2764

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THE ANALYSIS OF METALWORKING DEBRIS, DOMESTIC METALWORK AND PLATE ARMOUR FROM PONTEFRACT CASTLE, WEST YORKSHIRE

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Summary

The castle was demolished during the English Civil War (ECW) in 1649. Excavations were carried out between 1982 and 1986. The 39 kg of ferrous debris showed that the main activity was ironsmithing centred on the kitchen area in the 14/15th century. Examination of four 'jack plates' (armour) showed them to be entirely mineralised. Differing relict microstructures in two of the plates sampled supported the suggestion that jack plates were sometimes constructed from old armour plate. The 1 kg of non-ferrous debris produced evidence for metalworking and melting operations again centred on the kitchen area, this time in the 17th century. The primary alloys were brass and gunmetal. Thirty seven pieces of ECW domestic metalwork were analysed by X-ray fluorescence, several objects were surface coated (tinned or mercury gilded). Food utensils were made of lead (Pb). Some non-ferrous alloys also contained arsenic, nickel, silver and antimony.

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The analysis of metalworking debris, domestic metalwork and plate armour from Pontefract Castle, West Yorkshire.

Paul Maclean and David Starley

Introduction

Pontefract Castle, West Yorkshire is situated on a sandstone promontory at the eastern extremity of the modern town of Pontefract (SE461224).

The most recent excavations were co-ordinated by the West Yorkshire Archaeology Service between 1982-86 as part of a programme of conservation and consolidation of the degraded castle fabric. Prior to this some excavation had been undertaken during the 1880s when the site was used as a framework for a Victorian Park.

Following Scheduled Monuments Consent (9/2/157), the modern programme involved excavation in discrete peripheral areas where structural work was to take place. The areas referred to in this report include the bakehouse, kitchen, Norman chapel, Elizabethan chapel, Constable Tower, and sections of the curtain wall.

The objectives of the project were to integrate documentary and archaeological evidence to provide details of the structural and spatial development of the castle from the early medieval period to 1649 and the slighting of the castle during the English Civil War. The project also encompassed the assessment of evidence for Saxon activity on the castle site and of the impact of the Victorian excavators.

With reference to this report the site phasing is as follows:

Table 1 Pontefract Castle site phasing	
Area	Period of deposits
Bakehouse	Pre-castle (?Saxon)
Norman chapel	Pre-castle (?Saxon)
Constable Tower	Late Saxon & disturbed medieval / 17th century
Kitchen	11-17th century
Pit 290	Late 15th century
Elizabethan chapel	?15/16th century

Several contexts are not securley dated due to recognised distrubance caused by the 19th century excavations.The phase interpration of metalworking activity on the site should be considered in light of this.

Overview of study

A range of methods was used to investigate the material remains and interpret the significance of metalworking activities at Pontefract Castle. Firstly, all bulk slag and other metallurgical debris was examined visually to identify types which could be used to distinguish different processes.

A series of seven soil samples of soil from hearths and other contexts were also examined to see if these could indicate the function of the hearths.

It had also been intended to study a selection of the plate armour, found in Civil War contexts, metallographically. This required small samples to be cut from the armour which were prepared and examined under an optical microscope. After examining two of the better-preserved items the metallographic study was curtailed as the armour was completely corroded.

X-ray fluorescence (XRF) analysis was used to identify alloys found in the non-ferrous debris as well as surface coatings on some of the domestic metalwork.

Ferrous slags and metalworking debris. Visual examination

About 39kg of bulk metalworking debris was recovered from the site. All this material was examined to identify diagnostic material. The results are summarised in Table 2, whilst full details are listed in Appendix I. The data was further broken down according to phase (Table 3) and location (Table 4).

Table 2 Summary of Pontefract Castle slag. Total weight of each type

Debris type	Weight (g)
SMITHING	
smithing hearth bottoms	18753
flake hammerscale	not quantified
UNDIAGNOSTIC	
undiagnostic ironworking slag	15148
vitrified hearth lining	1080
cinder	1051
FUEL ASH WASTES	
coal/shale waste	869
clinker	222
fuel ash slag	15
OTHER MATERIAL	
iron objects	798
ferruginous concretion	538
stone	138
? Melted paint	2
Total	38614

Visual examination of metalworking debris categorised the material on criteria of morphology, density, colour and vesicularity. For certain 'classes' of material, visual examination is able to identify the specific technological processes which created them and these materials are referred to as diagnostic. 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.

Table 3 Summary of Pontefract Castle slag. Weight of significant types by phase.

Debris type	Weight (g)									
	Saxon	11/12th	13th	14th	14/15th	15th	16th	17th	other	Total
SMITHING										
smithing hearth bottoms			415	407	7952	2592	472	1291	5624	18753
flake hammerscale (instances)			(1)		(6)	(1)	(1)	(3)	(3)	(15)
UNDIAGNOSTIC										
undiagnostic ironworking slag		15	28	557	6266	942	438	3997	2905	15148
vitrified hearth lining, cinder	14			42	965	141	7	771	191	2131
FUEL ASH WASTES										
clinker, coal, burnt shale, fuel ash					224	62		275	545	1106
iron objects	60			36	170	17		167	348	798

Table 4 Summary of Pontefract Castle slag. Weight of significant types by location.

Debris type	Weight (g)						
	kitchen	Constable Tower	bakehouse	Norman chapel	pit 290	other	total
SMITHING							
smithing hearth bottoms	15408				2592	753	18753
flake hammerscale (instances)	(14)					(1)	(15)
UNDIAGNOSTIC							
undiagnostic ironworking slag	13852				942	354	15148
vitrified hearth lining + cinder	1808	167		14	141	1	2131
FUEL ASH WASTES							
clinker, coal, burnt shale, fuel	656	432			18		1106
iron objects	403	285	60		6	44	798

Because the bulk slags from Pontefract Castle had been cleaned before bagging, there was little opportunity to identify hammerscale. However, occasional flakes of hammerscale were observed within the packaging, providing supporting evidence for ironsmithing on the site. All hammerscale was of the flake variety, suggesting that work concentrated on simple forging rather than more complex welding of artefacts or the consolidation of blooms from smelting furnaces.

Several of the categories of material could have been produced by a wide range of high temperature activities and are of little help in distinguishing between these processes. Material listed as **vitrified hearth lining** may derive from either iron working from non-ferrous metal working, or possible other high temperature processes (XRF analysis showed a fragment from context 4205 contained contamination from copper working). It forms as a result of a high temperature reaction between the clay lining of the hearth and the alkali fuel ash or fayalitic slag. The material may show a 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 lining or another source of silica, such as the sand used as a flux during smithing.

A broad group of debris, **coal/shale waste,** included materials that had originally been described as slagged shale, burnt shale, burnt coal, shale, burnt and slagged shale. These all result from the combustion of poor quality coal, containing a high inorganic stony component. Further evidence for the burning of coal was provided by the light and porous **clinker**, as well as the presence of coal and shale inclusions in the smithing slag.

A minimal amount of debris was classified as **fuel ash slag**, a very lightweight, light coloured (grey-brown), highly-porous material. This again results from high temperature alkaline fuel ash/silica reactions and may result from many pyrotechnical processes.

A number of lumps of material bagged as slag appeared to be concretions formed around iron and these were termed **iron objects**. It is worth considering whether some of the iron may be scrap or fragments of partly worked iron from on-site metal working. However, without X-radiography and/or investigative cleaning it is not possible to prove this. Survival of at least some iron within the concretions was demonstrated by their strong attraction to a magnet.

The material identified as **ferruginous concretion** forms as a result of the redeposition of iron hydroxides, a process similar to iron panning. On archaeological sites such material may be of relevance in identifying ironworking activities and deserves close examination as the formation of iron pan is likely to be enhanced by the nature of the surrounding archaeological deposits. In particular, examination may reveal the presence of hammerscale within concretions and hence help to identify the location of iron smithing. However none was found to contain hammerscale.

Investigation of industrial samples

During excavation soil samples were retained from three hearths and four other deposits. Sub-samples from these were examined to determine the origin of the material and whether the hearths had been used for metallurgical purposes.

Context 4109 Sample No. 2518 (Hearth, Kitchen 14/15th century)
Contains lead-rich glassy slag.

Context 4118/A Sample No. 2500 (Kitchen 14/15th century)
Contains lead-rich glassy slag and two corroded iron objects.

Context 4294 Sample No.2589 (Hearth, Kitchen 13/14th century)
Mostly charcoal, some baked clay. No evidence of metalworking.

Context 4387/A Sample No. 2546 (Kitchen 13/14th century)
Fire cracked stones, few flakes of hammerscale, ashy soil.

Context 4387/B Sample No.2544 (contents of Rawmarsh cistern, Kitchen 13/14th century)
Lead working debris, metallic lead dribbles, lead oxide-rich waste and charcoal.

Context 4387/C Sample No. 2545 (Kitchen 13/14th century)
Lead scraps, charcoal, ceramic and bone.

Context 4394 Sample No. 2554 (Hearth, phasing details not available)
Mostly charcoal with some bone and shell fragments. No metallurgical purpose.

Examination of the samples suggested that two of the hearths (contexts 4294 and 4394), had no metallurgical purpose. The third hearth (4109) and a further context (4118/A) contained some lead-rich slag (see below).

The lead waste in a ceramic vessel (sample 2544) may imply that this material was being collected for recycling, although it should be emphasised that the dribbles may result from the accidental melting of lead, rather than being a waste product of lead working. The presence of a few flakes of hammerscale in sample 2546, may indicate iron smithing nearby, although much larger quantities would be expected if smithing was being carried out in the immediate area.

Distribution of ferrous metalworking debris by phase and location

Breaking down the bulk slag assemblage by phase and location (Tables 3 and 4) reveals that evidence for ironsmithing spanned the 13th to 17th centuries. With the exception of some 15th century material dumped in Pit 290 this was almost entirely restricted to the kitchen. More detailed examination of the data in Appendix I shows important individual deposits including finds of unusually, but consistently, small smithing hearth bottoms from hearths 4042 and 4442. Some caution should be exercised in automatically interpreting these as smithing hearths; illustrations of medieval smiths generally show hearth and anvil at waist height. The ground level hearths may have served other purposes before becoming a convenient place to dump metalworking debris. The relatively modest quantities of slag present do not indicate long term activity. The extent to which some of this material has been disturbed, must therefore be carefully considered. If this were the case then it could be suggested that the focus of the smithing activity appears to have been 14th/15th century, with small quantities intruding into early deposits and larger quantities being redeposited in later contexts. Limited later evidence for a 17th century smithing phase may be upheld if the integrity of its contexts can be confirmed.

Although debris was found in the Constable Tower, bakehouse and Norman chapel, none was diagnostic of metalworking and there is therefore no reason to believe that these structures were used for such activities. Quantities of slag prior to the 13th century are insignificant, whilst that for the 13th century is minimal and, as mentioned above, may have resulted from disturbance of contexts. Therefore, for those parts of the castle excavated it can be said that there is no evidence for ironworking on a significant scale prior to the 14th century.

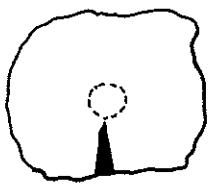
Examination of armour

Recovery of any armour by archaeological excavation is a rare occurrence. Despite the poor condition of the Pontefract armour, it had been hoped that sufficient iron survived that metallography (*ie* examination of prepared samples by optical microscopy), would provide an insight into the materials and method of construction. Initial investigation concentrated on 'jack plates', the small, pierced pieces of sheet metal (Figure 1) which were sewn into the lining of the defensive upper garment known as a jack. This form of armour has received very limited study (Starley 1998, 2-4).

Four jack plates were examined visually, by X-radiography and using a magnet before two were sampled. The location of samples is indicated in Figure 1.

SF No. 3849

SF No. 4641



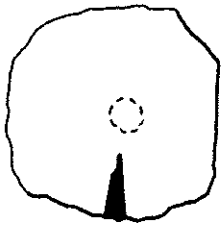


Figure 1 Jack plates from Pontefract Castle showing sample locations

A small wedge was cut from each plate using a low speed cut-off wheel with 0.2mm thick rubber-bonded silica blade. The sections were mounted in thermosetting phenolic resin and prepared using standard metallographic techniques; grinding on successively finer abrasive papers then polishing with 1μm grade diamond impregnated cloths. The specimen was examined on a metallurgical microscope in the 'as polished', *ie* unetched, condition .

Unfortunately, even in the sections which were taken from the plates which appeared most sound and gave a reasonably strong magnetic response, no metallic iron was visible.

Small Find 3849
AML Sample Number: 990001, Context 090, Date of deposition: Civil War
Condition: mineralised.
Metallography, Unetched: The corrosion appeared relatively homogenous, with some changes in phase but little distortion. Slag inclusions were visible (2%) as were very occasional, tiny specks of uncorroded iron. No relict carbide structures were seen.
Interpretation: Probably, a low carbon iron, relatively free of slag.

Small Find 4641
AML Sample Number: 990002, Context 098, Date of deposition: Civil War
Condition: mineralised.
Metallography, Unetched: Corroded structure banded/laminated. Very occasional specks of uncorroded iron and 5% slag inclusions. Some bands appear to show ghosting, perhaps due to the presence of phosphorus.
Interpretation:Unclear but quite possibly a piled structure including ferritic and phosphoric iron.

Despite a strong magnetic response and externally sound appearance, the two jack plates were found to be effectively entirely mineralised. The relict structures within the corrosion hinted at two dissimilar original structures; one a clean and largely carbon-free ferritic iron, the other possibly a piled mixture of phosphoric and ferritic iron. The apparent variation in composition between plates may support suggestions that jack plates were sometimes constructed from old armour plate.

Non-ferrous debris and metalwork. Visual and chemical examination

The quantity of debris identified with non-ferrous metalworking totalled just over 1kg. As with the ferrous debris, all material was visually examined and in certain cases chemically analysed using XRF analysis. Full details of the results of examination are given in Appendix II and are summarised in Table 6. This summary is broken down by phase and location in Tables 7 and 8.

Table 6 Summary of Pontefract Castle non-ferrous debris. Total weight of each type.

Debris type	Weight (g)
Copper alloy dribbles	179
Copper alloy lumps	132
Corroded copper alloy fragments	392
Lead-rich glassy slag	236
Charcoal/ Shale	3
Other material	
Copper alloy sheet	133
Copper alloy objects	2
Total	1077

The debris was classified into seven groups comprised of copper alloy dribbles, corroded fragments, sheet metal, lumps and objects, as well as lead-rich glassy 'slag' and charcoal/shale.

Table 7 Summary of non-ferrous debris. Weight of significant types by phase.

Debris type	Weight (g)												
	Saxon	'Early Med.'	11/ 12th	13th	14/ 15th	15th	15/ 16th	Med.	15/ 17th	16/ 17th	17th	other	Total
Dribbles	148	2									29		179
Corroded frags.	31	1	16	6	1	107					221	9	392
Pb-rich slag								204		32			236
Charcoal/ Shale											3		3
Lumps	5					121	6						132
Sheet		1			2	2		26	1	5	92	4	133
Objects											2		2
Total	184	4	16	6	3	230	6	230	1	37	347	13	1077

Table 8 Summary of non-ferrous debris. Weight of significant types by location.

Debris type	Weight (g)					
	kitchen	Constable Tower	bakehouse	Elizabethan chapel	pit 290	Total
Dribbles	31		148			179
Corroded fragments	249	5	31		107	392
Pb-rich slag	236					236
Charcoal / Shale	3					3
Lumps		5		6	121	132
Sheet	128		3		2	133
Objects	2					2
Total	649	10	182	6	230	1077

The greatest proportion of material by weight is the corroded metal fragments (36%) comprised of residual copper alloys surrounded by often extensive corrosion products. The frequent inclusion of mineralised plant remains (straw?) suggested a rapid build up of corrosion from an agressive burial environment.

The metal components confirmed by XRF analysis showed the accretions to commonly contain copper, lead and iron, and in some cases have additional zinc or tin. The presence of iron most likely derived from the surrounding soil environment rather than being an alloy component. The metal compositions suggested brass and gunmetal. Lead quantities were insufficient to consider the alloys as 'leaded'.

The next largest group of material were metal dribbles, which included prills, droplets or spillages of metal that have either soldified away from a mould or formed from accidental melting of objects. Not unexpectedly, the dribbles had similar alloy types as the metal fragments, *ie* brass and gunmetal.

Among the debris were more than 180 pieces of thin (<1mm thick) metal sheet. XRF analysis of the sheet pieces from several contexts [4034, 4072, 4267b] showed it to be made of brass (Cu, Zn) or gunmetal (Cu, Zn, Sn) with minor amounts of lead. A few fragments selected for XRF [contexts 335, 4205] also contained traces of nickel and arsenic. The metal sheets appeared to be off-cuts, some showing evidence of cut marks along their edges.

Three amorphous metal lumps were identified, the largest of which weighed 120g . All were leaded bronze (Cu, Pb, Sn).

An unusual hard, brittle and glassy green slag was found in contexts within the kitchen (contexts 4118, 4237, 4238, 4399). Qualitative XRF analysis showed the presence of significant amounts of lead in this material, hence its description as lead-rich glassy slag. X-radiography also showed lead droplets in the glassy matrix. The origin of this material is not clear. A medieval castle would have made use of large quantities of lead, particularly in roofing and the lead cames used to join window glass, as well as the wide range of everyday objects and, later, the need for musket balls. However, although lead working crafts generally involve melting the metal, this is carried out at a relatively low temperature and, apart from some powdery dross, no significant slag is produced. Primary smelting of lead ore does produce slag, but it normally has a dark colour and is not vessicular. Not only is there is a lack of further evidence for this in the castle, but it would seem very unlikely that such an activity would be carried out there, rather than near the ore source. The most probable explanation for this material is that it results from either deliberate or accidental severe heating of lead in the presence of siliceous material, perhaps the result of window panels with lead cames being caught in a conflagration.

Two small copper alloy objects were identified from the assemblage, part of a needle and what appeared to be a broken pen nib. The needle fragment (25mm l., 2mm th.) was made of a gunmetal and the pen nib of brass.

Context 4205 produced pieces of vitirified hearth lining. XRF analysis showed the presence of copper and possibly zinc and lead (Appendix I), which indicate some copper alloy melting operations.

Taken together, the debris suggests that zinc-rich copper alloys (brass and gunmetal) were melted and worked on site, but as with iron, there is no evidence for any smelting activity.

Discussion of non-ferrous metalworking activity by phase and location

Evidence for non-ferrous metalworking appears scattered from the late Saxon period to the 17th century, with the majority (71%) of the metalworking debris allocated to three phases: Saxon, 15th and 17th centuries. Material from the Saxon phase comprised only four pieces from the bakehouse and Constable Tower. However these areas were disturbed by countermine shafts during the English Civil War and XRF analyses (Appendix II) show a remarkable degree of similarity to material from later phases, suggesting the 'Saxon' finds may be intrusive. Debris from a late 15th century context derived from Pit 290 cannot be related to any particular metalworking location. The greatest quantity of non-ferrous debris, both by weight and number came from the kitchen area, this context alone accounted for 60% of the non-ferrous assemblage, and except for metal lumps included all identified types.

The lead-rich glassy slag also derives entirely from the kitchen area. Both the soil samples and the bulk finds of this material point to a broad but early date range from 13th to 14/15th centuries for the activity that produced it. Later finds of this distinctive material probably indicate disturbance of the deposits.

The kitchen area had the greatest concentration of corroded copper alloy and metal sheet. Material recovered from the kitchen spanned a wide date range (11th to 17th centuries) with the majority tentatively dated to the 17th century. In light of the severe disturbance caused by 19th century excavations it is difficult to allocate datable metalworking phases with any certainty.

A possible metalworking structure / 'furnace' has been identified in the southern end of the kitchen (I. Roberts, pers. comm., 21.12.98). Corroded copper alloy and metal sheet have been recovered from associated contexts 4042 and 4205. XRF analysis of vitrified hearth lining from context 4205 showed the presence of copper and possibly zinc and lead (Appendix I). The concentrations and types of material identified from contexts within the kitchen is consistent with the suggestion that this area may have been used for non-ferrous metalworking, probably during the 17th century.

Domestic Metalwork from Pontefract Castle

Thirty seven small metalwork items predominantly from Civil War demolition contexts, were analysed using XRF. The results are presented in Appendix III. The objects analysed included buckles, knives, spoons, plates, door fittings and casket furniture.

Just over half the objects (19) were manufactured from iron (buckles, knives, padlocks, hinges) and half of this group (9) had been subject to tin or tin-lead plating, the majority of the latter found on either buckles or hooks and hinges. One knife (sf. 1226) was found to have a silver disc set into the handle.

The rest of the metalwork comprised 11 lead objects (spoons, plates, bowls), and eight copper-based objects (fittings and domestic ware). The copper-based material included three examples of mercury (fire) gilding on a pendant, strapfitting and casket mount. The use of fire gilding was interpreted from the presence of mercury (Hg) in the XRF spectra. The remaining items were manufactured from leaded bronze or brass alloys which also included additional minor elements such as antimony, arsenic and nickel. Similar compositions have been associated by Blades (1995, 31) with alloys used for making skillets and cauldrons from the medieval period onwards, and other examples are known from medieval foundry site at Bedern (Bayley & Richards 1993, 189).

The element chromium was detected on four of the iron objects (three buckles and a casket binding strip). The deliberate use of chromium is only found in modern alloys so its apparent presence is unexpected. It may have been picked up from surrounding soil and bound to the corroded surface of the objects.

Summary of examination

Visual examination of the ferrous debris, showed that the main activity was iron smithing and this was centred on the kitchen area in the 14th/15th century. Although further ironworking slag was found in 17th century contexts in the same area, this may be disturbed material from the earlier phase of metalworking. In addition, slag from ironworking was deposited in Pit 290 in the 14th/15th century. Ironworking probably concentrated on simple forging rather than welding. There is no evidence for the smelting of iron.

Investigation of the armour (jack plates), while completely mineralised, did support the suggestion that they were sometimes constructed from old armour plate.

Non-ferrous metalworking was attested by copper alloy lumps, dribbles and off-cuts, as well as occasional copper corrosion products on hearth lining. The presence of glassy slag containing lead is more likely to be the product of the destruction of leaded windows, rather than lead working. Although the latter may have occurred on site, no massive slags are likely have been produced to identify the process. There is no evidence for non-ferrous metal smelting. The majority of copper-zinc alloys used prior to the end of the 17th century would probably have been imported. Southern Flanders is a well known source at this time (Crossley 1990, 199).

Most of the non-ferrous debris appeared to derive from 17th century contexts in the kitchen area, however the distribution of material such as metal sheet from pit 290 suggests that either very similar metal sources were used from the 15th to 17th centuries or, as with some of the ferrous debris, the finds from the later contexts may be residual.

The metalwork, non-ferrous slags and vitrified hearth lining, along with a structure identified as a furnace suggest that the kitchen was an area of metalworking activity.

The copper alloys were identified as either brass or gunmetal. The sheet fragments were predominantly gunmetal and may have been used as a metal source for melting operations.

Charcoal was the usual fuel source however coal, often of very poor quality, was also used, both for metallurgical and non-metallurgical purposes

The majority of domestic metalwork analysed derived from Civil War contexts. Food utensils were made of lead (plates and spoons) and several iron objects were tinned or had a lead-tin coating. Precious metals were also identified, with mercury (fire) gilded copper alloy pieces and a bone handle with a silver inlaid disc. Some of the copper alloys were polymetallic containing, besides tin, arsenic, nickel, silver and antimony.

The examination of metallurgical debris and objects from Pontefract Castle suggested that the kitchen area was a centre of metalworking activity both for iron smithing in the 14th/15th centuries and for non-ferrous (copper-based) metalworking during the 17th century. Several of the metal objects were subject to surface treatments. There is no evidence that these objects were manufactured on the site.

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Appendix I Result of examination of ferrous debris from Pontefract Castle

context	SFNo	area	date	type	Weight(g)	comments & SHB dimensions
103	928	Constable Tower	disturbed medieval/C17th	vitrified hearth lining	167	
103	928	Constable Tower	disturbed medieval/C17th	ferruginous concretion	184	With burnt shale and coal
103	928	Constable Tower	disturbed medieval/C17th	burnt shale	432	
116	1238	Constable Tower	disturbed medieval/C17th	?melted paint	2	
133	1266	Constable Tower	disturbed medieval/C17th	iron object	285	Organic material, green vitrified, XRF analysis showed Pb and Ti, flammable
290	2894	Pit 290	late C15th	smithing hearth bottom(s)	62	55x45x25mm
290/A	3183	Pit 290	late C15th	burnt shale	10	
290/A	3184	Pit 290	late C15th	undiagnostic ironworking slag	63	
290/D	2888	Pit 290	late C15th	undiagnostic ironworking slag	232	
290/D	2910	Pit 290	late C15th	undiagnostic ironworking slag	119	
290/D	3313	Pit 290	late C15th	undiagnostic ironworking slag	7	
290/D	3385	Pit 290	late C15th	smithing hearth bottom(s)	145	70x55x50mm
290/D	3389	Pit 290	late C15th	undiagnostic ironworking slag	46	
290/D	3415	Pit 290	late C15th	cinder	1	
290/D	3472	Pit 290	late C15th	vitrified hearth lining	2	
308	2930	Pit 290	late C15th	iron object	6	
309	2828	Pit 290	late C15th	undiagnostic ironworking slag	23	
333	4435	Pit 290	late C15th	undiagnostic ironworking slag	15	
334	3331	Pit 290	late C15th	undiagnostic ironworking slag	43	
334	3332	Pit 290	late C15th	ferruginous concretion	7	
334	3374	Pit 290	late C15th	undiagnostic ironworking slag	80	
334	3568	Pit 290	late C15th	vitrified hearth lining	8	
336	3322	Pit 290	late C15th	vitrified hearth lining	4	
338	3515	Pit 290	late C15th	undiagnostic ironworking slag	21	
338	3516	Pit 290	late C15th	vitrified hearth lining	78	Black glaze XRF no non-ferrous metal
340	3403	Pit 290	late C15th	undiagnostic ironworking slag	23	
340	3407	Pit 290	late C15th	smithing hearth bottom(s)	29	50x40x20mm
340	3432	Pit 290	late C15th	undiagnostic ironworking slag	21	
341	3440	Pit 290	late C15th	undiagnostic ironworking slag	38	

Appendix I Result of examination of ferrous debris from Pontefract Castle

context	SFNo	area	date	type	Weight(g)	comments & SHB dimensions
341	3478	Pit 290	late C15th	undiagnostic ironworking slag	7	
341	3576	Pit 290	late C15th	cinder	1	
341	3640	Pit 290	late C15th	undiagnostic ironworking slag	2	
342	3441	Pit 290	late C15th	smithing hearth bottom(s)	226	90x80x55mm
342	3441	Pit 290	late C15th	undiagnostic ironworking slag	25	
342	3442	Pit 290	late C15th	vitrified hearth lining	8	
343	3427	Pit 290	late C15th	undiagnostic ironworking slag	1	
343	3584	Pit 290	late C15th	undiagnostic ironworking slag	6	
343	3585	Pit 290	late C15th	vitrified hearth lining	12	
343	3588	Pit 290	late C15th	burnt shale	5	
344	3536	Pit 290	late C15th	undiagnostic ironworking slag	140	
344	3537	Pit 290	late C15th	undiagnostic ironworking slag	8	
344	3571	Pit 290	late C15th	smithing hearth bottom(s)	483	100x90x60mm
344	3579	Pit 290	late C15th	undiagnostic ironworking slag	6	
345/A	3632	Pit 290	late C15th	undiagnostic ironworking slag	10	
348	3611	Pit 290	late C15th	undiagnostic ironworking slag	3	
346	3591	Pit 290	late C15th	burnt shale	2	
346	3603	Pit 290	late C15th	burnt shale	1	
347	3461	Pit 290	late C15th	vitrified hearth lining	27	
348	3615	Pit 290	late C15th	smithing hearth bottom(s)	541	120x100x50mmm
348	3615	Pit 290	late C15th	undiagnostic ironworking slag	9	
349	3624	Pit 290	late C15th	smithing hearth bottom(s)	1150	690g 110x90x50mm, 460g 120x80x60mm
365	3676	Pit 290	late C15th	smithing hearth bottom(s)	439	110x100x40mm
614	1971	Norman Chapel	Phase 1: Pre-castle (?Saxon)	vitrified hearth lining	14	
3115	784	Bakehouse	Phase 1: Pre-castle (?Saxon)	iron object	60	
4016	2040	Kitchen Hearths 4042, 4442	?C14th	smithing hearth bottom(s)	83	65x45x20mm
4016	2040	Kitchen Hearths 4042, 4442	?C14th	undiagnostic ironworking slag	219	
4016	2048	Kitchen Hearths 4042, 4442	?C14th	undiagnostic ironworking slag	338	
4016	2048	Kitchen Hearths 4042, 4442	?C14th	ferruginous concretion	67	

Appendix I Result of examination of ferrous debris from Pontefract Castle

context	SFNo	area	date	type	Weight(g)	comments & SHB dimensions
4016	2048	Kitchen Hearths 4042, 4442	?C14th	vitrified hearth lining	42	
4016	2048	Kitchen Hearths 4042, 4442	?C14th	iron object	36	
4016	2048	Kitchen Hearths 4042, 4442	?C14th	smithing hearth bottom(s)	324	90g70x60x40mm, 115g 75x60x40mm 60g 60x40x30mm, 59g 65x55x30mm
4016	2053	Kitchen	?C14th	iron object	33	
4016	2053	Kitchen	?C14th	undiagnostic ironworking slag	55	
4017	1467	Kitchen	C14/15th	undiagnostic ironworking slag	1020	
4017	1467	Kitchen	C14/15th	flake hammerscale		
4017	1467	Kitchen	C14/15th	smithing hearth bottom(s)	3828	190g 105x60x25mm, 322g 75x70x30mm, 52g 50x30x25mm, 75g 75x35x20mm, 180g 80x60x30mm, 127g 80x50x25mm, 213g 85x65x30mm, 157g 75x60x30mm, 155g 75x50x30mm, 398g 90x65x65mm, 500g 130x90x55mm, 96g 70x60x30mm, 360g 120x80x50mm, 644g 130x80x40mm, 280g 90x75x35mm, 52g 60x45x15mm, 27g 50x40x10mm.
4017	1848	Kitchen	C14/15th	undiagnostic ironworking slag	1995	
4017	1848	Kitchen	C14/15th	vitrified hearth lining	83	
4017	1848	Kitchen	C14/15th	smithing hearth bottom(s)	600	144g 80x70x25mm, 120g 70x70x20mm, 180g 70x60x20mm, 156g 80x60x40mm.
4017	1848	Kitchen	C14/15th	flake hammerscale		
4017	1879	Kitchen	C14/15th	undiagnostic ironworking slag	1049	
4017	1879	Kitchen	C14/15th	shale	12	
4017	1879	Kitchen	C14/15th	smithing hearth bottom(s)	227	141g 75x60x40mm,86g 50x55x30mm
4017	1955	Kitchen	C14/15th	smithing hearth bottom(s)	936	289g 120x90x30mm, 647g 110x80x50mm
4017	1955	Kitchen	C14/15th	flake hammerscale		
4017	1961	Kitchen	C14/15th	undiagnostic ironworking slag	65	
4017	1961	Kitchen	C14/15th	vitrified hearth lining	210	
4017	1961	Kitchen	C14/15th	smithing hearth bottom(s)	40	50x35x30mm Including shaly coal fragmen
4017	1961	Kitchen	C14/15th	iron object	22	
4017	1961	Kitchen	C14/15th	undiagnostic ironworking slag	29	Including shaly coal fragment
4017	1961	Kitchen	C14/15th	flake hammerscale		
4017	1984	Kitchen	C14/15th	iron object	18	
4017	1984	Kitchen	C14/15th	smithing hearth bottom(s)	130	74g 70x40x25mm, 56g 55x40x25mm
4017	1984	Kitchen	C14/15th	cinder	205	
4017	1984	Kitchen	C14/15th	undiagnostic ironworking slag	150	
4017	1984	Kitchen	C14/15th	iron rich stone	5	

Appendix I Result of examination of ferrous debris from Pontefract Castle

context	SFNo	area	date	type	Weight(g)	comments & SHB dimensions
4017	1984	Kitchen	C14/15th	vitrified hearth lining	125	
4017	1996	Kitchen	C14/15th	undiagnostic ironworking slag	676	
4017	1996	Kitchen	C14/15th	smithing hearth bottom(s)	319	235g 80x70x40mm, 52g 55x45x30mm, 32g 50x40x15mm
4017	1996	Kitchen	C14/15th	iron object	62	
4017	1996	Kitchen	C14/15th	vitrified hearth lining	56	
4017	1996	Kitchen	C14/15th	cinder	39	
4017	1996	Kitchen	C14/15th	slagged shale	62	From coal burning
4017	1996	Kitchen	C14/15th	flake hammerscale		
4028	1952	Kitchen	C15th or later	vitrified hearth lining	15	
4028	1952	Kitchen	C15th or later	iron object	13	
4028	1952	Kitchen	C15th or later	cinder	8	
4076	1509	Kitchen	C17th or later	flake hammerscale		
4076	1509	Kitchen	C17th or later	undiagnostic ironworking slag	1800	
4076	1509	Kitchen	C17th or later	smithing hearth bottom(s)	4745	2451g 130x150x90mm, 657g 155x90x70mm, 309g 120x80x40mm, 333g 130x70x35mm, 373g 110x70x45mm, 196g 85x80x40mm, 184g 95x75x40mm, 242g 80x70x40mm
4088	2265	Kitchen	C?C16th or later	undiagnostic ironworking slag	70	
4088	2265	Kitchen	?C16th or later	smithing hearth bottom(s)	126	80x65x35mm
4088	2265	Kitchen	?C16th or later	burnt and slagged shale	47	
4088	2344	Kitchen	?C16th or later	stone	65	
4088	2344	Kitchen	?C16th or later	undiagnostic ironworking slag	48	
4088	3171	Kitchen	?C16th or later	cinder	1	
4089	2209	Kitchen	poss. medieval	undiagnostic ironworking slag	15	
4089	2214	Kitchen	poss. medieval	iron object	6	
4089	2214	Kitchen	poss. medieval	undiagnostic ironworking slag	66	
4096	2236	Kitchen	C14/15th	cinder	13	
4096	2236	Kitchen	C14/15th	iron object	4	
4106	2215	Kitchen	C17th	cinder	15	
4106	2216	Kitchen	C17th	undiagnostic ironworking slag	2	
4106	2238	Kitchen	C17th	undiagnostic ironworking slag	147	Burnt shale inclusions
4106	2247	Kitchen	C17th	burnt and slagged shaly coal	130	
4106	2247	Kitchen	C17th	undiagnostic ironworking slag	145	
4106	2247	Kitchen	C17th	clinker	36	
4106	2247	Kitchen	C17th	iron object	14	
4106	2247	Kitchen	C17th	flake hammerscale		
4111	2253	Kitchen	C14/15th	vitrified hearth lining	5	

Appendix I Result of examination of ferrous debris from Pontefract Castle

context	SFNo	area	date	type	Weight(g)	comments & SHB dimensions
4111	2253	Kitchen	C14/15th	undiagnostic ironworking slag	214	
4111	2253	Kitchen	C14/15th	smithing hearth bottom(s)	1215	39g 50x40x20mm, 194g 80x75x30mm, 982g 140x100x70mm
4118	2529	Kitchen	poss. C17th	undiagnostic ironworking slag	30	
4118	2529	Kitchen	poss. C17th	smithing hearth bottom(s)	157	70x60x40mm
4118	2534	Kitchen	poss. C17th	cinder	18	
4118	2557	Kitchen	poss. C17th	cinder	14	With shale
4196	2062	Kitchen	C14/15th	smithing hearth bottom(s)	129	70x60x30mm
4196	2062	Kitchen	C14/15th	iron object	20	
4196	2246	Kitchen	C14/15th	clinker	130	Coal-fuelled waste
4196	2246	Kitchen	C14/15th	vitrified hearth lining	9	
4196	2246	Kitchen	C14/15th	part burned coal	4	
4205	4277	Kitchen	possible ?C14/15th	vitrified hearth lining	139	Green corrosion on surface. XRF showed presence of Cu, poss Pb, no Sn, poss Zn
4205	4277	Kitchen	possible ?C14/15th	cinder	22	With shale remnants
4235	2300	Kitchen	C16th	undiagnostic ironworking slag	438	Some ?roasted to produce a haematite surface
4235	2300	Kitchen	C16th	flake hammerscale		
4235	2300	Kitchen	C16th	cinder	7	With shaly coal
4235	2300	Kitchen	C16th	smithing hearth bottom(s)	472	189g 80x60x40mm, 131g 70x60x40mm, 152g 75x60x35mm
4238	2617	Kitchen	medieval	undiagnostic ironworking slag	293	
4238	2617	Kitchen	medieval	flake hammerscale		
4238	2617	Kitchen	medieval	iron object	11	
4238	2617	Kitchen	medieval	smithing hearth bottom(s)	270	95x70x50mm
4238B	2569	Kitchen	medieval	stone	68	With slagged end
4238B	2571	Kitchen	medieval	flake hammerscale		
4238B	2571	Kitchen	medieval	undiagnostic ironworking slag	206	
4238B	2571	Kitchen	medieval	burnt shale	10	
4267/D	2279	Kitchen	C17th	flake hammerscale		
4267/D	2279	Kitchen	C17th	undiagnostic ironworking slag	2114	
4267/D	2279	Kitchen	C17th	cinder	373	
4267/D	2279	Kitchen	C17th	vitrified hearth lining	17	
4267/D	2279	Kitchen	C17th	burnt and slagged shale	41	
4267/D	2279	Kitchen	C17th	smithing hearth bottom(s)	831	213g 90x70x40mm, 265g 95x80x60mm, 226g 95x70x45mm, 74g 70x50x40mm, 53g 40x35x30mm
4267/E	2292	Kitchen	C17th	flake hammerscale		
4267/E	2292	Kitchen	C17th	undiagnostic ironworking slag	1314	

Appendix I Result of examination of ferrous debris from Pontefract Castle

context	SFNo	area	date	type	Weight(g)	comments & SHB dimensions
4267/E	2292	Kitchen	C17th	slagged shale	57	
4267/E	2292	Kitchen	C17th	smithing hearth bottom(s)	303	239g 110x60x35mm, 64g 70x50x30mm
4267/E	2292	Kitchen	C17th	ferruginous concretion	34	
4267/E	2292	Kitchen	C17th	cinder	334	
4284	2332	Kitchen	poss. medieval	clinker	56	
4290	2312	Kitchen	C15th	flake hammerscale		
4290	2312	Kitchen	C15th	burnt and slagged shale	44	
4290	2312	Kitchen	C15th	iron object	11	
4290	2312	Kitchen	C15th	ferruginous concretion	152	
4296	2425	Kitchen	C17th	ferruginous concretion	56	
4296/11	2429	Kitchen	C17th	undiagnostic ironworking slag	138	
4296/4B	2411	Kitchen	C17th	undiagnostic ironworking slag	13	
4296/6	2466	Kitchen	C17th	iron object	34	
4296/9	2445	Kitchen	C17th	undiagnostic ironworking slag	94	
4296/9	2445	Kitchen	C17th	iron object	16	
4296/9	2478	Kitchen	C17th	undiagnostic ironworking slag	346	
4309	2609	Kitchen	C14/15th	iron object	44	
4309	2609	Kitchen	C14/15th	vitrified hearth lining	59	
4309	2609	Kitchen	C14/15th	undiagnostic ironworking slag	1068	
4309	2609	Kitchen	C14/15th	flake hammerscale		
4309	2609	Kitchen	C14/15th	smithing hearth bottom(s)	528	185g 70x60x40mm, 120g 65x55x25mm, 129g 95x45x30mm, 66g 50x40x25mm, 26g 40x30x25mm
4373	2519	Kitchen	?medieval, ?C13th	smithing hearth bottom(s)	415	90x90x50mm. With coal inclusions
4373	2519	Kitchen	?medieval, ?C13th	undiagnostic ironworking slag	28	
4373	2519	Kitchen	?medieval, ?C13th	flake hammerscale		
4399	2627	Kitchen	?medieval, ?C13th	glassy Pb slag	185	
4423	2774	Kitchen	C17th	iron object	103	
4439	3011	Kitchen	C14/15th	ferruginous concretion	6	With stone
4439	3022	Kitchen	C14/15th	ferruginous concretion	27	With stone
4439	3040	Kitchen	C14/15th	ferruginous concretion	5	With bone
4439	3041	Kitchen	C14/15th	slagged shale	12	
4439	3052	Kitchen	C14/15th	fuel ash slag	4	Possibly from coal burning

Appendix I Result of examination of ferrous debris from Pontefract Castle

context	SFNo	area	date	type	Weight(g)	comments & SHB dimensions
4450	2694	Kitchen	C11/12th	undiagnostic ironworking slag	15	

Appendix II Result of examination of non-ferrous debris from Pontefract Castle

context	SF No	area	date	type	weight [g] (pieces)	XRF	comments
52	1153	Elizabethan Chapel	?C15-16th	metal lump	6 (1)	Cu, Pb, Fe, Sn, As	
99	3864	Kitchen	C17th	corroded copper alloy	1 (1)	Cu, Zn, Fe, Pb, Sn	Object?
99	4035	Kitchen	C17th	slag	2 (2)	Cu, Zn, Pb, Fe	Buckle?
141	1345	Constable Tower	Late Saxon	metal lump	5 (1)	Cu, Zn, Fe, Pb	Metal lump
204	1353	Constable Tower	n.d.	sheet	3 (3)	Cu, Sn, Pb, Fe	
290/A	3182	Pit 290	Late C15th	corroded copper alloy	1 (1)	Cu, Fe, Pb	
290/A	3181	Pit 290	Late C15th	corroded copper alloy	106 (1)	Cu, Pb, Fe, Sn	Charcoal flecks.
290/D	3300	Pit 290	Late C15th	metal lump	120 (1)	Cu, Pb, Fe, Sn	65x60x25mm
335	3506	Pit 290	Late C15th	sheet	1 (1)	Cu, Zn, Pb, Fe, Sn, Ni	
340	3559	Pit 290	Late C15th	sheet	1 (4)		
344	3378	Pit 290	Late C15th	metal lump	1 (1)	Cu, Sn, Pb, Fe	
3115	665	Bakehouse	?(Saxon)	'dribble'	148 (1)	Cu, Pb, Sn, Zn, Fe	
3115	3998	Bakehouse	?(Saxon)	corroded copper alloy	31 (2)	Cu, Pb, Fe, Sn	
4034	1439	Kitchen	?C15-17th	sheet	1 (1)	Cu, Zn, Pb, Fe, Sn	
4040	2045	Kitchen	C17th	sheet	1 (4)		
4040	2054	Kitchen	C17th	corroded copper alloy	1 (1)		
4040	2054	Kitchen	C17th	sheet	1 (1)		
4042	2059	Kitchen	?C13th	corroded copper alloy	1 (2)		
4052	2043	Kitchen	?C13th	corroded copper alloy	5 (1)		
4072	1480	Kitchen	?C16-17th, u/s	sheet	5 (1)	Cu, Zn, Pb, Fe	Striated surface
4096	2457	Kitchen	?C14-15th	sheet	2 (1)		
4106	2248	Kitchen	C17th	sheet	6 (6)	Cu, Zn,Pb, Fe	

Appendix II Result of examination of non-ferrous debris from Pontefract Castle

context	SF No	area	date	type	weight [g] (pieces)	XRF	comments
4106	2248	Kitchen	C17th	corroded copper alloy	3 (1)		
4114	2262	Kitchen	'Modern'	sheet	1 (1)	Cu,Zn, Fe, Pb	
4118	2990	Kitchen	?C17th	Pb-rich slag	17		
4194	2064	Kitchen	C11-12th	corroded copper alloy	16 (1)	Cu, Fe, Pb	Coal/charcoal inclusions, plant impressions
4205	2077	Kitchen	?Medieval	sheet	26 (c.80)	Cu, Fe, Pb, As?	Striated surfaces from working?
4237	2358	Kitchen	C16th	Pb-rich slag	15		
4238	2388	Kitchen	Medieval	glassy Pb slag	19		
4267	2225	Kitchen	?C17th	corroded copper alloy	14 (8)	Cu, Pb, Zn, Fe	
4267	2349	Kitchen	?C17th	corroded copper alloy	1 (1)		
4267	3994	Kitchen	?C17th / Victorian	sheet	3 (2)		Plant remains in encrusted surface
4267a	2303	Kitchen	?C17th	sheet	13 (14)	Cu, Zn, Fe, Pb	Plant remains in encrusted surfaces.
4267a	2303	Kitchen	?C17th	corroded copper alloy	24 (29)	Cu, Zn, Pb, Fe	
4267a	2303	Kitchen	?C17th	needle fragment	1 (1)	Cu, Zn, Fe, Pb, Sn	25x2mm
4267a	2303	Kitchen	?C17th	'dribble'	10 (1)	Cu,Fe, Zn, Pb, Sn	
4267a	2303	Kitchen	?C17th	charcoal	2 (4)		
4267a	2269	Kitchen	?C17th	sheet	1 (3)	Cu, Zn, Fe, Pb	
4267b	2302	Kitchen	?C17th	corroded copper alloy	59 (c.30)		Plant remains in encrusted surface.
4267b	2302	kitchen	?C17th	sheet	1 (21)	Cu, Zn, Pb, Fe, Sn	
4267b	2302	Kitchen	?C17th	slag	2 (1)		
4267b	2302	Kitchen	?C17th	metal prills	2 (2)	Cu, Zn, Fe, Pb	4x4x3mm
4267b	3856	Kitchen	?C17th	pen nib	1 (2)	Cu, Zn, Fe, Pb	
4267b	3857	Kitchen	?C17th	sheet	1 (1)		Plant remains in encrusted surface.
4267b	3858	Kitchen	?C17th	sheet	4 (16)	Cu, Zn, Pb, Fe, Sn	
4267/B	4017	Kitchen	?C17th	sheet	6 (2)		Plant remains in heavily encrusted surface.

Appendix II Result of examination of non-ferrous debris from Pontefract Castle

context	SF No	area	date	type	weight [g] (pieces)	XRF	comments
4267/B	4018	Kitchen	?C17th	sheet	19 (1)	Cu, Zn, Pb, Fe, Sn	(Thick, 3mm) Plant remains in corrosion. 3x1mm slot in middle of sheet.
4267c	2268	Kitchen	?C17th	sheet	29 (9)		
4267c	2268	Kitchen	?C17th	corroded copper alloy	5 (1)		
4267c	2268	Kitchen	?C17th	Copper alloy 'dribble'	17 (1)		
4267c	2268	Kitchen	?C17th	corroded copper alloy	6 (4)		
4267c	2282	Kitchen	?C17th	corroded copper alloy	50 (4)		Charcoal inclusions
4267c	2282	Kitchen	?C17th	cinder/ FAS	3 (2)		
4267c	2282	Kitchen	?C17th	corroded copper alloy	16 (2)		
4267c	2307	Kitchen	?C17th	corroded sheet	6 (1)		Plant remains in encrusted surface.
4267c	3993	Kitchen	?C17th	sheet	1 (4)		
4267	2280	Kitchen	?C17th	corroded copper alloy	2 (2)	Cu, Zn, Pb, Fe, Sn	
4267f	2310	Kitchen	?C17th	corroded copper alloy	10 (6)	Cu, Fe, Zn, Pb	
4267f	2310	Kitchen	?C17th	cinder/ FAS	1 (1)		
4287/B	2376	Kitchen	?C17th	sheet with corrosion	1 (1)		
4287/B	2376	Kitchen	?C17th	corroded copper alloy	14 (3)	Cu, Fe, Zn, Pb, Sn	
4287/B	2376	Kitchen	?C17th	cinder/ FAS	7 (2)	Cu, Fe, Zn, Pb, Sn	
4287/B	2376	Kitchen	?C17th	corroded copper alloy	10 (7)		
4287/B	2376	Kitchen	?C17th	coal/ shale	1 (1)		

Appendix II Result of examination of non-ferrous debris from Pontefract Castle

context	SF No	area	date	type	weight [g] (pieces)	XRF	comments
4296	2465	Kitchen	n.d.	Corroded copper alloy	9 (1)	Cu, Fe, Pb, Mn	
4313	2471	Kitchen	?Early Medieval	corroded copper alloy	1 (1)		
4313	2458	Kitchen	?Early Medieval	sheet	1 (1)	Cu, Zn, Fe, Pb	
4313	3991	Kitchen	?Early Medieval	copper alloy 'dribble'	2 (1)		
4399	2627	Kitchen	?Medieval/ ?C13th	glassy Pb slag	185		
4439	3028	Kitchen	?C14-15th	Corroded copper alloy	1 (2)	Cu, Zn, Fe, Pb	

Appendix III

Analysis of selected domestic metalwork from Pontefract Castle by XRF.

Key to codes used in Table (below)

Area code	Definition
BU	Buttery (Kitchen)
CB	Chapel Bank
CT	Constable Tower
C1	Chapel I (Norman Chapel)
C2	Chapel II (Elizabethan Chapel)
KI	Kitchen

The metals detected by XRF analysis are given in order of descending peak height and do not necessarily reflect the relative quantities present.

Element nomenclature

Ag = Silver
As = Arsenic
Au = Gold
Cr = Chromium
Cu = Copper
Fe = Iron
Hg = Mercury
Ni = Nickel
Pb = Lead
Sb = Antimony
Sn = Tin
Zn = Zinc