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Evaluation of Archaeometallurgical residues from the M7/M8 Contract 3: Clonrud 4 (E2167)

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Abstract

This site comprised an isolated occurrence of two slagpit furnaces and a waste pit. Furnace 1 (C003) contained only a very small quantity of slag fines (approximately 200g), Furnace 2 (C005) contained about 2.6kg of mainly flow slag. Both furnaces contained a large quantity of fired clay(6.9kg and 5.6kg respectively)in their upper fills, derived from collapse of their superstructures.

The evidence for the furnace morphology is discussed in detail. The stratigraphic record is rather ambiguous, but is interpreted as the two furnaces being the surviving remnants of paired slagpit shaft furnaces. In slagpit furnaces the iron bloom is formed at about the contemporary ground level, at the base of the shaft, where air is blown into the furnace via a blowhole. Slag flows away from the area of bloom formation and accumulates in the basal pit, which in many cases appears to have packed with wood prior smelting. The pit could be cleared of slag after the smelt and the furnace reused. In both these furnaces the majority of the slag had been cleared after the last use, leaving just fine debris of flow slags in the pits. The construction of slagpit furnaces in pairs can be paralleled at some other Iron Age sites on this scheme.

What sets this site apart from most slagpit furnace occurrences is the waste pit. This pit contained 28kg of residues, mainly large blocks of slag showing down-wall slag flow, large pieces of furnace superstructure and accumulations of flow slags. Only small fragments attributable to the main slag mass (sometimes referred to as a "furnace bottom") were found. This suggests that the debris in the pit may have been materials removed from the furnaces during their repair between smelts, rather than the slag which would have been removed from the furnace with the retrieval of the bloom. Indeed, the pieces of vitrified wall included abundant pebbles, suggesting use of the local boulder clay, so it is possible that the pit may have originated as a quarry pit for obtaining clay for furnace construction or repair.

Although reconstruction of the furnace morphology is tentative, it suggests that several furnaces morphologies were employed in Iron Age Ireland.

Contents

Methods

All investigated materials were examined visually, using a low-powered binocular microscope where necessary. All significant materials were summarily described and recorded to a database (Tables 1 & 2). As an evaluation, the materials were not subjected to any high-magnification optical inspection, nor to any other form of instrumental analysis. The identifications of materials in this report are therefore necessarily limited and must be regarded as provisional.

Results

Residue description

flow slag: slags in the form of individual or multiple prills were the most abundant slag facies recovered (83% by weight of the residues recovered excluding fired clay). Much of the flow slag from Furnace 2 and from Pit F4 was in the form of large blocks of coalesced prills, some of which may represent fragments of "furnace bottom". One piece from the waste pit appears to be from the margin of a "furnace bottom". Some of the large blocks from the waste pit show accumulation against the wall of the furnace pit

fines: most of the residues from the deposit representing the last use Furnace 1 and about 30% of the residues from the equivalent deposits in Furnace 2 comprise very fine flows, blebs and sub-spheroidal particles of slag, together with more amorphous slag debris. These materials represent accumulation on the floor of the furnace pit. They comprise approximately 5% of the overall residue assemblage (excluding fired clay).

large dense slag pieces: these residues comprise dense slags with a massive texture (i.e. they do not include slag with an internally flow-lobed texture). The material included in the class comprises just two slag blocks, both from the waste pit, which together comprise 12% by weight of the overall residue assemblage. At least one of them is a piece of "burr", the zone of interaction between the slags and the furnace wall immediately below the blowhole.

indeterminate slag: this class includes fragmented slag material, frequently with abundant charcoal inclusions, that cannot be referred to a particular part of the smelting furnace with any confidence.

sinter: this class comprises material of a fine grain size, particularly ore dust and charcoal dust which accumulate on the pit floor and become indurated either by becoming a sinter (fusion of the hot particles) or through precipitation of secondary cements of iron oxides.

ore?: a single reddish-purple particle from Furnace 1 was tentatively identified as a small fragment of heated bog ore. The purple colour is an indication of heating of the particle, but this may have been during its passage through the furnace rather than being an indication that ore-roasting was being undertaken prior to smelting.

fired clay: the lower furnace deposits contain a small proportion of fired clay fragments, but most of the fired clay recovered comes from the upper furnace fills. A few discrete blocks of very well vitrified furnace wall were also recovered from the waste pit.

Furnace 1 yielded samples of about 5kg of fired clay in its upper fills and the samples from furnace 2 total approximately 4kg. The presence of large quantities of clay in the upper part of the furnaces is most likely due to collapse of their superstructures on disuse. There are several observations that can be made on this material that may be important in helping to interpret the nature of the superstructure.

Firstly the material contained quite large pebbles in some instances. The presence of the pebbles accounts for the instances of glaze noticed by the excavators for the exposed surfaces of the pebbles show a glaze from partial melting under the fluxing influence of the wood ash. Such pebbles would probably be very awkward if the superstructure was of the very thin-walled variety represented by Scharmbeck-type, known from the early centuries AD in northern Germany and adjacent areas (cf, Pleiner 2000 fig 36 4).

A thicker-walled superstructure would also be favoured by the lack of any finds which show both inner and outer surfaces of the clay. Indeed the outer surface was not recognised at all, showing the shaft was not thoroughly fired.

The most significant observation of the material, however, was that in most cases where the face was vitrified, the face was flat or very slightly convex. The possible significance of this is discussed below.

Most of the slightly fired clay was gently oxidised fired. Most of the more heavily vitrified material was reduced fired behind the vitrified face. One large fragment from the waste pit showed a small area of oxidised firing, whilst generally reduced fired. This suggests the fragment was from the wall adjacent to the blowhole (the blowhole region will have plenty of oxygen, which is rapidly used up away from the supply).

Structure description

Detailed description of the structures is quite difficult given the nature of the current stratigraphic record. The furnace pit cuts are described as F003 (Furnace 1): 0.49m x 0.45m x 0.15m, and F005 (Furnace 2): 0.46m x 0.41m x 0.19m. However, it seems these dimensions may include the "vitrified" natural boulder clay outside the cut, for the cut F8 is shown on Figure 8 of the Prelim. Report as lying above F8, fired clay in Furnace 1, and cut F005, lying above F11, the fired clay in Furnace 2. Both F8 and F11 overlies F12, a more general area of reddening (of the natural?), but the difference between these contexts is not explained in the text.

In the absence of evidence for a pit lining, it would appear most likely that these vitrified deposits, the supposed primary fill, may have been *in-situ* natural. The actual cut would therefore have been somewhat smaller. The "clay spread" (F012) is interpreted as oxidation of the natural to a lower degree than in F008 and F011. F008, F011 and F012 are therefore all taken to be stratigraphic synonyms of F002, the natural.

If this reading of the stratigraphic evidence is incorrect, and F012 is not fired natural but a deliberate clay fill to a wider cut, then the deliberate creation of a double furnace setting would be an extremely significant observation. The emplacement of significant clay pads in which furnaces could then be modelled and remodelled over prolonged periods of time is a feature seen in elaborate slag-tapping furnace installations (e.g. the Roman site at Sherracombe Ford, Exmoor), but has not been observed in non-slag tapping furnaces. However, in the absence of certain evidence that F012 is not natural, then the simpler interpretation of this material as fired natural is preferred.

The stratigraphic interpretation is further hampered by the different information given by the three sections through F003 and F005 on Prelim. Report Figure 8, which do not show corresponding profiles; in particular the section of F011 appears inaccurate. As a further complication the plan shown in Figure 8 erroneously labels the limit of general reddening (the "base" of F012) as F003. Further, either the section markers A-B on the plan are the wrong way round or the extent of F010 and F007 on the pre-ex surface is inaccurate, given their distribution in the section.

The working sizes of the slagpits are probably best indicated by the quoted dimensions of the slag-rich fills (interpreted here as their primary fills). For Furnace 1 F010 is given the dimensions of 0.41m x 0.39m and for Furnace 2, F007 is described as 0.46m x 0.41m.

The most likely interpretation is that F3 and F5 are the basal pits of slagpit non-slag tapping iron smelting furnaces. Paired furnaces are known from a wide variety of sites and periods across Europe, but typically from the medieval period onwards. There are possible paired furnaces on other sites within this scheme (Derryvorrigan 1, Derrinsallagh 4).

The illustrations appear to show Furnace 1 as containing rather less vitrified or fired clay around the pit than furnace 2, it has a more rounded pit and contained less charcoal-rich fill, so it is also just conceivable that F3 is not a separate feature, but the working pit outside furnace F5. Working hollows apparently connected to the furnace via a furnace arch have been demonstrated in some furnaces at Derrinsallagh 4 (Young 2008e) and probably also occur at Derrinsallagh 1 and Derrinsallagh 3. In this particular case the profile of the two structures seems rather abrupt; an interpretation of the features as two distinct furnaces appears more likely.

Whilst the problems with the fine details of the stratigraphy of the furnaces may initially appear trifling, it is the subtleties of construction of furnaces that allow differentiation of difference furnace types, even in such truncated remains.

Interpretation

The residues recovered were entirely from iron smelting in a non-slag tapping furnace. In this variety of shaft furnace the descending charge of ore and charcoal is burnt with a forced draught produced with bellows supplying air at about ground level. The air enters the shaft through a blowhole in the wall of the shaft; no evidence has yet been found in Ireland that the air supply was through a pre-formed tuyère. The bloom of iron forms at about ground level, with the slag flowing over the bloom and accumulating in a pit below.

Although the precise mechanisms have not yet been well-studied, the migration of slag into the pit seems to have been facilitated by the prior packing of the pit with some form of readily combustible organic material. In most examples, particularly in the Iron Age, this packing appears to have been of short lengths of wood (sizes of up to 200mm x 60mm x70mm have been observed; Young 2005a, 2006a), but in Eastern Europe the most common pit-packing is straw (Pleiner 2000).

The development of slag in the furnace has several distinct facies. The main characteristic of the slag is that it mainly forms as small volumes of melt which then trickle down through the charcoal. These may solidify as elongate flows or prills, or may chill as discrete drops, forming sub-spheroidal blebs. The part of the furnace immediately below the bloom may become filled with a dense mass formed of coalesced prills, forming a "furnace bottom" of the kind seen at Tullyallen (Young 2003b) and Adamstown (Young 2006b).

Slag production will be most rapid, and the slags most fluid, in the area close to the hotzone, which extends in front of, and above, the blowhole. Rapid slag flow down the blowing wall will produce characteristic slags: at the foot of the wall the slag may chill to encase the pit-packing, leading to the formation of moulds of the wood fragments. Some of the slag may flow laterally across the pit floor before solidifying to produce lobed flows very similar to those produced during slag tapping. Some of the slag may chill and solidify against the wall before reaching the pit floor; such slags have a lobed texture with a non-wetted contact the wall, and are also often extremely shiny materials, having a very high wustite content.

The high rate of reaction in the hot area close to the blowhole also leads to a strong reaction between the slags being formed in this area and the adjacent wall. The wall melts back in characteristic scooped form below the blowhole, and on cooling the slags which fill this hollow are often very coarse (as they will be amongst the hottest slags in the furnace and also they are in a relatively insulated location so will cool slowly after the smelt), These dense, coarse, typically olivine-rich slags are termed here the "burr".

Some materials may filter down to the pit floor, particularly early in the smelt, leading to what is termed here as sinter, although it is not clear whether the material is a true sinter, or is cemented by secondary iron mobility. These "sinters" comprise charcoal and ore dust, together with sand grains and small amounts (sometimes) of dripped slags.

In normal operation the bloom would be removed through the top of the furnace (or perhaps through the arch in those furnaces with such a feature), and then as much of the slag removed as practically possible to ready the furnace for its next use.

Interpretation of the features described as "bowl furnaces" in the draft interim report, is not straight-forward, since such structures, particularly those comprising two adjacent pits, may be rather more complex than previous thought. In addition there are some inconsistencies between the text account, the plans and the successive partial sections, which create a degree of uncertainty of the precise physical nature of the structures.

The fired clay present in the upper fills of the two furnaces also provides unusual evidence for the nature of the superstructure. The vitrified pieces of shaft lining are mainly flat to slight convex. This indicates that the shaft did not continue upwards in a cylindrical form above the approximately circular basal pits (although it should be noted that the mid-ex plan of the features, draft prelim report Figure 8, shows the pits to be more roundedly quadrilateral than is apparent from the written description). The vitrified material is most likely to have formed on the blowing wall above the blowhole, where the hotzone will have its greatest area of impinging on the structure. The furnaces may thus have had roughly straight blowing walls, with the convexity being caused by a slightly curved overhang.

Unfortunately the current field description of the features does permit recognition of the blowing wall in the pits. Re-examination of the field records, both plans and photos, is urged as part of the second stage analysis of this material in order to determine the likely direction of blowing.

The working dimensions of the two slagpits (0.41m x 0.39m and 0.46m x 0.41m) are moderately large. Large diameter slagpits seem on current evidence to be typical of the earlier Iron Age, with the following examples with working diameters of over 0.45m having been recorded:

- Cloncollig, Co. Offlay: very large (0.55x0.60m), 360-90 cal. BC (Young 2008b)

- Newrath Site 35, N25 Co. Kilkenny (Eogan *pers. comm.* 2006) : 400-200 cal. BC and 350-40 cal. BC

- Morrett D, N6 Co. Laois (Young 2005b): 170 cal. BC-30 cal AD and 770-410 cal. BC for charcoal pits, 370-110 cal BC and 400-200cal BC for ring-ditches.

- Cherryville, Co. Kildare (Young 2008a): 400-200 cal. BC.

- Carrickmines Great, Co. Dublin (Young 2003a): 360-110 cal. BC

- Adamstown1, N25 Co. Waterford (Young 2006b) undated

- Tullyallen 6, Co. Louth (Young 2003b), undated.

These sites share a common style of residue, with two sites, Tullyallen and Adamstown, having surviving intact hearth bottoms with weights of about 20kg. None of these sites with very large pits shows evidence for furnace pairing.

The site at Derryvorrigan 1 (Young 2008d) not only has paired furnaces, but also they appear to have working diameters of approximately 0.40m, so providing a very close analogue for the Clonrud 4 examples.

Other Iron Age sites appear to have smaller diameter furnaces. Those at Derrinsallagh 4 appear to be mainly approximately 0.30m working diameter (ignoring all arguments about whether any lining is present within a broader cut). The example with a furnace arch that was excavated in detail (Young 2008e) was rather irregular in plan but was approximately 0.36m diameter at the level of truncation (although slightly wider towards the base because the pit sides were overhanging).

The nature and purpose of paired furnace installations is far from clear. It is usually assumed that this is a method of allowing a smelting team to have one furnace under repair whilst the other is in use, with minimum complexity to the realignment of the bellows system. If this interpretation is correct, it has considerable implications for the intended intensity of the iron smelting activity. Such a furnace installation would not be required for occasional use.

Other interpretations are possible however, and a paired installation might be more structurally stable than having isolated furnace shafts.

Just to add to the stratigraphic problems, the database of 14C dates gives the two dates from Clonrud 4 as (Clonrud 4:E2167:F2:S6) and (Clonrud 4:E2167:F10:S5). F2 is natural, and it seems likely that this date was misread from F7. If so, there is one date from each furnace. As commonly occurs in such circumstances the date from “F2” (?F7) taken on oak is 335 uncalibrated 14C years older than the sample from F10 taken on willow. Dates on oak from furnace fills are notorious for giving “old” ages, since the “used” charcoal has almost always lost its superficial wood, so fragments are of unknown age at time of burning and oak may be very old. The two dates together do however indicate that these structures are probably Iron Age, very likely at some date within the 4th-1st centuries BC (S6 is calibrated as 790BC to 500BC (93.5%) and 440BC to 410BC (1.9%); S5 is calibrated as 360BC to 90BC (95.4%)).

The 4th to 1st century BC date is significant, for it permits comparison of the double furnace with those at Derryvorrigan 1 (probably dated to 1st century BC / 1st century AD) and at Derrinsallagh 4 (apparently with the period 4th century BC to 1st century AD).

In summary, the Clonrud furnaces appear to have been constructed as a paired furnace installation. They have roundedly rectangular basal pits, which appear to have been surmounted by shafts with at least one straight face (presumably the blowing wall). The shaft sides may have had overhangs leading to, perhaps, a bottle shape rather than a more cylindrical form, though how the paired shafts were shaped is conjectural. The slagpits contain small quantities of slag left in-situ, and the adjacent waste pit contains large slag pieces, possibly from refurbishment of the furnaces.

Evaluation of potential

The limited nature of this site means that there is a reasonable degree of confidence that all the residues recovered are linked into smelting in these furnaces, and so although they may not necessarily derive from the same smelt, they are likely to be representative of the same technique, the same technology and the same raw materials. This means that detailed analysis of these residues may be able to add considerable detail to understanding of the way in which these furnaces worked.

Retention of these materials is therefore recommended, with a view to a campaign of detailed further analysis of a representative suite of residues.

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F	sample	Sample wt	wt	no	notes
6	7	1500	1500		some flat-faced vitrified lining, but mainly powdered lining debris
6	7	2600	2600		fired clay debris
7	3	1825	1825	61	unwashed flow slag n large pieces
7	16	798	798	c600	flow slag in small prills mainly, coffee bean spheroids and associated sinter (very dark and fresh looking)
9	8	3215	1860	27	mainly grey-buff lining, with vitrified face, particularly over stone clasts. Vitrification mainly clear green glass, more iron-rich glasses/slagging restricted to just a few pieces. Flat to very slightly convex.
9	8	3690	3180	c200	orange oxidised fired clay fragments
10	4	138	88	8	flow slag
10	4	138	22	1	slagged clay
10	4	138	28		broken up fired clay
10	15	104	34	39	coffee bean and other spheroids
10	15	104	10	18	fired clay
10	15	104	26	28	sinter
10	15	104	2	2	prills
10	15	104	27	13	slag fragments
10	15	104	1	1	roasted ore?
10	15	104	4	7	stones
11	1	1450	1450		fired clay debris
13	5	3340	3340	2	2 massive, dense slag blocks - one probably a burr
13	6	3450	3450	2	2 large blocks of flow slag attached to sandy material - probably the foot of the wall
13	7	552	552	1	large block of furnace lining with a big apparently horizontal groove in it - clearly a discontinuity at base of shaft? -or top of bloom?
13	8	2660	2660	43	flow slags with some associated lining
13	9	228	228	2	2 pieces of extremely well vitrified furnace wall
13	9	2960	2960	28	wall related slags with lining attached, plus top of main "furnace bottom" bowl edge, plus small bits
13	10	3595	2920	7	large blocks of flow slag associated with wall/floor
13	10	3595	674	1	vitrified lining with patch oxidised fired, so probably near blowhole
13	11	3553	2955	58	flow slags
13	11	3553	598	9	lining
13	12	1244	692	c400	flow slag in small prills mainly, coffee bean spheroids and associated sinter
13	12	3430	3430	48	large pieces of flow slag - in part fused onto sandy base
13	13	3520	3520	58	flow slag mainly in large blocks

Table 1. Summary catalogue by context and sample

F	sample	context wt	wt	no	notes
Furnace 1					
10	4	138	88	8	flow slag
10	4	138	22	1	slagged clay
10	4	138	28		broken up fired clay
10	15	104	34	39	coffee bean and other spheroids
10	15	104	10	18	fired clay
10	15	104	26	28	sinter
10	15	104	2	2	prills
10	15	104	27	13	slag fragments
10	15	104	1	1	roasted ore?
10	15	104	4	7	stones
9	8	3215	1860	27	mainly grey-buff lining, with vitrified face, particularly over stone clasts. Vitrification mainly clear green glass, more iron-rich glasses/slagging restricted to just a few pieces. Flat to very slightly convex.
9	8	3690	3180	c200	orange oxidised fired clay fragments
Furnace 2					
11	1	1450	1450		fired clay debris
7	3	1825	1825	61	unwashed flow slag n large pieces
7	16	798	798	c600	flow slag in small prills mainly, coffee bean spheroids and associated sinter (very dark and fresh looking)
6	7	1500	1500		some flat-faced vitrified lining, but mainly powdered lining debris
6	7	2600	2600		fired clay debris
Pit F4					
13	5	3340	3340	2	2 massive, dense slag blocks - one probably a burr
13	6	3450	3450	2	2 large blocks of flow slag attached to sandy material - probably the foot of the wall
13	7	552	552	1	large block of furnace lining with a big apparently horizontal groove in it - clearly a discontinuity at base of shaft? -or top of bloom?
13	8	2660	2660	43	flow slags with some associated lining
13	9	228	228	2	2 pieces of extremely well vitrified furnace wall
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13	12	3430	3430	48	large pieces of flow slag - in part fused onto sandy base
13	13	3520	3520	58	flow slag mainly in large blocks

Table 2. Summary catalogue ordered by feature

F	*notes*	*flow slag*	*fines*	*large dense slag pieces*	*indeterminate slag*	*sinter*	*ore?*	*fired clay*	***total***
Furnace 1									
10	*lower fill of Furnace 1, 0.46m x 0.43m x 0.08m. Dark charcoal- and slag-rich deposit*	90	34	0	27	28	1	60	***240***
9	*Upper fill of Furnace 1, collapsed superstructure*	0	0	0	0	0	0	5040	***5040***
Furnace 2									
11	*fired clay surrounding pit*	0	0	0	0	0	0	1450	***1450***
7	*lower fill of Furnace 2, 0.46m x 0.41m x 0.11m. Dark charcoal- and slag-rich deposit*	1825	798	0	0	0	0	0	***2623***
6	*Upper fill of Furnace 2, collapsed superstructure*	0	0	0	0	0	0	4100	***4100***
Pit F4									
13	*lower fill of waste pit 1, 1.1m x 0.40m x 0.40m. Dark charcoal- and slag-rich deposit*	21895	692	3340	0	0	0	1463	***27390***

Table 3. Distribution of residue type by feature and context

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