035	iron-rich cinder	bulk"dense	0.5	0.6	6.2	1.3	0.7	0.3	0.1	0.6	0.1	0.1	51.9	0.3	0.0	0.1	19.2	82.2
90	94035	iron-rich cinder	bulk"dense	0.3	0.1	6.9	2.0	0.5	0.4	0.0	0.0	0.0	0.0	46.8	0.1	0.0	0.1	20.1	77.4
90	94035	iron-rich cinder	dendrites"dense	0.0	0.5	1.0	0.0	0.2	0.2	0.0	0.1	0.0	0.0	94.7	0.0	0.1	0.0	0.7	97.5
90	94035	iron-rich cinder	dendrites"dense	0.2	0.4	2.3	0.2	0.1	0.5	0.0	0.3	0.0	0.0	82.9	0.0	0.0	0.0	4.2	91.3
90	94035	iron-rich cinder	matrix"dense	0.6	0.4	2.9	0.7	0.6	0.1	0.0	0.0	0.0	0.0	54.7	0.2	0.0	0.1	20.8	81.1
90	94035	iron-rich cinder	matrix"dense	0.4	0.0	10.8	2.5	1.5	0.2	0.0	0.0	0.0	0.1	35.2	0.8	0.0	0.2	25.2	76.9
90	94035	iron-rich cinder	bulk"soft region"	0.3	0.1	3.6	0.3	1.9	0.2	0.0	0.0	0.1	0.0	27.7	0.3	0.1	0.4	8.2	43.3

Con-	Sampl	Slag "type"	Area analysed					EDX Analysis				% Oxide							
text	No.			Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
90	94035	iron-rich cinder	bulk"soft region"	0.2	0.2	9.5	2.3	2.0	0.5	0.0	0.1	0.0	0.0	31.0	0.5	0.1	0.2	22.0	68.7
90	94035	iron-rich cinder	bulk"soft region"	0.7	0.2	5.6	0.3	1.8	0.3	0.0	0.3	0.1	0.0	34.6	1.0	0.1	0.3	10.7	56.1
104	94036	cinder	bulk"dense	1.2	2.0	11.0	0.0	5.7	0.7	0.1	0.3	0.0	0.0	22.6	3.3	0.0	0.0	54.9	101.9
104	94036	cinder	bulk"dense	1.1	1.7	10.9	0.5	6.5	0.7	0.3	0.3	0.0	0.0	22.1	2.9	0.1	0.0	56.4	103.4
104	94036	cinder	bulk(quartz	0.9	1.5	10.5	0.0	4.0	0.9	0.1	0.0	0.0	0.3	21.5	3.5	0.1	0.0	56.3	99.7
104	94036	cinder	bulk(quartz	0.9	0.9	8.1	0.0	1.2	0.5	0.2	0.0	0.0	0.0	6.6	4.5	0.2	0.0	73.3	96.7
104	94036	cinder	bulk(quartz	2.0	1.2	11.9	0.0	2.7	0.8	0.1	0.2	0.0	0.2	10.4	5.1	0.0	0.0	62.2	96.8
104	94036	cinder	matrix	1.7	0.8	13.7	0.0	3.1	0.8	0.0	0.1	0.0	0.0	10.9	5.6	0.1	0.0	63.9	100.8
104	94036	cinder	matrix	1.7	1.1	11.6	0.3	4.6	0.6	0.0	0.2	0.0	0.0	18.8	4.1	0.0	0.0	59.9	103.0
104	94036	cinder	quartz grain?	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	102.0	102.5
446	94037	glassy	bulk	1.4	2.3	9.7	0.0	9.9	0.9	6.8	0.4	0.0	0.1	18.1	3.0	0.1	0.2	54.0	107.0
446	94037	glassy	bulk	1.5	2.1	10.0	0.1	9.0	0.8	4.4	0.2	0.0	0.0	13.7	4.1	0.0	0.0	58.8	104.8
446	94037	glassy	bulk	1.5	2.0	9.9	0.1	9.5	1.0	6.8	0.1	0.1	0.0	16.7	3.8	0.0	0.0	55.8	107.3
446	94037	glassy	bulk	1.7	2.1	8.9	0.0	10.7	1.2	8.2	0.0	0.0	0.0	20.5	2.6	0.0	0.1	50.4	106.2
446	94037	glassy	bulk	2.0	2.0	9.0	0.2	8.7	0.8	7.2	0.1	0.0	0.0	20.9	3.0	0.1	0.0	51.4	105.5
446	94037	glassy	bulk Fe	0.4	0.0	0.1	2.5	0.1	0.0	1.2	0.3	0.0	0.0	86.9	0.0	0.0	0.1	1.0	92.6
446	94037	glassy	bulk Fe	1.0	0.4	0.1	3.5	0.0	0.0	1.2	0.7	0.0	0.0	87.3	0.0	0.1	0.0	0.8	95.2
446	94037	glassy	bulk Fe	0.2	0.0	0.0	2.8	0.0	0.0	1.3	0.3	0.0	0.0	87.1	0.0	0.1	0.1	0.9	92.9
446	94037	glassy	Fe pearlite	0.5	0.1	0.0	0.0	0.1	0.0	0.9	0.2	0.0	0.1	92.4	0.0	0.1	0.0	1.2	95.6
446	94037	glassy	Fe pearlite	0.0	0.2	0.2	0.3	0.0	0.0	0.8	0.1	0.0	0.1	93.6	0.0	0.0	0.0	1.4	96.7
446	94037	glassy	Fe ledeburite	0.0	0.1	0.3	8.3	0.0	0.0	1.4	0.3	0.0	0.0	84.6	0.0	0.0	0.0	0.3	95.3
446	94037	glassy	Fe ledeburite	1.0	0.1	0.0	8.3	0.1	0.1	1.3	0.3	0.0	0.0	85.4	0.0	0.0	0.0	0.3	97.0
446	94037	glassy	Fe	0.1	0.0	0.1	3.0	0.0	0.1	1.5	0.3	0.0	0.1	88.5	0.0	0.1	0.0	0.1	93.9
446	94037	glassy	Fe	0.7	0.3	0.1	2.9	0.0	0.0	2.0	0.5	0.0	0.0	87.8	0.0	0.2	0.0	0.1	94.5
446	94037	glassy	Fe	0.6	0.5	0.2	6.5	0.0	0.0	1.1	0.2	0.0	0.0	89.3	0.0	0.0	0.0	0.6	99.2
446	94037	glassy	Fe	0.2	0.1	0.0	6.9	0.1	0.0	1.0	0.4	0.0	0.1	88.0	0.0	0.0	0.0	0.6	97.4
446	94037	glassy	Fe graphite	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.1	9.3	0.0	0.0	0.1	0.3	10.1
485	94038	dense	bulk	1.9	0.2	7.6	0.3	3.7	0.3	3.3	0.0	0.0	0.0	45.9	3.5	0.0	0.1	37.2	104.2
485	94038	dense	bulk	0.7	0.6	6.1	0.4	2.8	0.4	4.1	0.0	0.0	0.0	50.9	2.7	0.0	0.0	36.7	105.5
485	94038	dense	bulk	1.9	0.3	7.4	0.7	5.2	0.4	3.3	0.5	0.0	0.1	45.5	2.5	0.1	0.1	36.4	104.3
485	94038	dense	bulk	2.0	0.7	5.6	0.6	3.3	0.3	3.8	0.3	0.0	0.0	48.8	2.4	0.0	0.1	36.1	103.9
485	94038	dense	bulk	1.6	0.5	7.2	0.4	4.7	0.3	3.3	0.2	0.0	0.3	46.4	2.8	0.0	0.0	37.2	104.9
485	94038	dense	mid grey lath	0.0	1.9	0.0	0.0	0.6	0.0	5.9	0.7	0.0	0.0	58.6	0.0	0.1	0.0	32.2	100.1
485	94038	dense	mid grey lath	0.4	1.2	0.0	0.0	0.7	0.0	5.7	0.3	0.0	0.1	61.8	0.1	0.1	0.0	31.6	101.9
485	94038	dense	mixed matrix	4.3	0.0	12.0	2.4	15.0	0.7	1.0	0.0	0.0	0.2	25.2	2.0	0.0	0.7	37.8	101.4
485	94038	dense	mixed matrix	4.2	0.0	10.8	1.8	12.6	0.9	1.1	0.1	0.0	0.1	29.1	1.8	0.1	0.5	35.7	98.6
485	94038	dense	light grey lath in	1.2	0.0	13.4	0.9	12.8	2.5	1.0	0.0	0.0	0.2	39.1	0.4	0.1	0.1	29.0	100.8
485	94038	dense	white "matrix" of	5.1	0.0	10.5	3.0	13.9	0.4	1.1	0.2	0.0	0.2	20.7	2.6	0.0	0.6	38.6	96.9
285	94039	smithing hearth bottom	bulk "dark region"	4.1	1.2	12.3	0.0	3.3	1.1	0.1	0.1	0.0	0.0	5.4	3.8	0.0	0.0	63.3	94.6
285	94039	smithing hearth bottom	bulk "dark region"	3.9	0.5	9.3	0.0	0.6	0.8	0.0	0.2	0.2	0.1	4.4	2.9	0.0	0.1	65.2	88.0
285	94039	smithing hearth bottom	bulk "dark region"	3.9	1.2	10.3	0.0	0.5	0.3	0.2	0.0	0.0	0.0	6.4	3.1	0.0	0.0	65.1	91.1
285	94039	smithing hearth bottom	bulk "dark region"	2.8	0.9	10.4	0.0	2.1	0.9	0.1	0.1	0.0	0.0	6.4	3.1	0.1	0.0	65.1	92.0
285	94039	smithing hearth bottom	bulk "dark region"	3.9	0.5	9.3	0.0	0.5	0.4	0.1	0.0	0.0	0.0	4.1	3.2	0.2	0.0	62.5	84.8
285	94039	smithing hearth bottom	bulk "light quartzy	1.1	0.9	7.4	0.0	0.3	0.7	0.1	0.1	0.0	0.1	3.5	2.3	0.0	0.0	53.6	70.2
285	94039	smithing hearth bottom	bulk "light quartzy	0.5	0.7	3.4	0.0	0.0	0.2	0.1	0.0	0.1	0.2	3.7	1.3	0.0	0.0	71.9	82.2
285	94039	smithing hearth bottom	bulk "light quartzy	0.3	0.2	3.8	0.0	0.0	0.5	0.0	0.2	0.0	0.0	2.3	1.7	0.0	0.0	61.4	70.4
285	94039	smithing hearth bottom	bulk "light quartzy	1.0	0.8	9.2	0.0	0.2	0.5	0.1	0.1	0.1	0.0	3.3	2.8	0.2	0.0	65.1	83.2
285	94039	smithing hearth bottom	bulk "light quartzy	0.6	0.4	4.4	0.0	0.0	0.1	0.1	0.0	0.0	0.0	4.4	1.4	0.0	0.0	67.8	79.3
285	94039	smithing hearth bottom	matrix	7.1	0.8	19.0	0.0	2.3	0.2	0.1	0.0	0.0	0.2	5.5	2.8	0.0	0.0	52.6	90.7
285	94039	smithing hearth bottom	matrix	5.2	1.0	17.0	0.0	4.4	1.3	0.2	0.0	0.0	0.0	6.3	2.9	0.0	0.0	56.0	94.5
285	94039	smithing hearth bottom	quartz grain?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	90.1	90.5
285	94040	undiagnostic	bulk	1.7	0.4	7.0	0.0	2.2	0.4	0.0	0.1	0.1	0.1	52.2	2.4	0.0	0.0	36.6	103.1
285	94040	undiagnostic	bulk	0.3	0.7	2.7	0.2	1.0	0.0	0.1	0.0	0.0	0.0	61.4	1.0	0.1	0.0	33.7	101.2
285	94040	undiagnostic	bulk	0.4	0.8	2.7	0.5	1.0	0.2	0.0	0.0	0.0	0.0	58.3	0.3	0.0	0.1	28.9	93.2
285	94040	undiagnostic	bulk	2.0	0.3	9.2	0.5	3.6	0.6	0.0	0.0	0.0	0.0	41.9	3.5	0.0	0.0	40.3	101.9
285	94040	undiagnostic	bulk	1.4	0.0	7.6	0.1	3.1	0.7	0.0	0.0	0.1	0.1	44.3	2.6	0.0	0.1	38.0	98.1
285	94040	undiagnostic	matrix	1.7	0.0	12.3	0.1	5.3	0.9	0.0	0.1	0.0	0.2	35.3	4.7	0.1	0.0	42.3	103.0
285	94040	undiagnostic	matrix	2.1	0.1	13.3	0.5	6.6	1.1	0.1	0.0	0.0	0.1	28.3	4.4	0.0	0.1	41.9	98.7
285	94040	undiagnostic	laths	0.3	0.9	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	61.5	0.0	0.0	0.0	27.6	90.6
285	94040	undiagnostic	laths	0.2	1.0	0.4	0.0	0.4	0.0	0.0	0.1	0.0	0.0	60.5	0.2	0.1	0.0	27.2	90.1

Appendix 4 Bulk analyses of slag samples from Ribchester Graveyard

Con-text	Find No.	Sample No.	Slag type	EDX Oxide total % Na	Mg	Al	P	Ca	Ti	Mn	Co	Ni	Cu	Fe	K	Cr	S	Si	Tot.
5	5698	94005	tap slag	-	-	1.1	1.2	4.7	0.5	4.4	0.1	0.0	0.0	53.0	2.2	0.0	0.1	22.9	90.4
19	5705	94025	tap slag	1.0	0.5	5.3	0.7	2.8	0.4	7.4	0.2	0.0	0.1	47.1	2.5	0.0	0.1	37.0	105.1
5	5698	94009	dense	-	-	1.4	0.2	0.5	0.3	0.2	0.2	0.0	0.0	57.8	0.3	0.0	0.1	17.4	78.5
18	6526	94013	dense	-	-	0.7	0.0	1.1	0.3	0.0	0.2	0.0	0.0	59.0	1.6	0.0	0.0	22.6	85.7
19	5705	94026	dense	1.3	0.4	3.6	0.3	3.4	0.2	0.1	0.1	0.0	0.1	55.8	2.1	0.0	0.0	36.5	104.0
485	9902	94038	dense	1.6	0.5	6.8	0.5	3.9	0.3	3.6	0.2	0.0	0.1	47.5	2.8	0.0	0.1	36.7	104.6
3	6301	94004	smithing hearth bottom	-	-	1.4	0.0	1.0	0.5	0.1	0.0	0.0	0.0	8.9	2.2	0.1	0.0	41.9	56.3
5	5698	94012	smithing hearth bottom	-	-	1.5	0.2	2.6	0.1	0.1	0.2	0.0	0.1	63.1	3.0	0.0	0.0	25.5	96.6
18	6526	94015	smithing hearth bottom	-	-	0.9	2.3	6.4	0.5	0.2	0.2	0.0	0.1	36.5	2.2	0.0	0.1	23.7	72.9
19	5705	94020	smithing hearth bottom	1.7	0.2	7.2	0.1	2.1	0.5	0.0	0.2	0.0	0.1	41.4	2.5	0.0	0.0	42.9	98.9
90	7422	94031	smithing hearth bottom	1.1	0.6	5.5	0.1	1.4	0.2	0.0	0.2	0.0	0.0	70.5	1.3	0.0	0.0	23.8	104.7
285	9981	94039	smithing hearth bottom	2.2	0.7	8.0	0.0	0.8	0.6	0.1	0.1	0.0	0.0	4.4	2.6	0.1	0.0	64.1	83.6
3	6301	94003	undiagnostic	-	-	0.5	0.1	0.3	0.0	0.0	0.2	0.1	0.1	63.2	0.0	0.0	0.2	6.5	71.3
5	5698	94006	undiagnostic	-	-	1.4	0.0	1.4	0.6	0.0	0.1	0.0	0.0	10.8	2.1	0.0	0.0	51.8	68.2
18	6526	94016	undiagnostic(<cindery)	-	-	0.8	0.0	0.6	0.9	0.1	0.0	0.1	0.0	5.4	2.6	0.0	0.0	37.8	48.2
18	6526	94017	undiagnostic(>cindery)	-	-	0.7	0.0	0.9	0.6	0.0	0.0	0.0	0.1	2.8	2.6	0.1	0.1	40.3	48.2
19	5705	94022	undiagnostic	1.2	2.2	10.5	0.2	1.4	0.7	0.0	0.1	0.0	0.1	17.9	3.2	0.1	0.0	61.6	99.0
37	7309	94028	undiagnostic	1.1	0.8	5.1	0.0	0.3	0.5	0.0	0.0	0.0	0.1	9.7	1.4	0.0	0.0	73.9	93.0
90	7422	94032	undiagnostic (cindery)	0.9	1.0	9.2	0.0	0.3	0.5	0.0	0.0	0.1	0.0	3.9	2.5	0.0	0.0	67.8	86.3
90	7422	94033	undiagnostic (<cindery)	1.0	0.8	8.0	0.1	3.1	0.4	0.2	0.1	0.0	0.0	45.8	2.2	0.1	0.0	39.7	101.6
285	9981	94040	undiagnostic	1.2	0.4	5.8	0.3	2.2	0.4	0.0	0.0	0.0	0.0	51.6	2.0	0.0	0.0	35.5	99.5
5	5698	94011	iron-rich cinder	-	-	0.9	0.9	1.6	0.3	0.0	0.3	0.0	0.1	56.2	1.5	0.0	0.0	18.6	80.4
18	6526	94018	iron-rich cinder	0.9	0.8	9.9	0.0	0.3	0.8	0.1	0.2	0.0	0.1	4.6	2.6	0.0	0.0	69.8	89.9
19	5705	94021	iron-rich cinder	0.6	0.3	1.2	0.1	0.3	0.1	0.0	0.2	0.0	0.1	76.1	0.1	0.1	0.0	15.5	94.9
76	7488	94027	iron-rich cinder	0.8	0.7	3.3	0.1	0.7	0.2	0.0	0.1	0.0	0.1	64.3	0.6	0.0	0.0	30.2	101.2
37	7309	94029	iron-rich cinder	0.6	0.3	2.6	0.5	0.7	0.2	0.1	0.2	0.0	0.1	54.4	0.1	0.1	0.1	11.8	71.6
90	7422	94035	iron-rich cinder	0.5	0.2	6.4	1.3	1.3	0.4	0.0	0.2	0.1	0.0	40.5	0.4	0.1	0.2	16.8	68.4
5	5698	94008	vitrified hearth lining	-	-	2.3	0.0	1.0	0.9	0.0	0.1	0.0	0.2	3.9	3.4	0.0	0.0	46.8	58.8
18	6526	94019	vitrified hearth lining	1.5	1.2	7.0	0.3	4.5	0.5	0.1	0.1	0.0	0.1	35.4	2.6	0.1	0.0	46.8	100.3
19	5705	94023	vitrified hearth lining	1.1	1.6	11.6	0.4	1.6	0.8	0.1	0.0	0.1	0.0	6.7	2.9	0.0	0.0	58.9	87.2
90	7422	94030	vitrified hearth lining	1.2	1.2	11.4	0.1	1.0	0.7	0.1	0.0	0.0	0.1	4.6	3.3	0.0	0.1	52.1	75.9
5	5698	94007	cinder	-	-	1.8	0.0	1.1	0.9	0.0	0.0	0.1	0.1	5.6	2.6	0.1	0.0	58.1	70.4
18	6526	94014	cinder	-	-	0.6	0.4	1.9	0.4	0.0	0.2	0.0	0.1	43.6	1.3	0.0	0.1	19.3	67.6
19	5705	94024	cinder	2.2	3.2	7.2	0.4	0.2	0.7	0.0	0.2	0.0	0.1	5.3	2.2	0.1	0.0	76.2	98.3
90	7422	94034	cinder	1.2	1.8	13.3	0.0	0.4	0.9	0.0	0.0	0.0	0.0	8.1	3.6	0.0	0.0	64.5	94.0
104	7417	94036	cinder	1.2	1.5	10.5	0.1	4.0	0.7	0.2	0.2	0.0	0.1	16.6	3.9	0.1	0.0	60.6	99.7
5	5698	94010	fuel ash slag	-	-	0.7	4.6	9.8	0.4	0.3	0.0	0.0	0.0	2.7	3.5	0.0	0.0	30.9	53.0
446	9022	94037	glassy	1.6	2.1	9.5	0.1	9.6	0.9	6.7	0.2	0.0	0.0	18.0	3.3	0.0	0.1	54.1	106.2

Appendix 5 Magnetic susceptibility data

Sample No.	Context No.	Phase	Feature	Large sample: Mass (g)	Large sample: Mag sus. (x10-5)	Large sample: Mass specific mag. sus. (m2/kgx10-8)	Small sample: Mass (g)	Small sample: Mag. sus. high freq. (x10-5)	Small sample: Mag. sus. low freq. (x10-5)	Small sample: Mass specific mag sus high freq (m2/kgx10-8)	Small sample: Mass specific mag sus low freq (m2/kgx10-8)	Small sample: Freq. dependance	Weight of magnetic portion: total (g)	Weight of magnetic portion: fired clay (g)	Weight of magnetic portion: hammerscale flake (g)	Weight of magnetic portion: hammerscale spher. (g)
4319	370	1.2	layer	123	60	49	6.9	29	31	42	45	6.5	not determined			
4320	385	1.2	layer	170	225	133	11.4	108	117	95	103	7.7	0.474	0.013	0	0
4334	395	1.2	pit fill	146	468	321	8.4	217	237	258	282	8.4	not determined			
4334	395	1.2	pit fill	125	267	214	9.3	207	222	223	239	6.8	1.56	0	0	0
4337	396	1.2	pit fill	117	530	455	9.2	336	372	365	404	9.7	not determined			
4337	396	1.2	pit fill	144	687	477	9.3	476	506	512	544	5.9	not determined			
4349	407	1.2	pit fill	141	11	8	10.7	7	7	7	7	0.0	not determined			
4395	434	1.2	layer	147	236	160	11.5	142	151	123	131	6.0	not determined			
4594	535	1.2	pit fill	168	631	376	9.3	294	325	316	349	9.5	not determined			
4623	552	2.1	rampart layer	149	9	6	11.7	7	6	6	5	-16.7	0.008	0	0	0
4581	107	2.2	linear feature fill	130	9	7	10.5	8	7	8	7	-14.3	0.014	0	0.005	0
4367	282	2.2	hearth debris	162	247	153	11.9	174	191	146	161	8.9	not determined			
4354	319	2.2	hearth debris	178	80	45	11.9	38	41	32	34	7.3	not determined			
4352	320	2.2	hearth debris	152	66	44	11.3	57	60	50	53	5.0	not determined			
4357	334	2.2	hearth base	154	747	484	8.4	259	281	308	335	7.8	not determined			
4346	335	2.2	hearth debris	215	628	293	13.3	295	325	222	244	9.2	not determined			
4289	382	2.2	redep. rampart	148	28	19	11.9	23	24	19	20	4.2	not determined			
4356	409	2.2	hearth debris	201	294	146	11.7	136	149	116	127	8.7	not determined			
4359	412	2.2	hearth debris	141	232	165	9.8	155	166	158	169	6.6	not determined			
4729	659	2.2	pit fill	180	412	229	9.9	178	188	180	190	5.3	not determined			
4665	545	3	layer	168	764	456	8.8	420	422	477	480	0.5	not determined			
4636	560	3	layer	144	48	33	11.6	29	30	25	26	3.3	not determined			
4638	564	3	hearth debris	142	703	496	10.2	415	457	407	448	9.2	not determined			
4644	567	3	hearth debris	187	155	83	9.7	77	88	79	91	12.5	not determined			
4646	570	3	hearth debris	137	38	28	9.5	21	23	22	24	8.7	not determined			
4658	571	3	hearth debris	133	140	105	10.6	120	127	113	120	5.5	0.772	0	0.006	0
4781	703	3	layer	136	71	52	10.1	44	46	44	46	4.3	not determined			
4893	800	3	layer	123	764	620	9.1	517	572	568	629	9.6	not determined			
4714	55	4.1	layer	192	64	33	11.5	39	39	34	34	0.0	not determined			
4822	698	4.1	hearth debris	158	750	475	10.5	376	407	358	388	7.6	3.004	0.014	0	0
4668	61	4.2	surface	210	44	21	12	20	25	17	21	20.0	0.041	0	0.003	0
4536	78	4.2	layer	151	33	22	10.2	15	14	15	14	-7.1	not determined			
4558	223	4.2	hearth debris	162	1227	758	11.1	682	749	614	675	8.9	4.359	0	0.007	0
4572	223	4.2	hearth debris	191	31	16	11.8	17	17	14	14	0.0	not determined			
4573	223	4.2	hearth debris	153	28	18	11.9	20	20	17	17	0.0	not determined			
4671	245	4.2	linear feature	179	33	18	10.7	16	17	15	16	5.9	not determined			
4399	443	4.2	linear feature fill	148	276	186	11.4	153	163	134	143	6.1	0.537	0.022	0.029	0.01
4599	470	4.2	pit fill	182	84	46	11.8	42	44	36	37	4.5	not determined			
4552	485	4.2	hearth debris	173	1564	904	10	791	858	791	858	7.8	6.471	0.173	0.022	0
4546	486	4.2	hearth debris	134	168	125	10.1	82	90	81	89	8.9	not determined			
4537	487	4.2	hearth debris	140	89	63	10.7	67	58	63	54	-15.5	0.331	0	0.006	0
4531	491	4.2	layer	133	318	238	10.5	271	301	258	287	10.0	not determined			

Ribchester Magnetic Susceptibility Data																
				Large sample			Small sample						Weight of magnetic portion			
Sample No.	Context No.	Phase	Feature	Mass (g)	Mag sus. (x10-5)	Mass specific mag. sus. (m2/kgx10-8)	Mass (g)	Mag. sus. high freq. (x10-5)	Mag. sus. low freq. (x10-5)	Mass specific mag sus high freq (m2/kgx10-8)	Mass specific mag sus low freq (m2/kgx10-8)	Freq. depen-dance	total (g)	fired clay (g)	hammerscale flake (g)	hammerscale spher. (g)
4532	492	4.2	layer	147	166	113	11.1	84	90	76	81	6.7	0.177	0	0.002	0
4583	498	4.2	layer	166	127	77	11.1	63	70	57	63	10.0	not determined			
4569	499	4.2	layer	150	45	30	11.8	32	34	27	29	5.9	not determined			
4633	505	4.2	layer	170	26	15	11.9	10	11	8	9	9.1	not determined			
4554	510	4.2	pit fill	159	45	28	13.1	55	60	42	46	8.3	not determined			
4561	514	4.2	pit fill	188	167	89	10.9	80	95	73	87	15.8	not determined			
4565	518	4.2	pit fill	159	252	158	10.6	157	163	148	154	3.7	not determined			
4602	538	4.2	hearth debris	164	139	85	10.3	79	82	77	80	3.7	not determined			
4605	539	4.2	hearth debris	156	134	86	11.1	69	73	62	66	5.5	not determined			
4607	540	4.2	layer	187	157	84	12.1	88	116	73	96	24.1	0.38	0.007	0.009	0
4613	542	4.2	layer in hearth	198	2600	1315	10.2	1181	1300	1158	1275	9.2	15.054	14.56	0.007	0
4615	543	4.2	hearth debris	182	88	48	12.4	54	58	44	47	6.9	not determined			
4625	559	4.2	layer	188	31	17	12.9	16	17	12	13	5.9	not determined			
4660	574	4.2	hearth debris	161	579	361	10.1	284	311	281	308	8.7	not determined			
4652	575	4.2	hearth debris	160	86	54	11.4	57	62	50	54	8.1	not determined			
4619	589	4.2	linear feat. cut	171	887	518	10.1	425	462	421	457	8.0	not determined			
4690	605	4.2	surface layer	165	14	9	12.2	8	6	7	5	-33.3	0.041	0	0	0
4695	614	4.2	hearth debris	169	68	40	10.8	39	46	36	43	15.2	not determined			
4698	616	4.2	hearth debris	182	324	178	11	180	198	164	180	9.1	not determined			
4715	617	4.2	layer	148	11	7	10.7	6	6	6	6	0.0	not determined			
4702	620	4.2	hearth debris	178	124	70	11	72	79	65	72	8.9	not determined			
4705	623	4.2	hearth debris	199	209	105	12	100	106	83	88	5.7	not determined			
4706	626	4.2	hearth debris	195	103	53	11.5	61	65	53	57	6.2	not determined			
4716	630	4.2	layer	166	17	10	11	13	13	12	12	0.0	not determined			
4720	632	4.2	hearth debris	175	42	24	11.5	22	23	19	20	4.3	not determined			
4722	633	4.2	hearth debris	166	30	18	11	15	15	14	14	0.0	not determined			
4773	690	4.2	layer	148	182	123	9	77	106	86	118	27.4	0.656	0.032	0	0
4518	18	5.1	industrial layer	156	286	183	8.7	114	119	131	137	4.2	not determined			
4409	435	5.1	ind. residue	161	434	270	10.8	238	242	220	224	1.7	not determined			
4858	272	5.2	subsoil	129	178	138	10.3	128	143	124	139	10.5	not determined			
4405	454	5.2	iron pan layer	124	50	40	9.6	37	39	39	41	5.1	not determined			
4407	455	5.2	iron pan layer	148	264	179	9.7	139	151	143	156	7.9	not determined			
4521	477	5.2	layer	133	402	303	10	307	326	307	326	5.8	not determined			
4730	664	1.2/3	post hole fill	120	291	242	8.3	165	179	199	216	7.8				
4333	393		natural	213	8	4	12.8	4	4	3	3	0.0	0.001	0	0	0
4641	5661			190	237	125	10.7	107	120	100	112	10.8	not determined			