Interim report on the evaluation of metallurgical residues from Clonfad 3 (A001:036)

Dr T.P. Young

Abstract

Clonfad 3 has yielded a large collection, approximately 2 tonne, of archaeometallurgical residues. Although dating of all contexts is not yet possible, it is likely that the vast majority of the metallurgical activity is of Early Christian age. This places the Clonfad assemblage as one of the largest assemblages of its period in Ireland. The close association of the residues with structures interpreted as metallurgical hearths is also very important. The discovery of evidence for production of wrought iron handbells is unique.

This report summarises the state, results and implications of the project after completion of three days sorting the collection, five days inspection of material (corresponding to approximately half of the archived collection) and two days of data entry onto a database and preliminary data sorting. The report tries to convey a flavour of the likely very exciting results from the full evaluation.

The total material sampled from Clonfad 3 weighed 4 tonne. Of this 2.8 tonne is from a slag dump within a former stream course, within which the slag is heavily overgrown by secondary bog iron ore formation. Work to date has focused on the better-preserved material outside this dump, and 0.87 tonne out of the 1.1 tonne from other contexts has been examined so far; archaeometallurgical residues comprise 0.76 tonne of this material.

The assemblage is dominated by residues, particularly smithing hearth cakes (SHC), attributable to iron-working. There is almost no evidence for iron smelting on the site. The technology involved in the iron-working remains poorly understood, with a wide variety of SHC morphology suggesting a diversity of practice. The presence of a large volume of tuyère debris, but no other vitrified hearth material suggests the use of a wide hearth, with a central pit, and with the air blast fed from the bellows to the central part of the hearth through an elongate tuyère.

The recognition of pieces of vitrified clay coating from the brazing of Type 1 wrought iron handbell is of enormous significance. Such handbells formed an important symbol in the Celtic church, and were made from the seventh (and probably the sixth) century through to the tenth. Although widely distributed across the area of influence of the Celtic church (Wales, Scotland, Ireland), they are most common in Irish South Midlands. The thin non-ferrous coating on the iron bells has not been studied in detail, but the Clonfad evidence suggests for the first time that it was applied by brazing.

The assemblage has enormous potential for unravelling the technologies and process chains involved in iron production in the Early Christian period. The significance of the assemblage is such that completion of the full evaluation of all the material is urged most strongly.

Contents

Material

The total collection from Clonfad 3 comprises 4015kg of material. This collection is dominated by 2845kg collected in bulk from two contexts (478/479) that formed a dump on either side of the former stream course. The remainder of the collection includes 1170kg from 108 numbered samples from 82 different contexts. The whole collection is divided between 580 individual bags or boxes of material.

Techniques, Project Design and Current state of the investigation

The original project design was based on an estimated collection of 2700kg, which was the total weight of material identified as slag in the site sample register. An initial estimate of five weeks for an evaluation of this material was given, but an initial single week's work was commissioned. During this week (20-24th June 2005), substantial additional material was discovered in the collections, so the evaluation commenced with a complete re-appraisal of the archive. This re-appraisal took several days and eventually raised the total collection size to 4015kg. Since completion of the reappraisal of collection size, some five days investigation of the material has been undertaken (2 in the first week and 3 in second week, 15-19th August 2005, of which the remainder was spent evaluating part of the collection from Ballykilmore 6).

The slag material from the large dump (478/479) is often water-worn and encased in bog iron ore. Indeed, the vast majority of the material from 478/9 is simply bog ore and not slag. In contrast, the material from the other contexts is typically much fresher and free from overgrowth. The evaluation of the Clonfad 3 collection has, therefore, been focused on material from contexts outside the large dump, which is capable of much more certain visual identification and interpretation. Of the 1170kg from those contexts, 802kg has so far been examined. This rate of sample examination (approximately 160kg per day) is much more rapid than a standard evaluation, as normally undertaken, and therefore, the resulting catalogue is much less detailed than normal. The catalogue currently contains approximately 800 measured items or groups of items. In addition to this, rapid screening of material from contexts 478/9 has so far identified 1250kg of material that is bog ore without any slag.

This report summarises the state, results and implications of the project after completion of three days sorting the collection, five days inspection of material (corresponding to approximately half of the archived collection) and two days of data entry onto a database and preliminary data sorting.

Preliminary results

The assemblage investigated so far comprises material dominated by plano-convex slag cakes with a wide variety of form (555kg out of the 802kg total comprises certain slag cakes, or parts thereof). Such slag cakes have been widely interpreted in the past as including residues from both smelting and smithing (e.g. Pleiner 2000, Scott 1990, Tylecote 1986), however, with improvements in the interpretation of iron-working residues outside Ireland this view has been challenged (e.g. Crew and Rehren 2002), particularly in the light of extensive experimental work (Crew 1991). Recent development work, particularly large road schemes, has resulted in large number of iron smelting sites being recognised, although most are unpublished (e.g. Young 2003a, 2003b, 2003d, 2005a), and a new view of early Irish iron smelting has been developed (Young 2003c, revised in Young 2005a). In this view the old idea of the "bowl furnace" is abandoned in favour of a model of non-slag tapping shaft furnaces with a basal slag pit. This technology is closely related to that found in many parts of Britain in the pre-Roman Iron Age (e.g. Clogg 1999, Halkon 1997). Using this new model for iron-working residues, the plano-convex cakes cakes from Clonfad can all be interpreted as "smithing hearth cakes" (SHCs) from iron-working processes, rather than "furnace bottoms" (FBs) from iron smelting.

Number	*Weight*
8	<200g
82	200-500g
104	500-1000g
70	1000-2000g
30	2000-3000g
15	3000-4000g
3	4000-5000g
2	5000-6000g
2	6000-7000g
2	7000-8000g
0	8000-9000g
4	9000-10000g
2	10000-11000g

Table 1: distribution of SHCs by weight

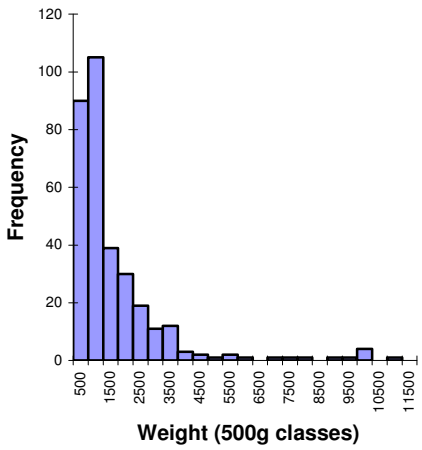

Figure 1: Histogram of distribution of SHCs by weight with 500g class intervals

Within the Clonfad 3 assemblage there is an enormous range of both size and morphology of SHCs. The catalogue so far contains 325 individually described SHCs for which a total cake size could be measured or estimated, representing a total original weight of 452kg and an average weight of 1.39kg. The distribution by weight is given in Table 1. It remains uncertain how representative this table is, for there is a greater degree of fragmentation among some of the larger cakes (much of the material from which is therefore not classifiable as certain SHC), but on the other hand some of the smaller apparent SHCs may just be the upper layer of quite complex cakes. None-the-less the distribution is indicative of the generally rather large size of the SHCs from Clonfad, a feature seen on other Early Christian sites too. Established nomenclature for such slag cakes (Crew 1995, 1996) has been developed in Britain, but also widely applied in Europe,

where SHCs from blacksmithing are typically less than 2kg in weight and most are between 200 and 500g (Crew 1996). The larger ones are often ascribed to production during bloomsmithing. In contrast, the main class at Clonfad 3 is from 200g up to 1200g, with 186 examples (57%) in this interval. 62 examples (19%) exceed 2kg in weight, and form 54% by weight of the collection of measurable SHCs.

As well as being of large size, the larger Clonfad SHCs show a divergent development. One group shows a large, porous slag cake, often with a concentric internal structure, and with little development of a basal crust. A second group shows a thick basal crust, often clearly having formed a substantial slag puddle.

As well as the SHC material, the assemblage includes a large number of pieces of tuyère, with 12.6kg of material so far identified (excluding pieces separately archived as tuyère during excavation). The presence of tuyères on Early Christian iron-working sites has long been recognised, but a probably erroneous association between tuyères and smelting has been claimed. Instead, the tuyères should be recognised as a essential component of an iron-working technology which also produced the abnormally large SHCs. Details of the morphology of the Clonfad SHCs clearly show a strong vertical differentiation, with the base of tuyère lying at a height of 120mm or more above the base of the SHC, with the complete slag mass involving up to five distinct compositional components.

In addition to the slag and tuyère debris from iron-working there is a group of ceramic materials that form a very important find. These pieces can be interpreted as fragments of a clay coating, placed on a workpiece to be brazed. The inside of the largest pieces clearly shows the characteristic form of the side of a Type 1 wrought iron handbell, with upper flap, central seam and two of the original three widely-spaced round-headed rivets (Bourke 1980, 1986). The most significant group of these clay pieces comes from a single pit [464] adjacent to the stream-side slag dumps, but smaller fragments occur in at least 5 other contexts. It is not clear whether all the pieces may come from the coating of a single bell. Certainly, one piece shows much more iron contamination of the external glaze than the others and a collection from [508] shows some different features including, apparently, binding of the workpiece in fabric, a feature seen in some Viking period brazing in Scandinavia (Söderberg and Holmquist Olausson 1997).

This style of brazing, involving attaching sheets of brazing metal to the iron object, then wrapping in a protective clay coating before firing, was described by Theophilus (himself a metal-working monk) in the early 12th century, and is a common feature of Viking metalworking, particularly lock manufacture. The copper alloy coating on hand-bells has long been noted, but only two coatings appear to have been analysed: Anderson (1881) has provided an analysis of the coating on the Fortingall Bell (Perthshire) which recalculates (subtracting iron) as a 6.9% Sn bronze, and Smith (1881-2) gave three analyses of material from the Ednam Bell (Berwickshire) which were all of a 16% Sn-bronze.

The Ednam Bell weighs 13lbs 8 ounces (Smith 1881-2; equal to 6.12kg) overall and is 280mm tall (excluding the handle). Bourke (1980 p.62) commented on the bells representing an unusual use of iron sheet at this period. The forging of iron into a sheet is a demanding process, requiring a good quality bloom, and it is likely that it would have been forged from a single bloom if possible, rather than welding several smaller pieces together. No evidence for welding of the iron sheet has been noted by any previous studies of the Type 1 bells.

The determination of the possibility that suitably large blooms may have been forged at Clonfad may be approached circumstantially by consideration of data from the experimental production of bloomery iron from bog iron ores. The experimental yield figures of Crew (1991) indicate that the production of a 5.5kg iron sheet might require 18kg of raw iron bloom or 9.5kg of consolidated bloom (billet). Crew's figures also suggest that bloomsmithing of a 9.5kg bloom would produce 10.5kg of bloomsmithing slag. Interestingly, this weight of slag corresponds to the upper limit of the SHCs from Clonfad, and thus may indeed provide circumstantial evidence for the working of very large blooms, although no blooms this large actually survive in Ireland. In Crew's experimental smelting of bog iron ores the waste smelting slags total approximately 2.6 times the weight of the raw bloom. To date, no *in-situ* smelting slag assemblages of 25kg are known from Irish furnaces (Tullyallen 6 contained approximately 16kg, suggesting a 6kg raw bloom on this basis), but "furnace bottoms" in excess of 33kg are known from the Early Iron Age of Britain (e.g. author's unpublished work at Hartshill) and these appear to be of a very similar technology.

The production of wrought iron bells may therefore be suggestive of the working of very large blooms, which may in turn suggest an origin for the extremely large SHCs encountered at Clonfad 3.

Other important facets of investigation of this site will be the geographical distribution of slag and the morphology of the identified hearths. Much of the slag derives from ditch fills that are not immediately adjacent to known hearths; of the 1170kg of material outside the stream-side dumps, 1058kg derives from the two enclosure ditches (including at least 568kg from the outer enclosure ditch and at least 391kg from the inner ditch). Much of the detailed technological information is merging from these deposits. On the other hand, the stream-side dumps (c478 and 479) are more closely associated with the recognised hearths, so interpretation of these less well preserved assemblages will be very important.

Assessment of potential

The Clonfad 3 slag assemblage, whilst probably not quite as large as originally believed by the excavators, is likely to amount to between 1.5 and 2 tonne of residues, dominantly of Early Christian age. Quite apart from the significance of this assemblage for the general archaeology of the site and the role of metals in the monastic system, this is an exceptional assemblage comprising materials for which the detailed interpretation is highly significant for understanding of iron-working technology of the period in Ireland.

Key areas in which understanding will be enhanced are:

1. the significance of large SHCs
2. the significance and function of tuyères
3. the chain of bloom processing – including the size of blooms and the materials efficiency of the bloom processing
4. the manufacture of handbells

5. the brazing process
6. the relationship between iron-working process and hearth morphology.

The potential of the will be enormously enhanced by the completion of examination of all material for the evaluation.

Further work

The assessment

320kg of material from contexts outside the large dump remain to be examined (49kg recorded in the register has not yet been located in the archived material). This material should be examined in the same way as the previous 802kg, taking 2 days (slightly longer should the "missing" 49kg of material be located). The material from the large dump required additional rapid assessment to determine the proportion of slag in the deposit, and where possible, whether this slag appears similar to the better-preserved material from other contexts; 1.6 tonne out of a total of 2.85 tonne remain to be assessed. It is envisaged that this will take 1 day.

Post-ex studies

The recommendation of further post-ex analysis is rightly addressed in the full evaluation report, but some indication of the likely areas of recommendation are given here, because they are indicative of the importance of the full evaluation. The key issues to be addressed by more detailed analysis during the post-ex studies are:

1. the characterisation and clarification of the brazing, including analysis of the surface of the clay coating to determine the alloy(s) used in the brazing process.

2. the chemical and textural differences between the various classes of SHC: do the differences reflect temperature, a different style of using the hearth, a different fuel or some other factor?

3. can differences be identified between residue types that might reflect the differences between bloomsmithing and blacksmithing? Does this support the contention that the large (>8kg) SHCs may be from bloomsmithing?

4. can the development of the SHCs be modelled using a mass balance approach (similar to that used for modelling smelting processes; Thomas & Young 1999a, 1999b)?

5. can the information from questions 2 to 5 be combined with the size – texture distribution of the SHCs to provide some description of the flow of iron through the various processes undertaken on the site?

6. can this information also be integrated with understanding of hearth morphology?

6. can any changes be observed through the chronological distribution of slag?

References

ANDERSON, J. 1881. *Scotland in early Christian times*. Edinburgh.

BOURKE, C. 1980. Early Irish hand-bells. *Journal of the Royal Society of Antiquaries of Ireland*, **110**, 52-66.

BOURKE, C. 1986. Early Irish Bells. *Seanghas Dhroim Mor, Journal of the Dromore Historical Society*, **4**, 27-38.

CLOGG, P. 1999. The Welham Bridge Slag. pp 81-96 *In* P. Halkon and M. Millett, *Rural settlement and Industry: Studies in the Iron Age and Roman Archaeology of Lowland East Yorkshire*. Yorkshire Archaeological Society.

CREW, P. 1991. The Experimental Production of Prehistoric Bar Iron, *Historical Metallurgy*, **25**, 21-36

CREW, P. 1995. *Bloomery iron smelting, slags and other residues*. Historical Metallurgy Society, Archaeology Datasheet No. 5.

CREW, P. 1996. *Bloom refining and smithing, slags and other residues*. Historical Metallurgy Society, Archaeology Datasheet No. 6.

HALKON, P. 1997. Fieldwork on early iron working sites in East Yorkshire. *Historical Metallurgy*, **31**, 12-16

PLEINER, R. 2000. *Iron in Archaeology: The European bloomery smelters*, Prague.

SCOTT, B.G. 1990. *Early Irish Ironworking*. Ulster Museum Publication 266, Belfast, 238pp.

SMITH, J.A. 1881-82. Notice of an ancient Celtic ecclesiastical bell, now preserved in the museum, Kelso. *Proceedings of the Scottish Society of Antiquaries*, **16**, 277-84.

SÖDERBERG, A & HOLMQUIST OLAUSSON, L. 1997. On Bronzing Iron Objects - Archaeological Evidence of Weight-manufacture in Viking Age Scandinavia? Pp. 188-191 *in* Edgren, T (ed). *Iskos 11. Proceedings of the VII Nordic Conference on the Application of Scientific Methods in Archaeology - Savonlinna, Finland, 7 - 11 September 1996.* The Finnish Antiquarian Society. Vammala.

THOMAS, G.R. & YOUNG, T.P. 1999a. A graphical method to determine furnace efficiency and lining contribution to Romano-British bloomery iron-making slags (Bristol Channel Orefield, UK). *In:* YOUNG, S.M.M., BUDD, P.D., IXER, R.A. and POLLARD, A.M. (eds). *Metals in Antiquity*, British Archaeological Reports International Series, **792**, 223-226. Archaeopress, Oxford.

THOMAS G.R. & YOUNG, T.P. 1999b. Bloomery furnace mass balance and efficiency. In: POLLARD, A.M. (ed) *Geoarchaeology: exploration, environments, resources*, Geological Society of London, Special Publication, 165, 155-164.

TYLECOTE, R.F. 1986. *The Prehistory of Metallurgy in the British Isles*. The Institute of Metals. 257pp.

YOUNG, T.P. 2003a. *Evaluation of slag from the SE Motorway, Co. Dublin (02E0428, 02E0272, 02E0074 and 02E0076)*. Geoarch Report 2003/02. 3pp.

YOUNG, T.P. 2003b. *Evaluation of slag from Celbridge Site 5, County Kildare (01E0306)*. Geoarch Report 2003/07. 5pp.

YOUNG, T.P. 2003c. *Is the Irish iron-smelting bowl furnace a myth? A discussion of new evidence for Irish bloomery iron making.* Geoarch Report 2003/09. 4pp.

YOUNG, T.P. 2003d. *Evaluation of slag from Tullyallen 6, Co. Louth (00E00944)*. Geoarch Report 2003/10. 2pp. + 2 figs.

YOUNG, T.P. 2005. *Evaluation of archaeometallurgical residues from the Heath-Mayfield N7 development (03E0151, 03E0966, 03E0461, 03E0603, 03E0633, 03E0679, 03E0602, 03E0635)*. GeoArch Report 2005/12. 28pp.