Evaluation of Archaeometallurgical Residues from the Heath-Mayfield N7 development

(03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)

Dr T.P. Young

Abstract

This report evaluates the metallurgical residues from eight sites on the N7 Heath – Mayfield development. Seven of the eight sites provided evidence for iron-smelting, with a wide range of provisional dates from Iron Age to Medieval. Two of those sites also provided evidence for iron-working (smithing), as did the eighth site. The slags indicate an essentially similar iron-smelting technology across these sites and periods, employing a slag-pit shaft furnace, but subtle differences emerge and these are explored as possibly representing temporal variation in technology. The wide distribution of iron smelting sites across the landscape suggests a dispersed "industry". The iron smelting slags have great potential for advancing understanding of these sites and of the smelting technology and should be the subject of further detailed analysis.

This report also discusses the structural evidence for metallurgical processes, including smelting furnaces and charcoal-production pits. Two sites have produced slight evidence that the Irish slag-pit shaft furnaces may have had furnace arches, as recorded for somewhat similar non-slag tapping shaft furnaces elsewhere and the primary field evidence for this should be re-examined in detail. It is tentatively suggested that both the size of smelting furnaces and the size/shape of the charcoal pits may have some temporal significance.

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Background

This report is an evaluation of archaeometallurgical residues, mainly slags, from sites on the Heath – Mayfield N7 development excavated by various directors for Valerie J Keeley Ltd (VJK). In addition to the evaluation of the residues, comment is also made here on the significance of the associated structures.

The archaeometallurgical residues have been evaluated by brief visual inspection and the use of a lower-powered binocular microscope. Descriptions and interpretations of material are necessarily limited by this approach.

Site information is based on copies of interim reports supplied by VJK.

This report should not to be taken as a final interpretation of the materials described herein, but is a brief catalogue, description and interpretation of the materials, together with an evaluation of their potential for further post-ex investigation with recommendations for the form those investigations should take.

This report makes extensive reference to a previous report written for VJK summarising the evidence for the nature of early Irish iron smelting furnaces (Young 2003c) based on finds from four sites evaluated for VJK (Young 2003a, 2203b, 2003d). It is recommended that this report be read alongside that earlier summary report.

Ballydavis 2, Site A, 03E0151

Description

The catalogue for this site is presented in Appendix 1 p. 12 of this report.

The area of the main part of Site A yielded only a very small quantity of slag; just over 1000g:

A pit in Group 1 (c702) contained a piece of vitrified hearth or furnace lining.

In Group 2, the hearth close to entrance of the enclosure (c298) yielded a single small piece of dense slag prill, which is very likely to be from iron smelting, but which is unlikely to be good evidence for the function of the hearth. No dimensions are given for this feature, so no comment can be made on the likelihood of it being a furnace. A fill of a burnt pit (c257) yielded several small pieces of residue, including pieces of "smithing floor", a concretionary deposit with charcoal, slag and hammerscale, which often accumulates around the anvil in a smithy. Again, the evidence is very slight, but may well indicate that iron-working was undertaken in this area.

In Group 5, the ditch fills of each of the interlocking ditches yielded a single small piece of dense slag, both probably from iron smelting (c402 and c576).

In Group 6, immediately to the south, a circular pit yielded two small pieces of iron slag (c1141).

The enclosing ditch, Group 7 (c150, c202), yielded 3 larger pieces of slag, all of which are probably parts of smithing hearth cakes (SHCs). The pieces are very different from each other in detail and include pieces of both low density and high density SHCs.

A single small piece of an SHC with adhering flake hammerscale was retrieved from the fill of the burial pit, in test trench C (c33).

1853g of residues were retrieved from features from Group 8, mainly contexts 1032 and 1056, the fills of pits 1031 and 1062. These two assemblages are very similar, and comprise dense small prills, slag films, slag "flats" (which resemble slag picked up on a poker tip, but which may be slag coatings from charcoal particles), slag blebs/spheroids ("coffee bean" morphology) and sintery appearing, often rather rusty, small slag masses. These materials mainly resemble the fine-grained debris from the base of an iron-smelting furnace, but the associated fines in c1056 (especially those from sample 1016) are extremely rich in flake hammerscale, and indicator of iron working (smithing). In addition a fill (c1088) from the keyhole shaped feature (c1108) contained a single nub of slag of uncertain origin.

In Group 10, a hearth fill (c313) yielded a single piece of worn slag, possibly from iron smelting.

Interpretation

The finds from within the main enclosure are fairly insubstantial. They indicate that both iron smelting and iron smithing were taking place, or had taken place, in the area, but do not provide good evidence for a focus to that activity. The multiple fragments of smithing floor in the Group 2 pit (c257) are suggestive of activity in that area, because such materials do not normally survive much transport; but this is certainly not conclusive. It is also worth noting a broad similarity between the size of the area occupied by the features inside the Group 2 enclosure (c11m diameter), the position of the two large postholes at the entrance and the hearth between them, with the size and arrangement of the larger stake-wall Iron Age roundhouses, particularly J1, at Crawcwellt (Crew 1989, 1998) which contain iron smelting furnaces facing, and framed by, the entrance.

The fine-grained smelting debris assemblages recovered from the two pits in Group 8 (c1032 and c1056) are suggestive of *in-situ* residues, and are broadly similar to material from the basal pits of iron smelting furnaces elsewhere (Young 2003c). However, the co-occurrence of large quantities of flake hammerscale must indicate either the furnaces had dual roles as smelting furnaces and smithing hearths, or else that this is dump deposit of mixed origin. Crew (1998) provided evidence that the Iron Age shaft furnaces at Crawcwellt were reused as reheating hearths for bloomsmithing once they had been abandoned as active smelting furnaces. The provided field descriptions are insufficient to judge whether the deposits might have been produced *in-situ* or whether they are fills.

Discussion

The presumed Iron Age date of the smelting furnaces in Group 8 places them as probably the earliest examples within this project; confirmation of this is very important. The location of any metalworking within the main enclosure remains rather speculative, although there is some slight evidence for smithing and just possibly smelting within the penannular enclosure of Group 2. More convincing is the evidence for smelting and smithing having been undertaken in the furnaces belonging to Group 8, in the ground between Ballydavis 2 and Ballydavis 1. The occurrence of ironworking within an apparently ritual location

parallels the evidence from Tara (Crew & Rehren 2002).

Ballydavis, Site B, 03E0966

Description

The catalogue for this site is presented in Appendix 1 p. 14 of this report.

Residues were recovered from the fills (c16, c18) of two features (c15 and c17 respectively) that were tentatively identified as smithing hearths.

The fill of the larger "hearth" (c16) yielded a very large number of pieces of prills, flow lobes and small stalagmitic slag masses (total 1554g), all of which are indicative of an origin in the basal pit of an iron-smelting furnace.

The fill of the smaller "hearth" yielded just two, larger, pieces of slag (total 218g) indicative of slag flowage down the wall and across the base of an iron-smelting furnace.

Interpretation

The material from the larger hearth (c15) is typical of material from the base of the pit of non-slag tapping smelting furnace of the type known elsewhere. These deposits from the very base of the pit often appear to have escaped the clearance of debris from the furnace bottom at the end of a smelt, and are very likely to have been essentially in-situ in the feature, which is therefore probably to be identified as a smelting furnace, rather than a smithing hearth. The feature is unusual, however, if it is indeed the basal pit of a smelting furnace, because it is very deep (0.58m) for this type of feature. In the lack of a section of the feature, it is suggested that much of this depth may have been taken up by c22, which is suggested to have been a lining. The slag assemblage appears to be limited to c16 (on the bass of the submitted material, the context list implies slag occurs in c19 as well, which was not seen for this report), which has a reported maximum thickness of 0.20m, much more in keeping with the pit depths recorded in other instances (see Table 1 below). Why the basal pit should have been dug approximately 0.4m deeper than necessary is not known. The diameter of the feature at 0.33-0.34m is consistent with other early furnaces of this type, as is the presence of vertical pit sides.

The smaller "hearth" (c17) is also of appropriate size (0.28m diameter, 0.10m deep) for an early iron-smelting furnace. The slags contained within it are smelting slags, but comprise a small assemblage of larger pieces, in contrast to the larger quantity of smaller material in c15. The evidence is thus compatible with c17 also being the basal pit of an iron-smelting furnace, but the evidence is slightly less conclusive.

Discussion

The small smelting furnaces on this site can be compared with those of Celbridge 5 (three examples with diameters of 0.29m and depths of 0.15 to 0.26m, one of which widened to 0.37m maximum width at the base; Young 2003b, 2003c), Carrickmines Great (0.37m diameter and 0.09m deep; Young 2003a, 2003c) and the smallest example at Cappakeel West (0.26m; this report, see below). It is not yet known whether small size is a feature of earlier furnaces, but it remains a possibility. Dating of this site is very important, for extremely few prehistoric iron-smelting sites are known in Ireland.

Morrett, Site D, 03E0461

Description

The catalogue for this site is presented in Appendix 1 p. 15 of this report.

This site produced abundant evidence for iron smelting with features interpreted during excavation as "bowl furnaces" and charcoal pits in Areas A and B, and a further possible furnace in Area C.

Area A
Two adjoining features (c324 and c172) were described as "bowl furnaces", although the supplied documentation was contradictory on which was the earlier. C324 is described as being 0.9m in diameter and 0.02m deep; c172 as 0.60m diameter and 0.18m deep.

C324 with its fills c323/327 yielded approximately 1kg of a rather derived-looking assemblage of smelting materials, including various types of slag and lining fragments.

C172 with its fills c174/175 contained 1.1kg of a mixed assemblage of larger pieces of slags, including burr fragments, pieces with a prilly texture, lining fragment and some dense slags bearing moulds of very large charcoal fragments. As with the fills of c324, this assemblage would be best interpreted as secondary dump of smelting-related materials, rather than an *in-situ* collection of pieces left in a furnace after smelting.

Area B
This area contained three "bowl furnaces" clustered closely together. In each case the excavator notes most of the slag was on the floor of the furnace and against one side.

C140 was a circular feature 0.37m in diameter and 0.19m deep. The fill of the feature also appears to be assigned to c140, apart from a basal charcoal-rich later. The main fill contained 1.5kg of isolated prills and sintery material, slags consistent with an origin on the base of a basal pit for a smelting furnace.

C141 was recorded as a larger feature, 0.56m diameter and 0.28m deep, but c193 appears to be a burnt lining to the feature, so the functional pit would have been slightly smaller (no section or details are available to the author to confirm the dimensions). Slag was archived against the cut number (c141) as well as two fills (c164 & c177; an upper clay fill and a lower charcoal-rich deposit respectively). Material from c141 and c164 includes a variety of material types commonly encountered at the base of smelting furnaces, including sintery-appearing slags, prills, moulds of charcoal fragments and "coffee bean" morphology droplets. The slag from c177 however appears to be pieces of a single broken prilly slag cake with coarse charcoal moulds, of which further fragments appear in c164, giving a total weight of this material of approximately 5.6kg. This material closely resembles the textures seen in the large slag cakes found in the upper part of the basal pits of iron smelting furnaces elsewhere (e.g. Young 2003c, 2003d). Such a slag cake might be termed a "furnace bottom" *sensu* Crew 1986. However, it seems clear from the evidence available from the Irish furnaces that the block does

not form in the bottom of the furnace, but slightly higher in the shaft, immediately below the bloom.

C142 was another large feature, 0.67m in diameter and 0.18m deep. It is recorded as having a single fill, c163. C163 contains 2.2kg of residues comprising large slag pieces, including burr fragments, a piece of slag accumulation from the foot of the pit wall on the blowing side and a block with very large charcoal moulds, together with a large proportion of wall and lining debris. This is not likely to be an *in-situ* assemblage, but comprises the coarse debris from clearing out a furnace and the demolition or repair of its superstructure.

Area C
C3397 (=c335?), an upper fill of or adjacent to a corn drying kiln, yielded 5.5kg of smelting related debris (dense slags with very large charcoal moulds, down-wall flows, prills, stalagmitic slag accumulations), but also has a possible large tuyère fragment, much vitrified lining, and slags with a flow-lobed base overlain by an inclined body of granular slag. This is not an *in-situ* deposit. The possibility exists that some of the residues from this context (particularly the dense slag pieces with smooth, blown tops and the possible tuyère material) might have been produced during iron-working rather than smelting.

Interpretation

The material divides into assemblages of two types:

1. material from "furnaces" c140 and c141 only includes residues likely to be found in the lower part of the basal pit of an iron smelting furnace and it is very likely, therefore, that these assemblages are *in-situ*.

2. the assemblages from "furnaces" c324, c172 and c142, together with that from the corn drier (c335) in Area C all contain mixed assemblages which represent material cleared from the smelting furnaces during cleaning and repair. That does not preclude these features from being furnaces themselves, for disused furnaces were commonly employed as dumps during subsequent activities. The description of c335, in the Area C corn drier, seems to imply that this is not a furnace, but is a dump or spread of material.

The description of c324 indicates a larger size than normal for a smelting furnace (the description states 0.9m diameter, although the plan suggests that this may be the long-axis of a pit of a rather narrower width) and a shallower than normal depth (only 0.02m depth preserved). Nor does the description explicitly state there was in-situ burning. It is possible that c324 is a working hollow associated with furnace c172 rather than being a separate hearth/furnace. It is even possible that it is an example of the sort of pit in front of the furnace arch recorded by Crew (1989, 1998) in some examples of his non-slag tapping furnaces in north-west Wales. This shallow pit provided access to a furnace arch for the clearance of slag from the furnace by raking, or by breaking-out when cold. No evidence yet exists for such a feature in the Irish examples of non-slag tapping furnaces, which have a much more substantial basal pit than Crew's furnaces, but this arch/pit arrangement is possible. A similar situation may exist with c341 and c345 at Cappakeel (west) which are linked by a channel (c347), and which is discussed further below.

Features c172 and c142 are both large (0.60 and 0.67m diameter respectively), but both may be smelting furnaces. The large diameters may indicate the pits were originally lined, but this is not reflected in the recorded stratigraphy. Alternatively, these large diameter features may not be smelting furnaces but other features, perhaps smithing hearths (although there is no evidence for this) or ore-roasting pits, that were filled with smelting debris on abandonment. Finally, one possibility worth considering is that when the material in which the basal pit of a smelting furnace is cut becomes heated, it may show a strong change of colour and texture, which sometimes induces excavators to interpret it as part of the fill of the feature, with the consequence that the true pit becomes substantially overdug.

Discussion

The collection of iron smelting residues from Morrett is a very significant assemblage.

Much of the material recovered from Morrett appears to be residues dumped into pre-existing features for disposal. Two furnaces (c140 and c141) have apparently in-situ residues. In the case of c140 these are similar to the basal residues found in several other furnaces during this project, but the material in c141 includes a substantial part (approximately 5.6kg) of a charcoal-rich slag cake. This material does not include all the features expected of a "furnace bottom", and although fragmented, appears to represent just the distal and lower parts. It would appear likely therefore that the furnace was partially cleared after the smelt producing this slag. This likelihood is strengthened by the slag assemblage from c164, which apparently overlay the deposit, c177, containing the slag cake debris. The residue assemblage from c164 is similar to that from the basal deposit of furnace c140, in including prills, spheroids and sintery-appearing residues. This suggests that the furnace may have been again, despite having the only partially cleared slag cake within the pit.

The archaeometallurgical resides and features from Morrett appear slightly different from those of other sites in the project. The nature and implications of these differences are discussed further below (see Summary).

Cappakeel, Site F (west), 03E0603

Description

The catalogue for this site is presented in Appendix 1 p. 18 of this report.

Evidence for seven "bowl furnaces" was recorded from the area of Trench 19 and its extension. Five of these features have corresponding slag collections (239, 240, 299, 334 and 342), and two (341 and 345) do not. In this area residues were also recovered from the upper fill of a pit (c268).

Furnaces 239, 240, 299, 334 and 342 each have a single fill context (253, 254, 310, 335 and 344 respectively). However, for furnaces 240 and 342 slag has been archived under the cut, rather than fill, number and for furnace 239 slag has been archived separately under both the cut and the fill number.

The material from these five furnaces forms a very coherent group and can be described together. The quantities of slag involved are fairly small, and the slag is dominantly in very small pieces. The slags include forms that are prilly, with the prills generally being from

vertical flow; there are very few pieces showing cross-floor flow over any significant distance. There are many examples of stalagmitic morphology, where slag has dripped to the base of the furnace and built up a stalagmite, with very little lateral flowage. There are some roughly lobate slags, with lots of inclusions of ashy material and some sediment, suggesting interaction of the descending slags and the furnace floor. There are very few examples of isolated spheroids. Context 344 (furnace 342) was described in the narrative as containing possible tap slag; in fact this material includes prills and a few cross-floor flows, but not tap slag.

Furnaces 239, 240, 299, 334 and 342 have maximum diameters of 0.36m, 0.45m, 0.41m, 0.34m, and 0.26m, with maximum depths of 0.21m, 0.25m, 0.25m, 0.11m and 0.22m respectively.

Features identified as potential furnaces during excavation include c341 (maximum diameter 0.5m, depth 0.13m), which had no indication of burning, and c345 (maximum diameter of 0.35m and depth of 0.09m), which did have signs of burning but contained no slag. Unfortunately the slag from the fill (c343) of c341 was not present in the submitted material. C341 and c345 were linked by a shallow channel (c347) 0.3m long and 0.22m wide. These two features may be linked as furnace and working area, in a similar manner to that proposed above for c324 and c172 at Morrett, site D.

The upper fill (c291) of pit c268 yielded a very different style of residue assemblage, with 177 pieces totalling 19.3kg (i.e. average piece size of 108g compared with an average of 11.5g for the slag pieces in the furnaces). The collection from this context includes large slag blocks, probably derived from the blowing wall side of the furnace, with well-developed burrs from the zone just below the blowhole and dense slag blocks with large charcoal or wood moulds from the foot of the wall. There are also some well-developed cross-floor slag flows, and a large number of large blocks of highly vitrified furnace wall. The blocks with the coarse wood/charcoal moulds suggest that these reached sizes of least 60x40x120mm and probably much larger. One piece gave an outer contact, the curvature of which would have suggested a diameter of 550mm (although the pit might not have been circular). In the site narrative the lower fill of this pit was also recorded as containing slag, but this material was not seen.

The fill (293) of the possible ore-roasting pit (264) was reported as containing slag, but this material included burnt stone with secondary iron pan and not slag.

Interpretation

The iron smelting residues from this site show some slight differences with those from some of the other sites in the project; in particular the within-pit fines suggest a rather viscous slag - there are few cross-floor prills in the assemblage for instance.

Another interesting detail of slag distribution on this site is that the slags remaining in the furnace appear to be essentially in-situ, uncleared fines. The coarse fragments of “furnace bottom” and lining have been deposited elsewhere. The occurrence of a dump of 19kg of such material in pit c268 provides an instance of such a point of deposition.

Discussion

The differentiation of process with the whole of Cappakeel Site F may be very significant if the features of the west and east sections of the site are contemporary. Cappakeel East provides evidence for iron working (possibly bloomsmithing) of earlier Medieval date, whereas Cappakeel West has produced evidence for a cluster of iron smelting furnaces (of uncertain date) lying close to a former stream course (discussion of Site F as a whole is complicated by the area known as Cappakeel West 03E0603 actually lying to the east of that known as Cappakeel East 03E0633). If the two parts of the site are contemporary, then it suggests that smithing was an activity associated more with the focus of settlement (as suggested by the ditch in Cappakeel East) whereas smelting was taking place outside (in this instance in a probable streamside location).

Cappakeel, Site F (east), 03E0633

Description

The catalogue for this site is presented in Appendix 1 p. 23 of this report.

The residues from this site are not very abundant (a total of 4.2kg) and derive (apart from a single piece in the topsoil) from just three features:

- the upper fill of charcoal pit c82 in Area 1

- the early medieval ditch c24 (c52, 54, 55, 65; note that c54 is incorrectly attributed to ring-ditch c20 in the context catalogue) in Area 2

- pit c280 in Area 2 (according to the context catalogue, but this pit appears in neither the narrative nor the available plans)

Material listed from c204 was not slag.

The upper fill (c66) of the charcoal pit c82 yielded a single small, worn fragment of the basal crust from a smithing hearth cake (SHC), which is likely to be residual. Other pieces in the assemblage were stone.

Both the primary and secondary fills (C281 and c279 respectively) of the pit c280 yielded small quantities of degraded slag material, comprising a total of 29 pieces from the two contexts with a total weight of 245g, of which 168g was provided by a single SHC fragment from c279. All these pieces are compatible with an origin in a smithing hearth, although much of the material is too small for a positive identification.

The medieval ditch c24 yielded a total of 15 pieces of slag weighing 3.9kg. The basal deposit of the ditch (c55) yielded a single piece (502g) from the base of large, open-textured SHC, with only a thin crust on the base. This piece has a tool mark on the base suggesting the use of a 30mm wide poker.

Intermediate fills (c54, c65) yielded a large (1815g) block, probably comprising less than 50% of an SHC with a moderately thick basal crust, a probable slag cast of a poker tip measuring 15-20mm by 8mm, together with several smaller pieces, mainly from charcoal-rich textures.

The uppermost fill (c52) yielded a block from an SHC, probably comprising less than 20% of the original cake, which had a moderately dense basal crust, a block from the upper margin of a charcoal-rich SHC, showing a possible contact zone with the underside of a tuyère, a large part (98g) of a small dense SHC, and a variety of other small pieces, mainly of charcoal-rich textures of slag.

The slag piece from the topsoil was of an internally pale and vesicular slag with a maroon external surface. This piece is probably a smithing slag and may be of relatively recent origin.

Interpretation

The material found within the pits was rather degraded and should not necessarily be taken as indicative of filling of the pits being contemporary with iron working activity.

The material from the medieval ditch was also somewhat degraded, but the material appears likely to be broadly contemporary with the ditch. The presence of the large, open textured SHCs, with weights ranging up to well above 3kg, is a typical feature of Irish early Christian iron-working sites, although there is some evidence that similar residues may also have been produced into rather later periods. These large SHC sizes are very likely to be associated with bloomsmithing rather than the smithing of finished iron into artefacts. In general the type of smithing slags present in the ditch is entirely consistent with the other artefactual evidence from the ditch dating it to the earlier medieval period.

Discussion

Cappakeel East is significant for providing some evidence for the location of bloom refining. The number of smelting furnaces located during this project is not matched by finds of locations for bloom refining and smithing. This is likely to reflect the organisation of the chain of production, with the smithing being focussed on settlement, but much of the smelting taking place outside the settlements and nearer the raw materials.

Jamestown, Site I, 03E0679

Description

The catalogue for this site is presented in Appendix 1 p. 26 of this report.

The assemblage of material from this site comprised 128g from c5 (F8) and 126g from c24 (F12). F8 and F12 were a pair of adjoining pit-like features with strong evidence for *in-situ* burning. The slag pieces were small (average 6.8g).

Both contexts yielded slags, which appeared like sinters, but which probably comprised small slag particles, abundant fine charcoal and ash, cemented by a mixture of flown slag and corrosion. Such materials have been recovered from contexts on other sites of this project that are interpreted as the basal pits of iron smelting furnaces. In addition the assemblages both contained dense prilly slags, in some cases enclosing charcoal fragments, which are also indicative of an origin in such an iron-smelting furnace.

Interpretation

Given the small size of the assemblages and of the pieces comprising them, it is very likely that they are essentially *in-situ*, and the features should be interpreted as the remains of iron smelting furnaces.

Discussion

Although the slag assemblage from this site was extremely limited, it clearly demonstrates that iron smelting was undertaken. The excavations revealed many other burnt features on the site, and it is to be hoped that examination for micro-residues in soil samples might reveal whether more of these were associated with metalworking, and indeed whether there is any evidence to link the metalworking with the only dated feature on site, a medieval pit.

Lughill, Site L, 03E0602

Description

The catalogue for this site is presented in Appendix 1 p. 27 of this report.

The material from this site comprised 3 pieces of descending dense iron slag prill from F7 and a single complex descending lobate prill from F7b. In both cases the descent of the prills had been deflected around large pieces of charcoal. The total amount of material was only 204g.

Interpretation

The descending prills are good indicators of iron smelting in a non-slag tapping furnace with a basal pit, as seen on other sites on this project.

Discussion

As with Site I, the assemblage from this site is very small, but indicative of iron smelting. As also with site I, the context of the furnaces was unclear; for instance whether they were truly isolated, as appears taking the field evidence at face value, or whether they were associated with settlement.

Kill, Site O, 03E0635

Description

The catalogue for this site is presented in Appendix 1 p. 28 of this report.

The material from this site all originated in a large, possibly defensive, ditch F3.

The assemblage includes 5 pieces (1.1kg) which are from iron smelting in a non-slag tapping furnace, 4 pieces (1.3kg) which are complete or partial smithing hearth cakes (SHCs) from iron working and 12 pieces (0.5kg) which are not diagnostic of process.

The smelting slags include dense slags bearing moulds of large charcoal or wood inclusions, and which suggest a furnace diameter of approximately 400mm, and slags with flow lobes, either stacked against the pit wall, or freely flowing on the furnace floor.

The SHCs include a small example (290g), but also several pieces (280g, 390g and 340g) which are small fragments of much larger cakes. At least two of those pieces are from cakes with a very thin basal crust and internal slags rich in fine fuel moulds.

The more indeterminate material includes a dense burr fragment, 2 pieces of vitrified lining, plus a variety of other iron slag fragments.

Interpretation

The interpretation of this material is limited by the rather small quantity, and by its deposition in a ditch rather than having association with any metallurgical features.

The smelting slags are of a type found from the Iron Age through to at least the medieval period. The occurrence of relatively large pieces in a ditch is in keeping with the pattern of dispersal of the more substantial slag fragments seen on other sites in this project.

The smithing slags are equally undiagnostic of age, but the large SHCs with a very thin basal crust appear on current evidence to be typical of sites of Early Christian age and probably continuing into later periods, at least in some parts of the country. Precisely how recently this technology continued in use is uncertain, but is being addressed through new data (e.g. Ballykilmore 6) and more confident discussion of this aspect is likely to be possible soon.

Discussion

Kill site O, provides a tantalising glimpse of a rural iron production site. The presence of a mixed slag assemblage in this possibly defensive ditch hints at a possible close association of the iron production with a settlement. This is interesting, for Early Christian/ Medieval iron production appears to involve process organisational styles where either smelting and smithing make take place at a single central location (e.g. Clonmacnoise, Young 2005) or where the iron-working (presumably including bloomsmithing) occurred at a central settlement site, but where the smelting may have been dispersed outside the settlement (e.g. Clonfad 3, author's unpublished observations).

Summary

The sites on this development add significantly to knowledge of iron-making in central Ireland. The full significance of the new data will only be fully realised once the sites involved are more securely dated.

Smelting

Technology

All the seven smelting sites reported herein employed essentially similar furnaces, which fall within the category of non-slag tapping furnaces commonly known as slag-pit furnaces. The terminology and typology of these furnaces is muddled and obscured by local usage (see discussion in Pleiner, 2000), but a widespread use of this spectrum of furnace types seems to have occurred across Europe in the first millennium BC. However, it is clear that these slag-pit furnaces have given rise to many local interpretations of bowl furnaces, mainly because of poor- or non-preservation of evidence for superstructure. The persistent myth of bowl furnaces for smelting in Ireland has been attacked by Crew & Rehren (2002) and Young (2003c). These Irish furnaces are actually a type of shaft furnace, as so elegantly demonstrated by Crew for Iron Age examples from North Wales (1987, 1989, 1991) and argued for several Irish examples by Young (2003c).

The sites described in this report change little in the basic understanding of the operation of the slag-pit smelting furnace as previously described (Young 2003c), but do add several significant details.

Furnace morphology

Finds of intensely vitrified furnace wall material (particularly those from Cappakeel Site F west, c291) indicate the existence of a substantial clay superstructure to the furnaces as previously proposed.

One of the most significant differences suggested by Young (2003c) between the non-slag tapping furnaces of the Iron Age of North Wales, studied by Crew, and the examples merging in Ireland, was the absence of evidence for a furnace arch in the Irish examples. The present study includes two examples which may provide evidence for such an arch in the Irish furnaces:

1. At Morrett Site D, it is possible that c324 is a working hollow associated with furnace c172 rather than being a separate hearth/furnace. C324 is a shallow (0.02m feature) described as being 0.9m in diameter, but shown on the supplied plan as a per-shaped feature, approximately 0.9m wide distally, narrowing to 0.3m near to C172, with a length of 1.3m. The contact between c324 and c172 was clearly difficult to interpret as two different accounts of their stratigraphic relationship were given. C324 is described as a pit, and does not appear to have evidence for in-situ burning, unlike c172.

2. A similar situation may exist with c341 and c345 at Cappakeel (west) which are linked by a channel (c347). No plan was provided of these features, but the narrative in the interim report states "feature [341] was sub-circular in plan with a maximum diameter of 0.5m and it was excavated to maximum depth of 0.13m"..."this feature did not exhibit signs of *in-situ* burning"; "feature [345] was sub-circular in plan with a maximum diameter of 0.35m and a maximum depth of 0.09m"..."subsoil in the immediate area surrounding the cut was oxidised to a reddish orange colour indicating probable burning *in-situ*. The features [341] and [345] were linked by the shallow cut [347] which was a maximum of 0.3m long and 0.22m wide and was excavated to a maximum depth of 0.1m".

Crew's (1991) reconstruction of the North Welsh furnaces includes an arch 0.10-0.13 wide through the 0.20m thick furnace wall, with the floor of the channel in the arch sloping down into the furnace. It is possible that in the examples from this project, Morrett c172 and Cappakeel West c345 are the bases of smelting furnaces, outside which are working hollows (c324 and c341 respectively), into which slag could be raked, and access to the furnace gained, through an arch, the position of the floor of which is represented by the narrow elongation of c324 and channel c347 respectively.

The new data from the N7 project certainly do not prove the existence of arches in the Irish furnaces, but do provide some circumstantial evidence, which should mean that presence/absence of such evidence in future excavations should be actively sought.

The recorded diameter of the furnace pits is highly variable between, and within, sites. Although, as noted above, it is possible that part of this variation may be variations in the way furnaces are dug (whether excavators over dig and remove baked natural...) and in the way they are built (whether the internal furnace lining is carried down to line the pit, as described by Crew (1987), particularly in unconsolidated subsoils), there appears to be genuine variation in the volume of the slag pit. Some sites, such as Ballydavis Site B of this project and Celbridge 5 (Young 2003b) have small furnaces with diameters of 0.30m, whereas the largest furnaces (such as Morrett Site D, Jamestown Site I and Tullyallen 6 (Young 2003d)) have diameters of approximately 0.50m or slightly more. There is reasonable expectation that the Ballydavis B furnaces are Iron Age, whereas some of the larger furnaces are interpreted as being medieval, but whether there is a general trend in the size of furnaces will not be revealed until all these sites are properly dated by C14.

Site	Feature	Diameter	Depth
This project			
Ballydavis 2, Site A, 03E0151	c1031	no dimensions given	
	c1062	no dimensions given	
	c298	no dimensions given	
	c257	no dimensions given	
Ballydavis, Site B, 03E0966	c15	0.34	0.20
	c17	0.28	0.10
		0.31	
Morrett, Site D, 03E0461	c172	0.6	0.18
	c140	0.37	0.19
	c141	0.56	0.28
	c142	0.67	0.18
		0.55	
Cappakeel, Site F (west), 03E0603	c239	0.36	0.21
	c240	0.45	0.25
	c299	0.41	0.25
	c334	0.34	0.11
	c342	0.26	0.22
	c345	0.35	0.09
		0.36	
Jamestown, Site I, 03E0679	F8	0.55x0.60	0.20
	F12	0.70x0.45	0.10
Lughill, Site L, 03E0602	F7	no dimensions given	
	F22	no dimensions given	
	F18	no dimensions given	
After Young 2003c			
Celbridge 5 01E0306	furnace 1	0.29	0.25
	furnace 2	0.29	0.16
	furnace 3	0.29	0.26
Carrickmines Great 02E0272		0.37	0.09
Tullyallen 6 00E0944		0.5	0.18

Table 1. Comparison of smelting furnace dimensions with previous examples. Figures in grey boxes are site average.

In parallel with the apparent variation in furnace size, there is a variation in the morphology of the slags retrieved from the basal deposits of the furnaces (the Type 1 assemblages, see below). In general, a comparison of the data in Tables 1 and 2, suggests that those assemblages from the smaller furnaces contain the smaller particle size of slag. This relationship is borne out in a simple way by the larger size of prills and basal flows from Morrett compared with material from Ballydavis or Cappakeel. This adds further circumstantial evidence for a genuine difference in the scale of process between sites.

Residue assemblage types

One interesting aspect of the smelting residue assemblages described herein, is that there appear to be a limited number of styles (composition and preservation) of assemblages. There are three broad categories of smelting slag assemblage recognised in this material:

1. dominantly (average usually less than 10g) small pieces of slag in various morphologies:

- slag spheroids of 4-8mm diameter
- sintery-appearing fine slags, with ash, charcoal debris and admixed sediment.
- vertically descending prills
- stalagmitic slag accumulations formed on the furnace floor beneath persistent slag drips
- small cross-floor flows

2. large blocks of coalesced prilly slags with abundant charcoal inclusions, often rather friable. The proximal (blowing wall) side may show development of one of more burrs, down-wall flow, and accumulation of stacked flow lobes at the wall foot. Massive slags developing near the wall foot may enclose large moulds of wood/charcoal often of sizes up to 40x60x200mm. These massive slags may grade laterally into cross-floor flow lobes. These slags blocks may be termed “furnace bottoms”.

3. Fragments derived from the more massive, less friable parts of the “furnace bottoms” described above, particularly the dense slags associated with the blowing wall (burr, down-wall flows, stacked flow lobes, massive slags with very large wood/charcoal inclusions). Typically these assemblages also include large blocks of vitrified furnace lining.

During normal operation of the smelting furnace the basal pit would be cleared of slag after each smelt. The more distal parts of the “furnace bottom” are rather friable and would be likely to become very degraded during extraction and disposal. The dense slags associated with the proximal side of the furnace will become broken-up during extraction, but are physically strong and have a much higher preservation potential. Disposal of this material, together with disposal of material created during repair of the superstructure would create a type 3 assemblage.

The very basal part of the furnace would accumulate deposits of ash and unburnt fuel fragments, but would

also contain the fine residues described as Type 1 above. If the basal part of the furnace was thoroughly cleaned then these would need disposal, but this might be undertaken separately from the large blocks of "furnace bottom" which could be carried by hand. If the furnace was not thoroughly cleaned, then some of this material might accumulate in the basal pit, giving rise to the apparently in-situ deposits recorded from most smelting furnaces recorded on sites in this study (Ballydavis2, Site A; Ballydavis, Site B; Morrett, Site D; Cappakeel Site F West; Jamestown, Site I; Lughill, Site L).

Type 2 assemblages, in which the furnace bottom is intact or largely so, have only been recorded so far in instances where the furnace bottom has been left in-situ, and not cleared from the furnace. In this study only furnace c141 at Morrett, Site D, yielded a substantial part of a "furnace bottom" (approximately 5.6kg). But even here the denser, stronger, parts of the FB seemed to have been extracted. In this instance the finds of Type 1 from above the partial FB hint that it may have been left in the furnace base of an operational furnace. In contrast, the FB encountered at Tullyallen 6, Co. Louth (Young 2003c, 2003d) appears to have survived intact; presumably the furnace was simply abandoned after that smelt.

Site/context	*Weight*	*No of pieces*	*Average weight*	*Assemblage type*
Cappakeel W, Site F				
Furnace 239	532	70	***7.6***	1
Furnace 240	1562	71	***22.0***	1
Furnace 299	262	43	***6.1***	1
Furnace 334	2747	260	***10.6***	1
Furnace 342	2	1	***2.0***	1
Pit 268	19238	177	***108.7***	3
Morrett, Site D				
Furnace 140	1544	165	***9.4***	1
Furnace 141	6307	380	***16.6***	2 & 1
Furnace 172	1090	29	***37.6***	3
Pit? 324	1015	31	***32.7***	3
Furnace 142	2155	9	***239.4***	3
Spread 335	5561	84	***66.2***	3
Ballydavis2, Site A				
1056	604	>242	***<2.5***	1

Table 2. Comparison of average fragment weight and assemblage type for residues recovered from smelting furnaces.

Charcoal Production

A close association between the location of iron smelting furnaces and of charcoal production pits has been noted for several sites, particularly Cappakeel and Morrett.

The charcoal production pits at Morrett may be distinguished from those of the other three sites on the basis of both dimensions and shape (Table 3 and Figure 1). The main body of pits from Ballydavis and

	Context	*L*	*l*	*d*	*L/l*
Ballydavis B	12	1.30	1.10	0.10	1.2
Cappakeel E	82	2.40	1.60	0.41	1.5
	95	1.90	1.10	0.08	1.7
	5	1.80	0.80	0.07	2.3
	93	1.17	0.86	0.08	1.4
	296	1.34	1.08	0.15	1.2
Cappakeel W	267	1.25	0.95	1.00	1.3
	60	1.30	0.75	0.22	1.7
	115	1.35	0.83	0.25	1.6
	220	1.25	0.70	0.33	1.8
	205	2.30	1.39	0.40	1.7
	207	3.05	1.30	0.22	2.3
	234	1.45	1.09	0.39	1.3
	16	3.23	1.55	0.19	2.1
Morrett	126	1.80	1.60	0.53	1.1
	37	1.90	1.60	0.45	1.2

Table 3. Long axes (L), short axes (l) and depths (d) recorded for charcoal production pits.

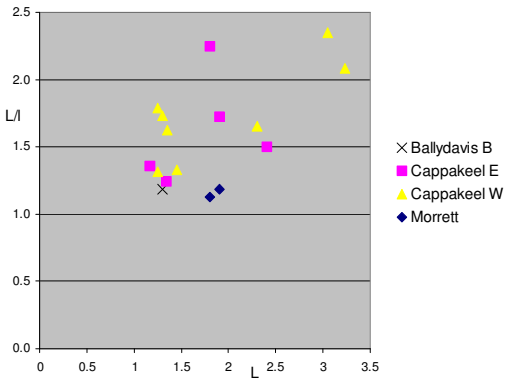

Figure 1. Graph of the ratio of the long to short axis of charcoal pits, plotted against the long axis dimension.

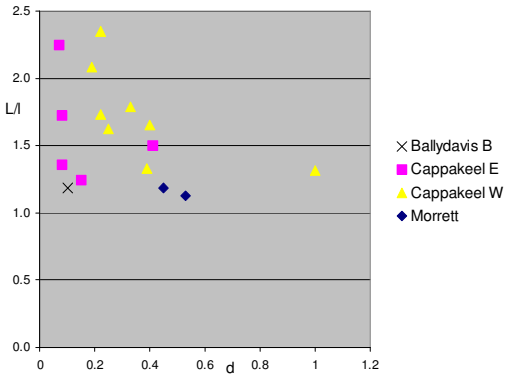

Figure 2. Graph of the ratio of the long to short axis of charcoal pits, plotted against their depth.

Cappakeel forms a trend from small pits (L from 1.2 to 1.4m) with relatively equant shapes (L/l of 1.2 to 1.3) through to large (L from 3 to 3.5m) and elongate shape (L/l of 2.1 to 2.3). These pits are almost all rectangular with rounded corners.

In contrast the pits at Morrett are much more irregular in shape, more equant (L/l of 1.1 to 1.2) and medium sized (L of 1.8 to 1.9m).

The graph of the long/short axis ratio against the depth of the pits (Figure 2) also shows a segregation (with some overlap) between sites. Ballydavis B and Cappakeel E show depths (with a single outlier) of 0.07 to 0.15m, Cappakeel W (with one outlier) shows depths of 0.19 to 0.40m and Morrett has depths of 0.45 to 0.53m. There is some suggestion that the more equant pits on each site are deeper.

These data for charcoal pit morphology should be compared with data from other comparable sites. They appear to emphasise that Morrett is slightly different in character from the Cappakeel and Ballydavis sites; a feature also noted in the characteristics of the iron smelting. It remains to be seen whether this has significance in terms of age of the site.

Smithing

This project produced surprisingly little residue from iron-working. Out of a total collection of some 54kg of slag, only 7kg was attributable to smithing.

A small amount of material (approximately 1kg), presumably Iron Age in date, came from Ballydavis 2, Site A. This material is rather fragmentary, but includes one piece of probable SHC weighing 484g, suggesting the presence of a cake size which might possibly be attributable to bloomsmithing in the Iron Age (Crew & Rehren 2002).

Cappakeel East, Site F produced a small amount of smithing debris (approximately 4kg) from a ditch which is likely to be earlier Medieval in date. The fragmentary SHCs included some material indicative of large examples (greater than 3kg), which seem likely to be indicative of bloomsmithing on early medieval sites.

Kill Site O, produced just under 2kg of smithing slag from a ditch, which also seems likely to be Medieval. This material was very fragmentary, but appeared to contain a spread of SHC size, ranging up from a small 290g example (presumably from blacksmithing), up to small pieces of much larger cakes (possibly from bloomsmithing).

Organisation of the industry

The archaeometallurgical assemblages from this project are unusual. A large number of iron smelting furnaces were located, but in most cases these only contained a small assemblage of smaller slag pieces which had escaped the cleaning of the furnace. In some cases dumps of coarse slag material from the main “furnace bottoms” were found, within abandoned furnaces or other features. However, it is clear that the main slag output of the located furnaces was not seen.

In a British Iron Age example of a similar smelting technology in East Yorkshire, large dumps of “furnace bottoms” survived as mounded landscape features (Halkon 1997). It is possible that a similar mode of disposal occurred with these sites, and subsequent agricultural activity has either degraded the mounds, or they became cleared into the field boundaries.

Equally striking is the relative lack of evidence for the working of the blooms produced in the furnaces. It is apparent that those locations where iron-working slags were retrieved are features associated with settlements (including the “ceremonial” enclosure at Ballydavis 2 and the Medieval boundary/defensive ditches at Cappakeel East and Kill).

Such a differentiation between dispersed smelting and focused bloomsmithing/smithing is a frequent feature of early iron making in the British Isles. It becomes strongly enhanced in the later medieval period when the bloomsmithy often became water-powered, but this functional differentiation is also seen earlier. In part it may have its origins in the large quantities of charcoal required for smelting. The smelting furnace tended to be a clay-built ephemeral structure, so it was relatively straightforward to locate the smelting activity at the point of manufacture of the charcoal. Such ephemeral smelting, following the coppicing or even clear-felling of timber has been described for Coed y brenin, North Wales, for the fourteenth century (Smith 1995). It may lie behind the use of the term “*fabricam arrantem*” in the thirteenth century in the Forest of Dean.

Assessment of Potential

The material described in this report has great potential for both increasing the understanding of the individual sites and as an enormous contribution to Irish archaeometallurgy.

The post-ex investigative programme should try to address the unresolved questions raised in this report concerning some of local details of stratigraphy and furnace morphology, establishing for instance the size of the true furnace pit, and examining further the primary field evidence for the presence of a furnace arch.

Detailed compositional studies of the smelting slags should be undertaken to improve understanding of the technology of the slag-pit furnaces and their yield. The examples of iron smelting all derive from fairly small area (16km separates sites A and O) and are therefore likely to be exploiting very similar resources of bog iron ore (Co. Laois has outcrops of rock ores, but these are some distance from the sites in question). They thus may well form a suitable database on which to model chemical composition and mass balance, in order to determine iron yields (following the approach of Thomas and Young, 1999a and 1999b). Production of mass balance models for the various sites will require a substantial number of chemical analyses from as many different slag types within each site as possible. Understanding mass balance variation between sites will help to illuminate changing technology through time. Although the fundamental technology of the smelting furnace appears not to vary greatly between sites, it appears that the scale of each smelt did vary, best on variations of the slag-pit diameter and of the size of slag prills and flows found within them.

The residues from iron-working encountered in this project are rather less significant, and are less likely to add further to present understanding.

One key factor in the potential of this material is the spread of likely dates for the assemblages. It is absolutely crucial therefore, that before publication all the metallurgical data should be reviewed in the light of C14 dating results.

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Appendix 1: Catalogue of material by context and bag

Site: ***Ballydavis2, SiteA, 03E0151***

Director: ***Grace Fegan***

context	sample	find	find note	total wt	description	deposit	group
33		1019?		78	Somewhat undiagnostic slag lump, but shape suggests margin of SHC. The base is dimpled and the top is rusty with some adhering flake hammerscale.	fill of burial pit, trench C	test
150		60	5020.45E 5022.12N	380	2 pieces, both showing smooth slightly lump outer surface, cf. "thin crust" SHCs. Large piece is vesicular and might be a burr, both probably from vesicular SHCs?	cut for V shaped external ditch	7
202	cut 150 section 3	50	5028, 5000	484	Extremely dense slag lump, showing some exploding due to included iron, lower face convex, probably from base of large SHC, but might just be a dense smelting slag.	fill of external ditch section III	7
257		11		30	4 small fragments of "smithing floor", 1 large lining slag flow of fused gravel, 4 tiny slag pieces, 1 possible bog ore fragment	fill of burnt pit	2
298		12		16	Dense lobate prill, with charcoal moulds and small area of lining attachment.	fill of furnace	2
313		24		32.53	Worn piece of slag, dense, flown around a charcoal mould.	fill of hearth	10
402	cut 140	56		2	Tiny piece of lobate dense slag, probably a prill.	fill of later circular ditch	5
576	cut 150 section 3	29	4997 4998.45	15.98	Small fragment of lobate slag, probably from basal flows, comprises stack of flow lobes.	fill of earlier circular ditch	5
702		53		68	Iron slag/fired wall junction - possibly a burr but not well formed, possibly where ore has got hung up, since wall appears fissured.	fill of pit	1
1032		1018	4954n 4970e	1085	Divides into four classes: 1. Small dense prills, each typically less than 10g (506g), 2 prilly material but hollow - some may be secondary reduction, v small pieces (98g); material that may be sintererd ore and/or charc rich slag (264g) and lastly stoney material - probably mainly natural stone but may include some slag (52g) rest is dust and small frags. Fines have no hammerscale.	fill of slag pit	8
1032		1008		164	6g stone and fired clay, 74g stoney slag, ore frags, and fe-charc material, 38g hollow slags and films, 44g dense prills ands coffee beans	fill of slag pit	8

1056		1011	256	5 small slag pieces (=36g), 3 flats from tongs/poker (=4g), 16 pieces (=32g) of tiny hollow prilly material, 4 pieces (=10g) of fired lining, 1 dense piece cf following probably has iron inside (24g), remainder of material is organic-rich, yellow-brown material, sometimes with flake - possibly fuel residues (89=142g)	fill of slag pit	8
1056		1011	108	7 (=8g) flats, 15 (=6g) coffee beans and hollow blebs, 13 (=8g) of crude possible flats, 23 (=20g) of blebby slags, 96 (=64g) rough material - includes a variety of slags, rusty material and organic-rich material. All in pale ashy matrix	fill of slag pit	8
1056		1016	240	Fines extraordinarily rich in flake scale, 76g rusty looking slags, 39 pieces of which 2 (6g) are flats, all very rich in fine organics; 52g 2 pieces of denser slag, 1 irregular bleb, other rather like basal flow from smelting; 42g irregular denser blebs and lobes, 12 pieces; 6g 6 small stones, 42g 4 pieces of dense slags with granular to microprilly form; 8g bleb of lining slag.	fill of slag pit	8
1088		1017	6	Irregular lumpy slag nub	ashy fill of keyhole cut	8
1141	sieve	1068	14	2 pieces of slag, one weathered showing textures in curious colours, other is iron slag with vesicles with almost cubic crystal terminations.	fill of circular pit	6
			2980	total (g)		

Site: ***Ballydavis, SiteB, 03E0966***
Director: ***Ros O'Maolduin***

context	sample	find	find note	total wt	description	deposit
16		2		1554	820g dense prills 127 pieces, 700g 12 pieces of floor flow-lobed material, looks like tap slag, but generally rather dull, at least one piece shows flow around moderately coarse charcoal. 34g dull irregular nub of dark slag with charcoal inclusions. All slags dense and dark. Some of the basal flows show sourcing in a central drip with radiating outward flows in one case at least, and of stacked lobes on basal obstacle in another.	main fill of larger smithing hearth
18		1		218	152g downwall flow with lobed wrinkly base, 66g flow lobe from furnace floor	fill of smaller smithing hearth
				1772	total (g)	

Site: ***Morett, SiteD, 03E0461***
Director: ***Eamonn Cotter***

Summary

context	sample	find	find note	total wt	description
140		15		1544	Isolated prills plus basal sintery material - see below
141			area 15	330	Fine prilly material - see below
163		26		2155	470g, large block from foot of blowing wall with accumulated downward flows, 270g dense block with very large charcoal impressions, 310g curious burr block, curved face with tighter curved burr incorporated, main curve c.320mm diameter, 564g large slab of vitrifed wall, possibly strongly overhanging with c200mm diameter fracture around b/h?, 416g large block of fired clay, c.150-200mm diameter fired clay, then covered internally with more clay and vitrfied on face at right angles, 120x90x55 mm overall, 76g fired clay piece, 18g small piece with coarse charcoal, 8g green glazed fired clay with adhering small dark slag drops, 4g small slag pieces, 3 small stones.
164		17		717	Prilly material, droplets and "sinter" - see below
174		33	area B	522	Indeterminate dense slags with large amount of lining debris - see below
175		35	area B	568	Not a primary slag deposit - these are massive pieces of probable smelting slags - see below
177		14	(fill of 141)	5260	large body of smelting slag, possibly *in situ* - see below
323		46	area 2	990	derived smelting debris - see below
327		47		25.13	3 pieces and 2 tiny fragments. All of dense slag prills. Probably internal slags from slagpit furnace but only small collection - see below
3397			area 11-12 (fill of 335)	5561	Large collection of material dominantly or entirely from smelting - see below
				17672	total (g)

Details

context	no. of pieces	weight	description
140	8	356	sintery basal material with lots of fine organics, with appreciably high proportion of included blebby slags
	89	434	sintery basal material with fine organics
	1	86	fragment of burr like zone

	4	10	curved lining fragments probably attached to cake outside cf small scale burr
	63	658	blebs prills and lobes not attached to sintery material, this material only has hints of coarse charcoal but does not form an enclosing matrix
		1544	large quantity of fines/washings to be bagged
141	71	318	spectrum of material with prills and charcoal moulds, generally quite dense
	9	12	stones
		330	fines show some thin magnetic pieces but these seem to be shells not scale
164	61	284	dominantly dense prilly with contacts with large charcoal, mainly dense but some shell material.
	11	7	fairly well formed "coffee bean" droplets (4-8mm non-magnetic)
	20	28	less well-formed and multiple droplets
	27	26	gravel
	56	208	granular and sintery material, full of fine organics and fused droplets, >1cm
		164	granular material <1cm, as above
		717	
174	14	178	Rather scrappy convoluted lining fragments, some show strong differentiation of slagged surfaces and later vitrified ones - suggesting failure of wall.
	2	26	Small pieces of indeterminate dense slag.
	2	12	Small dense pieces of orangey material, part slagged, showing strong similarity to Brawdy material
	4	306	Dense slags with large charcoal moulds, 1 at least is quite corroded.
		522	
175	4	166	Slag pieces with prill lobes and large charcoal moulds, v dense,
	1	272	Broken in 2, length of burr, 60x100x40, not clear what sort of slag this is.
	1	122	Piece of burr (?) showing very large charcoal - so may be a smelting furnace burr- possibly a wall foot.
	1	8	Scrap of indeterminate microprilly slag.
		568	
177	125	5260	remarkably homogeneous assemblage of prilly material surrounding large charcoal moulds. There are few discrete prills or blebs - this material looks like a broken large fragile "cake"
			large volume of fines from washing saved for inspection
		5260	

323		1	250	Large piece of burr, has smoothed edges and some corrosion. Looks most like a smelting furnace burr, but can't be certain
		11	458	Dense slags, partly corroded some show a degree of brecciation - apparently fairly early. Most bits probably burr but by no means certain. Mainly angular fragments.
		7	180	Dense prilly and lobed pieces of dense smelting slags.
		7	102	Lining debris
			990	
3397		10	410	Concretionary material, rich in rust, may include organics and pebbbles, largest piece shows cracking.
		7	35	Stones
		1	50	Burr material
		2	28	Dark but probably lining-related slags, slightly maroon surfaces.
		1	22	Chip of very dense wustite-rich slag.
		3	318	Dense slag accumulations from base of furnace, no good flows.
		1	22	Low density basal bleb - feels almost like coke, but forms flow lobe.
		7	70	Angular pieces of granular slags - not clear if any of these might actually be granular bog ores?
		1	72	Dense irregular slag fragment.
		1	762	Large block of slags on wall, with medium charcoal inclusions.
		20	486	Dense descending prills with charcoal moulds.
		1	268	Large block of normal-looking vitrified wall
		6	90	Normal wall fragments
		1	48	Broken piece of indurated wall - possibly adjacent to burr.
		2	56	Lining with adhering iron slag.
			2737	also has 200g of soil in bottom of bag - little or no scale
3397	second bag	1	458	Extremely irregular massive block of pale vitrifed wall. Might be a sub-b/h build-up but not at all obvious. Unusual material with pale wall with dark matt slag surface
		2	58	Granular slag/part reacted ore
		1	314	Dense block of slag with smoothish (blown?) top, massive slag with crystal terminations on lower face.
		1	516	Block of slag with lobate flows on base, overlain by inclined zone of granular slag, top appears dense and compacted zone of slag. Reminiscent of Clonmacnoise material where bloom working in smelting furnace is possibly suspected.

1	244	Dense flows radiation from central descending prill, formed against curved base wall zone, flow base to drip is about 100°.
6	136	smaller pieces of prilly material enclosing large charcoal fragments
1	432	Large block enclosing coarse charcoal. Open textured lobate contact with curved wall. Openness means diameter not estimateable.
1	242	Dense slag block - probably part of furnace floor drip accumulation.
1	128	Lump of odd furnace wall, dimpled matt slag surface on pale surafce grading back into fairly normal wall.
1	16	Slagged lining
2	52	2 small irregular slag lumps
1	100	Burnt stone
2	128	Fired clay as piece in 163 above. Apparently has fired tube at right angle to vitrified surface, curve of (small) length of fired clay suggests tube of 250mm diameter.
	2824	

Site: ***Cappakeel, SiteF (W), 03E0603***
Director: ***Audrey Gahan***

Summary

context	sample	find	find note	total wt	description	deposit
					For details see "details" section below…	
239		77		500	smelting slags from basal pit	cut of bowl furnace
240		78		1562	smelting slags from basal pit	cut of bowl furnace
253		39a		32	small assemblage of smelting slags	fill of furnace 239
291		46		19238	redeposited smelting slag material	upper fill of pit 268
293		49		0	none of this material is slag, this is burnt stone and ash, with a little secondary concretion	fill of ore roasting pit 264
310		83a		262	smelting slags from basal pit	fill of bowl furnace 299
335		64		2	single piece of blebby prill	fill of bowl furnace 334
344		72		2747	smelting slags from basal pit	fill of bowl furnace 342
				24343	total (g)	

Details

context	find	no. of pieces	weight	description
239	77	24	114	Rough textured slags with lots of sediment as well as lobate surfaces. Much of this looks like reaction between slags and sediment.
		1	12	Lobate slag fused to baked floor, fairly low density slag.
		28	374	Lobate slags, mainly stalagmitic and related material rather than free prills.
			500	
240	78	31	162	Simple prills - may be descending, or in some case be the tips of low angle ones.
		17	370	More complicated prills - possible mainly from stalagmites.
		16	938	Stalagmites and also some short basal flows - no really good long flows across floor.
		7	92	Very irregular slag fragments with lots of fine organics, one has lining attached.
			1562	

253	39a	17	32	Small pieces of descending prills
			32	
291	46	1	608	Very dense slab of fired lining. Vitrified layer 35mm thick, slab 160x90 with slightly irregular face.
		1	1010	Dense burr region. Elongate along edge - at least 160mm wide, central smooth iron-slag area 70w x 60 into hearth, triangular, basal surface micro-prilly.
		1	102	Large lining piece vitrified for at least 25mm depth.
		1	50	Lobate piece of lining slag.
		7	350	Discrete prills, grading to charcoal-mouldic material
		6	1140	Pieces of dense slag, locally prilly, with extensive moulds of very large charcoal pieces.
		5	2135	Large blocks of charcoal-mouldic and locally prilly slags with cake margin seen. These blocks seem particularly dense.
		23	168	Lining bits
		14	222	Dense iron slag bits - non diagnostic
			5785	also 36 stone
291	46	14	124	Misc. iron slag fragments
		10	502	Dense prilly iron slag with poor charcoal moulds.
		1	716	Slab of slag down, and interacting with, pit wall. Inside is very large piece of wood 60mm wide by at least 120mm long, piece seems crudely squared, block suggestive of c.550mm diameter pit.
		1	562	Very dense wall slab with some charcoal moulds, essentially slab 100hx55wx30thick.
		1	608	Wall-cake contact area at top, with series of prills dropping 70mm to furnace floor.
		1	376	Column of multiple prills dropping 80mm to furnace floor and starting to spread laterally.
		1	456	Dense slag piece with section of timber at least 40x40x80 long. Right angles seen on either side of 40 face
		1	606	140x90x40, piece looks like small SHC - if so it has very rough top and microprilly base - but this isn't necessarily what it is.
		2	222	Small fragments of dense slag with large charcoal moulds.
		3	446	Unclear fragments of dense slag with burr like contact area.
		14	196	Lining fragments - many look conventional.
		1	188	Large slab of pale wall with almost normal thickness of vitrified layer.
		1	520	Extremely dense block of dominantly pale wall, vitrified from at least 40mm, but shows multiple internal surface, curvature odd - maybe convex.
		3	82	3 small pieces of rather corroded iron-slag

			5604	
291	46	1	1365	Contact area (cf burr) of prilly cake, top rough rusty, thins from 70mm near wall to apparently 15mm 120mm in.
		1	1340	Corroded and messy burr region, appear to be massive below blowhole, thinning rapidly to a thin crust. Wall has some corroding iron in it. Extends 50mm in from burr before dropping rapidly to basal crust.
		1	690	Lip of hollow bowl shaped cake of granular slag. Lip must have iron in it because of rust and explosion. Lip 20-40mm wide, drops steeply down 90mm to lower part where only 10 thick. Not regular enough to estimate hearth curvature.
		11	570	Various, mainly charcoal bearing very dense slags, generally rather massive.
		14	628	Blebby and prilly dense slags, some showing contact with coarse charcoal.
		1	342	Large slab of pale vitrified lining with lots of rusty iron slag adhering to surface, c300 diameter.
		1	242	Large block of lining with multiple internal vitrified surfaces over depth of 45mm.
		8	400	Various blocks of lining, many pale and thickish.
			5577	
291	50	6	592	Prills - probably mainly cross-floor flows rather than descending.
		12	1270	Dense slags with moulds of coarse charcoal, some in very dense blocks.
		6	346	Lining pieces (note for his context lining is very hard, dominantly pale grey, well gritted with chert fragments and other gravel up to 5mm)
		2	64	Indeterminate lumps of iron slag
			2272	
310	83a	39	208	Prilly material - free prills, drops and stalagmites, but mainly in fairly small pieces.
		4	54	Less prilly material with large charcoal moulds.
			262	
342	72	101	574	Isolated descending prills, mainly single and mainly medium sized (5-8mm diameter).
	(prob the 344 above)	9	6	Poor isolated blebs and spheroids, several multiple.
		16	60	Fragments of slags with mainly fairly fine organics, some slightly lobate, all very friable.
		1	4	Flake of vitrfied lining.
			644	
342	72	103	1280	Descending prills, many multiple

(prob the 344 above)	9	710	Stalagmitic material - floor accumulations below prills mainly - very few good floor flows.
	18	96	Rough surfaced organic-rich slags.
	1	16	Rounded bleb of low density slag, partly vitrified surface.
	2	1	Two tiny fragments of vitrified lining
		2103	

Site: ***Cappakeel, SiteF (E), 03E0633***
Director: ***Ros O'Maolduin***

Summary

context	sample	find	find note	total wt	description	deposit
44		2	clean back 38-31		Flat sheet of slag. Internally pale and veiscular, surface has thin brick/maroon coat. Resembles modern forge slags. Top smooth, base dimpled to lobate. One possible hint of charcoal in a broken face, but this is not certain.	topsoil
52		71		476	Large irregular block, seems to have basal curved crust so probably from large SHC, still dense but slightly charcoal-rich above, base irregular, probably less than 20% of a cake	final fill of linear ditch c24
52		73		758	see below	final fill of linear ditch c24
54		18		278	see below	fill of linear ditch c24
55		84		502	Single large piece from base of open textured cake with abundant very fine organics. Small area of probable base seen, but this is interrupted by large ridge - suggesting tool mark on hearth base. This feature is 140mm long, 30mm wide - in one place the mark is square - suggesting the 30mm is the tool width.	primary silt of ditch c24
65		41		1895	see below	fill of ditch c24
66		3		60	see below	upper fill of charcoal pit c82
204		48			Stone	upper fill of pit 206
279		67		222	see below	secondary fill of pit c280
281		66		23	see below	primary fill of pit c280
				4214	total (g)	

Details

context	find		no. of pieces	weight	description
52		73	1	384	Large block from charcoal-rich slag cake; one end has abrupt termination with a sandy surface, if this is the top, could it be base of tuyere? This zone extends in 25mm, if this is horiz, then side dips at 50°, going down 95mm and in 65mm. Or is this surface some odd burr top? Cake fill appears charcoal.- rich (ie not that fine), internally shows dipping surfaces, no crust, surface slightly prilly.
			1	168	Blown top of charcoal- rich slag cake. Top is smooth but lobed, internlly finely organic, surface prilly and steep c45°.

		3	54	Pieces of charcoal-rich slag cake
		1	54	Slag piece with a very large charcoal mould - but not enough to demonstrate it was from smelting.
		1	98	Probably a large proportion of a very small dense slag cake. Thick dense lower crust with more charcoal-rich slag in shallow top hollow.
			758	
54	18	1	182	Worn piece - probably from crust of large charcoal-rich slag cake, but not easy to interpret.
		4	96	Grey coarsely crystalline slag fragments with fine organics. 1 piece shows tendency towards slightly granular texture.
			278	
65	41	1	1815	Part of complicated cake. Main cake crust thins from 20mm proximally to 15mm distally. Base microprilly, above crust is bowl filled (probably) with coarsely crystalline grey slag with lots of fine organics. Below main cake is slightly polished part of a second cake with thin crust (<10mm) with charcoal-rich slag above. If flat top can be identified, then it extends 60mm in proximally, bowl has 60mm deep hollow, whole bowl c.120mm deep - may not extend to distal half of bowl. Bowl c. 250-300mm across?
		1	44	Rod shaped slag piece - probably cast of a poker hole c15-20x8mm.
		1	34	Irregular slag piece with irregular lobed top and highly polished dimpled base (not clear what this is)
		1	2	Maybe small chip off a big slag block.
			1895	
66	3	1	60	Very worn crust fragment c.10mm thick from SHC
				rest of sample eroded stone fragments
279		1	168	Piece from double layer SHC, thin crusts with crystal terminations on top - "bipyramids" of olivine, bewtween two crusts is layer with medium charcoal.
		1	20	Rounded slag bleb
		17	34	Tiny iron-slag fragments, ranging from charcoal-rich, to free crystals on surface, to crude prill.
			222	
281	66	1	1	Tiny irregular prill, probably not a smelting slag prill.
		1	10	Irregular slag piece with smooth top and abundant charcoal inside.
		3	10	Smoothed top, vesicular, slightly flowed material.

5	2	Irregular rusty slag debris.
	23	

Site: ***Jamestown, Sitel, 03E0679***
Director: ***Ros O'Maolduin***

Summary

context	sample	find	find note	total wt	description	deposit
5	14		F8	128	sparse smelting assemblage - see below	hearth
24	23		F12	126	sparse smelting assemblage - see below	hearth
				254	total (g)	

Details

context	find	no. of pieces	weight	description
5		4	24	Pieces of dense prill
		1	6	Irregular vesicular slag bleb
		1	20	Very small dense slag fragment
		1	54	Bleb with attached sintery rough material, rather amorphous.
		6	24	Sintery material. Rough looking, but actually mainly a rather granular slag with adhering charcoal etc.
			128	
32		15	46	Finely organic-rich "sintery" slag - but actually this does not look to be a true sinter- it is fine slag wih lots of fine scale charcoal.
		1	24	Amorphous dense slag nub
		8	56	Prilly slag belbs sourrounding charcoal fragments
			126	*Fines checked for scale but none found*

Site: ***Lughill, SiteL, 03E0602***
Director: ***John Channing***

Summary

context	sample	find	find note	total wt	description
F7	13			94	3 pieces of prill, one broken in 3, 1 piece shows flowage past a large charcoal piece.
F7B	11			110	Single complex obliquely descending prill, lobate, penetrating between large pieces of charcoal, 110x40x40mm overall.
				204	total (g)

Site: ***Kill, SiteO, 03E0635***
Director: ***John Channing***

Summary

context	sample	find	find note	total wt	description	deposit
F3			77	2485	340g block of "thin crust" bowl, 65mm thick, edge and base at 70°, top with some green glass, lower microlobate, internally fine charcoal-rich slag; 438g dense block of furnace slag, one possible coarse charcoal piece on one side, presumed top rusty lobate; 290g small SHC, lower part pale & lobate, top dark smooth but largely covered in concretion, 100x75x40mm; 390g probable SHC fragment, lower crust 5-15mm, charcoal-rich slag above with rusty top; 280g SHC fragment c.90mm wide and 40mm deep; 124g very dense burr fragment; stack of lobes, presumably from blowing wall 144g; 2 pieces of lobate slag like tap slag 94g, presumably from floor; 24 dense slag frag; 210g 2 pieces of charcoal-rich slag; 22g lining, 2 pieces; 126g 6 pieces indeterminate slag.	linear ditch. Poss not post-med
F3			78	428	Single block of coarse smelting slag with large charcoal/wood inclusions to 25mm deep x 80mm long, outer face curved lobate, suggestive of contact with c.400 mm diameter wall, 90x90x60mm.	
				2913	total (g)	