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Archaeometallurgical residues from Platin/Lagavooren 1 (01E0822), Co. Meath, Northern Motorway (J2009)

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Abstract

The examined assemblage included fourteen sherds from very small crucibles, one fragment of ceramic mould, seven pieces of lining slag (one containing fragment of a failed crucible) and one fragment of hearth wall with the margin of the blowing-hole.

The crucibles are extremely small, with hemispherical bases of up to 25mm diameter. The upper parts of the sides may be locally flattened or slightly concave, but no complete profiles were recovered and there were no rim sherds. One rod-like fragment of similar fragment may indicate that the crucibles had elongate handles. These crucibles appear to be without close parallel, although they approach some forms of lidded crucible of early medieval age. The fabric is however more porous than most early medieval crucibles, although apparently more refractory than that of Iron Age crucibles from Tara.

The mould is for an unidentified object, with a lobed or possibly bifurcating section, possibly suggestive of a loop-and-button fastener.

Qualitative analysis by portable X-Ray fluorescence spectrometer (pXRF) showed the presence of traces of copper alloy in all the examined crucible and slag material. Evidence for the alloying elements was very variable, with evidence for lead in several samples and for zinc in some. Tin was only identified at trace levels in most samples, although present in many.

Analysis of the mould fragment showed a different pattern of contamination, with lead and zinc more strongly represented. Such a pattern of preferential enrichment of these more volatile elements has been observed both in archaeological and experimental moulds. It is not possible to predict with any degree of certainty what concentrations of lead and zinc would be required in the copper alloy to generate this contamination pattern, although it is argued that levels above trace amounts would be required, but that the contamination is probably not indicative of a deliberately alloyed leaded gunmetal.

Bronzes with low, but above trace, levels of zinc and lead are not usual in the pre-Roman Iron Age of Britain and Ireland. Both lead and zinc become significant alloying elements after contact with the Roman world in the 1st century AD. The one exception to this within Britain is a group of Middle Iron Age (4th to 2nd century BC) bronzes with elevated lead and/or zinc smelted from ores from the Llanymynech area of the Welsh borders, and distributed across mid- and North Wales. If the 2ndcentury BC-1st century AD 14C dates from Platin/Lagavooren 1are not anomalous then it is possible that the material being cast there came from Wales (or just possibly from some unknown geologically-similar source in Ireland). The date range appears a little too early for the casting metal to include Roman gunmetal, but this is an alternative possibility and just possible in terms of the chronology.

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Methods

All collected potential archaeometallurgical materials were examined visually, with a low powered binocular microscope where necessary, to identify material appropriate for further investigation. This formed the basis for the assessment report (Young & Kearns 2010). The catalogue from the assessment report is included as Table 1 here, with the analysed specimens indicated.

The programme of follow-up investigation described in this report is one of non-destructive analysis of the residues produced during non-ferrous metalworking on the site. The residues in this category (crucibles, a mould fragment and some slag) were investigated using a Bruker Tracer III-SD portable XRF. Measurements were taken with no filter, at 40kV and at 3.00 μA. Spectra were collected to a PC using S1PXRF software and then converted for basic processing in ARTAX. Given the measurement conditions the analyses are simply qualitative and provide little indication of the relative abundance of the various elements identified.

This project was undertaken for Irish Archaeological Consultancy Ltd.

Site background

The distribution details and a full catalogue of the residues within the site were presented in the assessment report (Young & Kearns 2010).

The metalworking is dated through association with three 14C dates:

SUERC-31886 (c295) cal. 170BC-AD20
SUERC-31937 (c312) cal. 160-130BC/120BC-AD20
SUERC-31938 (c25) cal. 160-130BC/120BC-AD20

Although the metalworking material forms a rather small assemblage, this apparently close dating and the almost unique nature of the material itself, gives collection a major importance.

Results

General description of material

The material examined included the following:

c71: 1 mould fragment
c220: 3 crucible sherds, 5 pieces of lining slag
c239: 1 crucible sherd
c255: 10 sherds of crucible, 2 pieces of lining slag (1 containing sherds of failed crucible)
c274: 1 piece of hearth wall with blowhole

The description below are based, with minor amendment, on the descriptions for these items in the assessment report.

Mould: Context 71 (upper fill of c70) contained one fragment of mould of oxidised fired clay. The part of the object cast in this fragment of the mould was 22mm long by 6mm deep in preserved section, with metal at least 3mm thick. At one end the object would have been 4mm wide with central groove giving a bilobed section. It widens to 10mm at other end of the mould with the surface curving through 90° after 5mm, the running straight for15mm then straight to the other fractured end. Over this distance the central groove widens to a 5mm wide hollow, of which the surface has spalled off so the details are unclear –it is therefore uncertain whether the piece had a central section between the lobes or was openwork (and therefore having a narrow 'Y' shape).

The incompleteness of the mould prevents identification at present. If the wide section was openwork, then the item might possibly be the loop for a loop-and-button fastener. However, since even this is uncertain, identification is not possible.

Crucible: the site yielded fourteeen small ceramic fragments interpreted as crucible sherds. They are quite delicate varying in thickness from 3-9mm.

The most common form for these sherds was hemispherical, with an external diameter of 20-25mm and with an internal void 10-12mm in diameter. One side of these hemispheres is flattened, but it is unclear here this flattened surface lies within the overall form of the crucible. These are interpreted as the bases of crucibles, giving a minimum of 6 vessels.

Although most sherds were from the stout, if small, bases of crucibles, one sherd appears to be from the side of a small crucible, with a height probably not much over 30mm. The internal void appears quite constricted above the basal hemispherical part. Externally the side constricts slightly above the hemispherical section giving a slightly concave profile.

Also present was a small fragment of elongated vitrified ceramic, tapered at one end, and of a similar fabric to the crucible sherds. This piece might be interpreted as a handle from crucible of a type with a long, rod-like handle (as opposed to a pinched handle).

One fragment of vitrified ceramic resembles a pinched handle, but is not convincingly a deliberate form and is probably a slag bleb.

The fabric of the crucibles is highly porous – probably indicating the former presence of extensive organic temper. Highly porous Iron Age crucible was also reported from Tara (Crew & Rehren 2002). Despite its unusual porosity, the crucible material has fired hard externally with, typically, a clear glaze, locally tinged red, over an almost white-fired body.

pXRF analyses of sampled material

Table 2 presents the results of the pXRF analyses by classifying the peaks of each alloying element into bands relative to the copper peak. This does not permit comparison of the concentrations between elements, but gives some idea of the variability within an element.

The three broad groups of archaeological materials, the crucibles, the slags and the mould, show different profiles of metal contamination (Table 3) .

The crucibles:
Copper is present in moderate amounts in all the analysed materials. The apparent concentrations are highest in the external glaze present on most of the sherds, particularly where there is a visible reddening from copper oxides.

Lead is present in varying amounts, but at significant levels in most of the contaminated ceramics. Lead is reactive with silicates and might be expected to be present in enhanced relative quantities compared with those of the metal. In contrast to copper, the lead was typically observed slightly better on the inside of the crucibles.

Zinc is present in variable quantities, often only trace levels, on the crucible sherds.

Tin is commonly present, but always in low concentrations. Tin would not be particularly reactive with the ceramic of a crucible (Kearns *et al.* 2010, p. 52), so the lack of significant concentrations of tin above trace levels in most instances does not preclude the ceramics having been used to handle a tin bronze.

The slags:
The analysed samples include both examples of low-density fuel ash and lining slags; also included here are analyses taken on the slag veneer on a piece of hearth lining, with the margin of the blowhole (E822:274:1).

In general the slags show a similar suite of elements to the crucibles, but in lower concentrations, so the alloying elements commonly fall below detection.

The exception to this was a piece of lining slag with an embedded fragment of failed crucible (E822:255:6). This sample showed a strong copper peak, a moderate peak from tin and trace levels of lead and zinc.

The lining slag around the blowhole showed relatively strong peaks form zinc.

The recognition of contamination from non-ferrous metals in these slags is instructive. The rather gravelly lining slags (or fuel ash slags, depending on terminology employed) found here are in themselves rather non-diagnostic. Although iron-working (because the workpiece is actually in the fire) tends to produce clear and obvious iron-enrichment in hearth slags, this may be limited if the working is of short duration or at particularly low temperature, or indeed masked by a particularly degradeable hearth wall. These slags did not show any colouration indicative of contamination by copper oxides and their origin a non-ferrous metalworking operation would not have been identified without the pXRF analysis. Triage by pXRF is clearly a desirable step in the examination of such material.

The mould
The mould shows a distinctly different elemental profile from the other materials. Copper is much less well represented, but lead and especially zinc are present at enhanced levels compared with the other materials.

Interpretation

The investigations did not reveal any actual metal droplets adhering to the ceramics that could be analysed to examine metal composition. The degree of metal contamination of the ceramics was low in general. The highest degrees of contamination found were in some of the external glazes, with visible reddening from copper oxides. These areas showed a very low proportion of other metallic elements.

The contamination of the lining slag associated with the failed crucible (E822:255:6) suggests the failed crucible had been associated with a tin bronze, containing low levels of zinc and lead. Although the results of such an investigation can only be rather tentative, it is suggested that the low levels of alloying elements probably are a reflection of a real low degree of alloying of the copper. Lead is very reactive with silica to form a slag and zinc may become concentrated because of its high volatility (Kearns *et al.* 2010). Since these processes of concentration are quite significant, it would be likely that lead and zinc would be even more important in the analyses if the original metal had contained even moderately large quantities of either element. The relative abundance of zinc in the mould will be due to its volatility in such settings – and its over-representation in the contamination on moulds is well documented (Kearns *et al.* 2010). Tin, on the other hand, is likely to be under-represented in the analyses because of its lack of affinity for silicate melts and its low volatility, so may not become trapped so easily in slagged materials.

In summary the metal was likely to have been a fairly low tin bronze (with minor lead and zinc).

Discussion

The identification of zinc in many of the analyses raises some important questions. Deliberate alloys of copper with zinc , brass (or with zinc, tin and sometimes lead , gunmetal) arrived in Britain immediately before the Roman invasion, but zinc-rich alloys are typical of the Roman period. There is little detailed information on copper alloys from Ireland at this period, but zinc-bearing materials would typically be thought of as indicative of contact with the Roman world.. In the post-Roman period there is continued circulation of recycled Roman metal for a while, but significant amounts of zinc-rich copper alloy did not come back into circulation until the later part of the early medieval period.

The experimental data of Kearns *et al* (2010) cannot be easily compared with the present data, but they form a basis for suggesting that casting a brass or gunmetal would have produced higher levels of zinc contamination in the mould and crucibles than observed. Thus it might be very tentatively suggested that the zinc content of the alloys being worked was above trace levels, but substantially below that of a deliberate brass. None the less, if the metal contained zinc at anything above trace levels, then a Roman or later age would normally be expected.

The presence of lead in almost all of the analyses is also interesting. The use of leaded bronze is very common in the later Bronze Age, but, in Britain at least, is not common in the Iron Age (disappearing from use c. 400BC according to Dungworth 1996), although it reappears in the Roman period. There is a paucity of Irish data to demonstrate whether the same pattern extends to Ireland, but that would seem likely to have been the case.

At first glance, therefore, there does not seem a great likelihood for the typical copper alloys circulating in the 1st/2nd century BC in Ireland being able to produce contamination patterns with significant lead and zinc, although it is just possible that the at the very end of the date range indicated by the 14C dates that alloys of 'Roman' type might have been in circulation. There are very few items, for instance, listed in the assemblage from the mainly Iron Age votive depositional site at Llyn Cerrig Bach (NW Wales;

Annheuser *et al.* 2007, Table 18) that show a zinc content of over 0.2% (excepting those artefacts interpreted as Roman in age) and none of these are items identified as being potentially of Irish origin (Macdonald 2007, 196). Dungworth (1996) argued that there were no pre-Roman artefacts from northern Britain with a deliberate zinc alloy composition. Crew & Rehren (2002) detected neither lead nor zinc as contaminants of crucible and mould fragments from Tara (2nd-1st century BC), nor did they report the specimens of copper and bronze prills as containing detectable lead or zinc. However, since the present data are not quantified, and there is little experimental data with which to interpret even quantified data, then it is still just possible that copper alloy with only trace levels of lead and zinc might be capable of leaving detectable levels of these elements in moulds and crucibles.

One other possibility also exists – and that is that the copper alloys might have been imported from Wales. The local occurrence of copper ores with naturally high levels of zinc and lead in the area of Llanymynech, on the border of Powys (Wales) and Shropshire (England), formed the basis for small-scale production of copper during 4th to 2nd centuries BC. Smelting sites are known from Llanymynech Hillfort (Musson & Northover 1989) and Four Crosses (Young 2010). The distribution of artefacts produced from copper from these, or nearby, sources, has been discussed by Musson *et al.* (1992), Musson & Northover (1989) and Northover (1991). The artefacts include items with elevated lead either with or without elevated zinc. Although other ore bodies with a similar mineralogy to Llanymynech might be postulated to occur in Ireland (which has some areas with similar geological setting to that of the Welsh borders), none has yet been described as having associated copper smelting and the author is aware of no artefactual evidence for high-lead or high-zinc copper alloys in the earlier Irish Iron Age.

The crucibles also provide a source of potential controversy. The fabric for the crucibles is surprisingly porous internally, probably reflect an original abundance of organic temper. Despite this, there is some quartz, they have fired hard and pale, and the external surfaces have a hard vitrification. The crucibles thus appear to be technically somewhat more advanced than the rather porous crucibles from the Iron Age of Tara (Crew & Rehren 2002).

Morphologically, they are very small, with a hemispherical base, a flattened side and an extended (and slightly narrowing) neck and possibly an elongate, rod-like handle. Away from the basal bowl, they are thin-walled. Unfortunately, there is no example sufficiently complete to allow these features to be reconstructed into the overall form. Individually, some of these features most closely resemble aspects of the small, lidded crucibles of early medieval date. Crew & Rehren (2002, p. 88) refer to some examples from Tara of small, round, 'thumb-sized' crucibles approximately 30mm wide and deep, but most crucibles there were 50mm wide and apparently triangular – a much more conventional form for the Iron Age. Very few other examples of Iron Age crucibles are known from Ireland. It is not known, for instance, whether the small, lidded, early medieval crucibles found in western Britain and Ireland may have had an origin in the Iron Age of Ireland; they certainly lack an obvious forebear in Roman Britain.

The assemblage is thus of unusual nature. Were it not for three coherent associated 14C dates indicating an age in the 2nd – 1st centuries BC, the combination of lead/zinc-bearing alloys and small 'thumb' crucibles would be very suggestive of an early medieval age for this material. The almost-complete lack of early Iron Age crucibles from Ireland limits the ability to date the crucibles on typological grounds. Technically, they appear more advanced than the crucibles from Tara (Crew & Rehren 2002), but arguably less refractory than most early medieval crucibles. If they do indeed date from the 2nd century BC to the earlier 1st Century AD, then it is possible that the lead/zinc-bearing bronze that they were employed to cast might just possibly have been an import from Wales. If the materials are just slightly later, then it is possible that they might indicate the influence of Roman brass entering the pool of metal in circulation.

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Table 1: Platin/Lagavooren 1 (01E0822), catalogue of material indicating analysed specimens (after Young & Kearns 2010). Analysed specimens indicated in coloured tone.

context	*sample no (#find)*	*weight (g)*	*quantity*	*description*
4	308	33	1	small fragment of slag, possibly from SHC. Top green, glassy with some charcoal, lower part more dense with smoothly lobed /dimpled base
8	328	72		oxidised fired clay debris
27	316 (#3)	13	1	low density vesicular fuel ash slag
27	316 (#7)	24	3	small fragments of slag: 2 pieces of iron-rich slag in a sheet form, 1 piece is an iron-poor lining/fuel ash slag
27	316 (#7)	6	1	quartz-rich fired clay furnace lining, highly vitrified and slagged
27	316 (#7)	150	2	indeterminate slag, both pieces very dense slag with signs of flowage. May be two very small SHCs
71	(#2)	12.1	1	fragment of mould of oxidised fired clay. The cast object would have been 4mm wide with central groove at one end, widens to 10mm at other, swinging 90° after 5mm, 15mm then straight to fracture, central groove widens to 5mm wide hollow, but broken, so details unclear. Part of object overall 22mm long by 6mm deep in preserved section, with metal at least 3mm thick.
71	312 (#3)	21	5	gravelly lining slag, with dark glass, resting on very coarse quartz-rich ceramic
71	312 (#4)	46	(2)	indeterminate slag, has superficial layer of lining slag, lying on denser slag attached to reduced fired ceramic. Where the slag is exposed it is maroon on the surface suggesting this is from near blowhole – could be SHC fragment from a very small hearth.
71	312 (#4)	1	2	fuel ash slag
182	313	34	1	indeterminate slag - possibly part of tiny SHC
182	313	2.1	1	low density vesicular fuel ash slag
182	313	9.3	1	low density gravelly fuel ash slag
203	317	33	1	limestone
208	319	42	1	weathered veined limestone
209	(#1)	28	1	fragment of fired clay, very fine soft pale grey fabric, paler to outside, with very fine mineral temper (56x39x11mm)
220	306 (#1)	16.1	3	low density lining slag attached to almost white ceramic at rear
220	306 (#1)	14.5	5	low density fuel ash/lining slags in complex blebby lumps
220	306 (#2)	50	4	low density lining slag – very heterogeneous material with pebbles, dark, pale and green glasses all in amorphous mass
220	306 (#3)	8	2	low density fuel ash slag

context	*sample no*	*weight (g)*	*quantity*	*description*
220	306 (#5)	8	2	low density fuel ash slag
220	306 (#6)	7.6	2	Low density gravelly slags
220	307 (#6)	15	1	Low density slag grading into dark dense slag with lobes
220	306 (#7)	3.3	1	small crucible base fragment, 6 to 4mm thick, vitrified on external surface , dark glass film on interior, flat base, clear external glaze, tiny mark of cuprite **(analysed as 'a')**
220	306 (#7)	27	8	low density fuel ash slag **(5 pieces analysed, 'b'-'f')**
220	306 (#8)	17	2	fired clay, oxidised on one surface, almost vitrified on the other – conventional orange lining with some coarse grit
220	306 (#9)	24.9	1	fuel ash slag, vitrified material binds gravelly debris, passes into denser black glassy slag at one end
220	306 (#9)	12	1	corroded iron - possible nail fragment
220	306 (#9)	9	2	weathered vitrified clay, oxidised on rear surface – hearth wall?
220	306 (#9)	11.5	2	low density vesicular fuel ash slag in rounded blebs – very weathered
220	306 (#10)	0.9	1	Crucible fragment, eternal clear/pale grey glaze, internal surface not seen
220	306 (#11)	13	1	low density lining slag, in irregular rounded lump
220	306 (#12)	20.56	3	blebby gravelly lining slag, low density
220	306 (#13)	17.4	1	iron rich concretion with occasional charcoal residues, uncertain if cored on iron or slag
220	306 (#13)	31.8	4	vitrified hearth wall with strongly laminated white ceramic behind
220	306 (#13)	6	2	small fragments of vitrified lining or lining slag
220	306 (#14)	3.1	1	Sherd from base of crucible, hemispherical but flattened on one side. Internally shows slight traces of brazing like internal glazed coat with bubbles
220	306 (#15)	11	1	indeterminate slag, lining slag with admixed, dark slag amongst gravel
220	306 (#16)	26	1	fuel ash slag, vitrified material binds gravelly debris, passes into denser black glassy slag at one end
239	310 (#1)	3.5	1	small crucible fragment, 23mm external diameter, 5-7mm thick, possible base, slight vitrification on exterior with red tinge, most likely cuprite (copper oxide). External surface deeply cracked
239	310 (#2)	12	2	corroded iron
255	(#1)	17	1	Glassy lining slag, of various colours (1 tiny reddened area might indicate copper-contamination), binding gravelly material
255	(#2)	2.1	1	Rounded crucible base? Pale glaze with extensive cuprite reddening, has odd hollow in base internally **(analysed as 'd')**
255	(#2)	0.9	1	Small 'crucible' fragment, fabric as above **(analysed as 'e')**
255	(#2)	.6	1	Small 'crucible' fragment, fabric as above **(analysed as 'a')**
255	(#2)	1.3	1	Small 'crucible' fragment, fabric as above **(analysed as 'c')**
255	(#2)	3.0	1	Lobed object with circular scar – could be a pinched crucible handle? Probably just bleb of slag attached to crucible sherd **(analysed as 'b')**

context	*sample no*	*weight (g)*	*quantity*	*description*
255	(#3)	4.4	1	30mm long ceramic rod, cross section oval, 15x11mm. Slight external transparent glaze with a few red minute dribbles. Internally porous but solid. Rounded tip. Internal flaw corresponds to traces of seam on exterior. Possible straight crucible handle. **(analysed as 'c')**
255	(#3)	2.8 & 2.4	2	conjoining fragments of semi-hemispherical external form, slightly flattened one side, internally porous, truncated smooth surface bubbly glaze internally, suggests sub-angular rectangular dished hollow with rounded corners, 18mmx13mm. Walls 3-5mm. External transparent glaze with red flecks, overall bowl external dimensions, 24mm x 22mm x 14mm deep. **(analysed as 'a' and 'b')**
255	318 (#4)	18.8	7	low density fuel ash slag
255	(#5)	2.2	1	hemispherical crucible base with central hollow, as #2, 2.1g piece above **(analysed as 'b')**
255	(#5)	3.5	1	side of crucible? 26mm high, base probably hemispherical (part only preserved) but constricts slightly above, some possible slag occluding cavity – but otherwise cavity is inverted mushroom shape internally **(analysed as 'c')**
255	(#6)	14.8	1	mass of lining slag with 2 sherds of 'crucible' entrapped, both with some red copper staining. All very quartz-rich
257	(#4)	9	1	lightly fired, partially oxidised fired clay, with vitrified reduced very slightly convex surface
263	320	60	(2)	indeterminate slag, broken piece with slightly concentric structure, base shows flowed lobes penetrating in sandy ceramic –could possibly be tiny SHC
272	(#1)	1.5	1	fuel ash slag?
	(#1)	0.6	1	stone
	(#1)	0.2	1	fuel ash slag/
274	(#1)	28	(2)	one side of blowhole 20mm diameter with adjacent vitrified wall face, broken in two. Very quartz rich pale fabric – almost like a crucible. Local dark glass developed but no real slag and no trace of copper staining
275	311	22	1	natural chert
282	314 (#1)	42	2	weathered basalt
282	324	35	1	lightly oxidised fired clay
282	324	11	2	lightly oxidised fired clay
283	309 (#1)	7	(4)	concretion formed around corroded iron, 5mm square cross section by 70mm in length
283	309 (#4)	48	2	concretions surrounding corroded iron – 5mm cross section square, one 40mm long one 25mm long
283	327	287		several blocks of hard fired oxidised clay
312	304 (#2)	0.7	1	fuel ash slag

context	*sample no*	*weight (g)*	*quantity*	*description*
312	307 (#4) (says 14 on object)	5	1	Small fragment of ceramic-like material, resembles pointed base, internal diameter 1.5mm, height 22mm (at highest point), small finger sized depression in centre, rounded base - very weathered appearance. Formed of coarse sand bound by very little – might be natural concretion, does not resemble fabric of 'crucibles'
312	307 (#6)	2	1	small fragment of corroded iron
312	326 (#3)	<1		powdered oxidised-fired clay
325	315	12	2	mica-rich rotten rock
327	#1	0.4	1	sandy fuel ash slag in amorphous shape – could be slag or failed ceramic
334	325	8	1	fragment of red sandstone, spalled from pebble
398	305	26	6	low density fuel ash/gravelly lining slag
	total	*1570*		

Table 2: Qualitative assessment of pXRF results. Intensities graded (from trace levels to a major peak in the spectrum): tr – x – xx – xxx – XXX - XXXX

analysis	find	material	location of analysis	Cu	Pb	Zn	Sn
e822-71-2 int	71-2	mould	general into mould cavity	xx	tr	x	
e822-71-2 sec	71-2	mould	section below reduced face	xx	x	xxx	
e822-71-2 sec2	71-2	mould	section on raised end of mould	xx	x	xx	
e822-71-2 sec3	71-2	mould	section on raised reduced long edge	xx	x	xxx	tr
e822-220-7 ext1	220-7a	well-formed crucible base with flat surface	exterior - flat base	XXXX	xx	tr	x
e822-220-7 ext2	220-7a	well-formed crucible base with flat surface	exterior - curved face	XXX	tr	tr	tr
e822-220-7 int1	220-7a	well-formed crucible base with flat surface	interior to one side	XXX	xxx	tr	tr
e822-220-7 int2	220-7a	well-formed crucible base with flat surface	interior - into central concavity	XXX	xx	tr	tr
e822-220-7 s1	220-7b	slag - dense		xxx	x	xx	
e822-220-7 s2	220-7c	slag low density		xxx		x	
e822-220-7 s3	220-7d	slag low density		XXXX	tr	tr	
e822-220-7 s4	220-7e	FAS		xxx	x	x	
e822-220-7 s5	220-7f	slag - glassy bleb		xxx	x	x	
e822-220-10-ext	220-10	crucible body sherd	general interior	XXX	tr	x	
e822-220-14 ext1	220-14	crucible with marked external angle	exterior - curved face	XXX	tr	x	tr
e822-220-14 ext2	220-14	crucible with marked external angle	exterior- flat (marked) face	XXXX	xx		x
e822-220-14 int	220-14	crucible with marked external angle	Interior - fractured surface	XXX	xx	tr	tr
e822-239-1 ext	239-1	well formed crucible base, dirty not slagged interior	exterior - red and fissured area	XXXX	xx	tr	x
e822-239-1 int1	239-1	well formed crucible base, dirty not slagged interior	interior with section on one side	XXX	xx	tr	tr
e822-239-1 int2	239-1	well formed crucible base, dirty not slagged interior	interior - centre of base	XXX	xx	x	tr
e822-255-1 s1	255-1	gravelly lining slag	area of black glass	XXX			tr
e822-255-1 s2	255-1	gravelly lining slag	rusty bleb	xxx			
e822-255-1 s3	255-1	gravelly lining slag	main slag on upper surface	XXX	tr	tr	
e822-255-2a ext	255-2a	small thin sherd with pale interior and glazed exterior	exterior (possibly marked)	XXXX	x	tr	tr
e822-255-2a int	255-2a	small thin sherd with pale interior and glazed exterior	interior	xxx	x	tr	
e822-255-2b ext	255-2b	small area of crucible with large slag bleb	external area where coloured	XXXX	tr	x	tr
e822-255-2b int	255-2b	small area of crucible with large slag bleb	internal fracture through crucible	XXX	x	x	
e822-255-2c ext	255-2c	rounded sherd from near base of crucible, poor interior	external	XXXX	tr	x	x
e822-255-2c int	255-2c	rounded sherd from near base of crucible, poor interior	internal	XXX	xx	x	
e822-255-2d ext	255-2d	good base with central cavity	external, red / white glaze	XXX	tr		tr
e822-255-2d int	255-2d	good base with central cavity	internal	XXX	x	tr	
e822-255-2e ext	255-2e	poor fragment of base	external	xxx	x	tr	x
e822-255-2e int	255-2e	poor fragment of base	internal	xxx	tr	x	x
e822-255-3a ext	255-3a	one of two conjoining base sherds	exterior on angle, pale glaze	xxx	tr	x	tr
e822-255-3a int	255-3a	one of two conjoining base sherds	interior of base	XXX	xx	tr	x
e822-255-3b ext	255-3b	second conjoining base sherd	coloured exterior glaze	xxx	x	x	
e822-255-3b int	255-3b	second conjoining base sherd	interior of base	xxx	x	tr	tr
e822-255-3c ext1	255-3c	glazed rod	exterior area 1	XXXX	xx	tr	xx
e822-255-3c ext2	255-3c	glazed rod	exterior area 2	XXXX	xx	tr	xx
e822-255-5a ext	255-5a	large crucible side with hollowed interior base	general exterior	XXXX	x		x
e822-255-5a int	255-5a	large crucible side with hollowed interior base	hollow interior	XXXX	xx	tr	xx
e822-255-5b int	255-5b	base with central hole	centre of interior	XXX		tr	tr
e822-255-6 ext1	255-6	lining slag containing crucible sherd	general slag area	XXXX	tr	tr	x
e822-255-6 int	255-6	lining slag containing crucible sherd	interior of crucible	xxx	x		
e822-274-1 s1	274-1a	margin of blowhole	glazed section near lip of blowhole	xxx	tr	x	
e822-274-1 s2	274-1a	margin of blowhole	raised slag bleb	xxx		xx	

Table 3: Qualitative assessment of pXRF results. Intensities graded (from trace levels to a major peak in the spectrum): tr – x – xx – xxx – XXX – XXXX. Ordered by residue type and surface

analysis	find	material	location of analysis	Cu	Pb	Zn	Sn
e822-71-2 int	71-2	mould	general into mould cavity	xx	tr	x	
e822-71-2 sec	71-2	mould	section below reduced face	xx	x	xxx	
e822-71-2 sec2	71-2	mould	section on raised end of mould	xx	x	xx	
e822-71-2 sec3	71-2	mould	section on raised reduced long edge	xx	x	xxx	tr
e822-220-7 ext1	220-7a	well-formed crucible base with flat surface	exterior - flat base	XXXX	xx	tr	x
e822-220-7 ext2	220-7a	well-formed crucible base with flat surface	exterior - curved face	XXX	tr	tr	tr
e822-220-14 ext1	220-14	crucible with marked external angle	exterior - curved face	XXX	tr	x	tr
e822-220-14 ext2	220-14	crucible with marked external angle	exterior- flat (marked) face	XXXX	xx		x
e822-239-1 ext	239-1	well formed crucible base, dirty not slagged interior	exterior - red and fissured area	XXXX	xx	tr	x
e822-255-2a ext	255-2a	small thin sherd with pale interior and glazed exterior	exterior (possibly marked)	XXXX	x	tr	tr
e822-255-2b ext	255-2b	small area of crucible with large slag bleb	external area where coloured	XXXX	tr	x	tr
e822-255-2c ext	255-2c	rounded sherd from near base of crucible, poor interior	external	XXXX	tr	x	x
e822-255-2d ext	255-2d	good base with central cavity	external, red / white glaze	XXX	tr		tr
e822-255-2e ext	255-2e	poor fragment of base	external	xxx	x	tr	x
e822-255-3a ext	255-3a	one of two conjoining base sherds	exterior on angle, pale glaze	xxx	tr	x	tr
e822-255-3b ext	255-3b	second conjoining base sherd	coloured exterior glaze	xxx	x	x	
e822-255-3c ext1	255-3c	glazed rod	exterior area 1	XXXX	xx	tr	xx
e822-255-3c ext2	255-3c	glazed rod	exterior area 2	XXXX	xx	tr	xx
e822-255-5a ext	255-5a	large crucible side with hollowed interior base	general exterior	XXXX	x		x
e822-220-7 int1	220-7a	well-formed crucible base with flat surface	interior to one side	XXX	xxx	tr	tr
e822-220-7 int2	220-7a	well-formed crucible base with flat surface	interior - into central concavity	XXX	xx	tr	tr
e822-220-10-ext	220-10	crucible body sherd	general interior	XXX	tr	x	
e822-220-14 int	220-14	crucible with marked external angle	Interior - fractured surface	XXX	xx	tr	tr
e822-239-1 int1	239-1	well formed crucible base, dirty not slagged interior	interior with section on one side	XXX	xx	tr	tr
e822-239-1 int2	239-1	well formed crucible base, dirty not slagged interior	interior - centre of base	XXX	xx	x	tr
e822-255-2a int	255-2a	small thin sherd with pale interior and glazed exterior	interior	xxx	x	tr	
e822-255-2b int	255-2b	small area of crucible with large slag bleb	internal fracture through crucible	XXX	x	x	
e822-255-2c int	255-2c	rounded sherd from near base of crucible, poor interior	internal	XXX	xx	x	
e822-255-2d int	255-2d	good base with central cavity	internal	XXX	x	tr	
e822-255-2e int	255-2e	poor fragment of base	internal	xxx	tr	x	x
e822-255-3a int	255-3a	one of two conjoining base sherds	interior of base	XXX	xx	tr	x
e822-255-3b int	255-3b	second conjoining base sherd	interior of base	xxx	x	tr	tr
e822-255-5a int	255-5a	large crucible side with hollowed interior base	hollow interior	XXXX	xx	tr	xx
e822-255-5b int	255-5b	base with central hole	centre of interior	XXX		tr	tr
e822-220-7 s1	220-7b	slag - dense		xxx	x	xx	
e822-220-7 s2	220-7c	slag low density		xxx		x	
e822-220-7 s3	220-7d	slag low density		XXXX	tr	tr	
e822-220-7 s4	220-7e	FAS		xxx	x	x	
e822-220-7 s5	220-7f	slag - glassy bleb		xxx	x	x	
e822-255-1 s1	255-1	gravelly lining slag	area of black glass	XXX			tr
e822-255-1 s2	255-1	gravelly lining slag	rusty bleb	xxx			
e822-255-1 s3	255-1	gravelly lining slag	main slag on upper surface	XXX	tr	tr	
e822-255-6 ext1	255-6	lining slag containing crucible sherd	general slag area	XXXX	tr	tr	x
e822-255-6 int	255-6	lining slag containing crucible sherd	interior of crucible	xxx	x		
e822-274-1 s1	274-1a	margin of blowhole	glazed section near lip of blowhole	xxx	tr	x	
e822-274-1 s2	274-1a	margin of blowhole	raised slag bleb	xxx		xx	

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