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Evaluation of archaeometallurgical residues from Clonfad 3, Co. Westmeath (A001:0036)

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Abstract

Clonfad 3 has yielded a large collection, approximately 1.5 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 total material sampled from Clonfad 3 weighed 4 tonnes. Of this 2.85 tonne is from a slag dump within a former stream course, within which the slag is heavily overgrown by secondary bog iron ore formation. Sampling of this material suggests that it contains 465kg slag. The assemblages from other contexts contained approximately 125kg bog ore out of the total 1.15t, leaving 975kg of archaeometallurgical residues. Thus there was a total of 1.44t of residue and 2.5t of bog ore.

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 (over 300 sherds totalling 17.5kg) 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 SHCs vary from forms with a thick dense slag puddle to forms with a highly porous, sometimes extremely friable, charcoal-rich texture. The dichotomy between these forms becomes particularly marked in the larger specimens.

The recognition of pieces of vitrified clay coating from the brazing of 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 ninth. 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.

Although there is no evidence for iron smelting, the large size of some of the slag cakes suggests that primary bloomsmithing was likely to have been carried out on the site. The size of the large cakes may be indicative of the size of blooms being smithed.

Contents

Material

The total collection from Clonfad 3 comprised 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.

Methods

All the macroscopic material from outside the large streamside dump was inspected visually (and with a low-powered stereo-microscope where necessary) and recorded to a database. All complete, or substantial parts of, smithing hearth cakes were weighed individually and the proportion they represented of the original cake was estimated. This database is available as a Microsoft Access file.

Representative material from the slag collection, plus all tuyère material, all crucible material and all microscopic residue assemblages were retained and collated into a separate collection, for use in the Stage 2 of the investigation of archaeometallurgical activity on the site.

A representative selection of material from the dump contexts (478/479) was examined and recorded in the same way. The high degree of overgrowth of the slag material within these contexts by secondary bog iron ore meant that quantification and interpretation of the slag from these deposits would not be feasible. The summary investigation of material from those contexts revealed no difference in the nature of the slag assemblage from those of the other contexts, so far as could be determined given the nature of the preservation. An estimate of overall slag content of the material from these contexts was obtained. A 16% sample of the material from [479] yielded 37% slag, suggesting that the 1147.5kg of material from this context contains 425kg of slag. The material from [478] amounted to 1698.2kg of which 1192.8kg was examined without recovery of any slag. One box of the material did contain a rich slag assemblage, and the total slag content of the context was estimated at 40kg.

The assemblages from other contexts contained approximately 125kg bog ore out of the total 1.15t, leaving 975kg of archaeometallurgical residues. Thus there was a total of 1.44t of archaeometallurgical residues and 2.5t of bog ore.

This report updates and supersedes the information in the interim report (Young 2005d).

Results

Smithing slags

The assemblage is dominated by plano-convex slag cakes with a wide variety of form (smithing hearth cakes, or parts thereof, comprise 711kg out of the 908kg total, 78%). 2% of the assemblage is other forms of smithing slag. 20% of the assemblage comprises indeterminate iron slags, but which are likely to be from smithing. Less than 0.1% of the assemblage comprises slags that are of a form suggestive of an origin in iron smelting, and even these are not certainly indicative of that origin. The morphologies of slag indicative of iron smelting in a low-shaft furnace with a basal pit, as seen elsewhere in central Ireland on sites of Early Christian age (Young 2003a, 2003b, 2003d, 2005b, 2005c) are apparently absent from Clonfad.

The plano-convex slag cakes are very variable in size, with a maximum size of approximately 11kg. 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 has resulted in large number of iron smelting sites being recognised, although most are unpublished (e.g. Young 2003a, 2003b, 2003d, 2005b and 2005c), and a new view of early Irish iron smelting has been developed (Young 2003c, revised in Young 2005c). 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 from Clonfad can all be interpreted as "smithing hearth cakes" (SHCs) from iron-working processes, rather than "furnace bottoms" (FBs) from iron smelting.

Within the assemblage there is enormous range of both size and morphology of SHC. 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. It was also not possible to determine cases in which multiple fragments from the same cake may be present in the collection. 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 is from 200-1200g, with 346 examples in this

<100	3				
100-200	10				
200-300	39	*0-500*	151		
300-400	51				
400-500	48				
500-600	36			*0-1000*	328
600-700	42				
700-800	33	*500-1000*	177		
800-900	37				
900-1000	29				
		1000-1500	72	*1000-2000*	114
		1500-2000	42		
				2000-3000	36
				3000-4000	21
				4000-5000	4
				5000-6000	4
				6000-7000	2
				7000-8000	0
				8000-9000	0
				9000-10000	1
				10000-11000	2
				11000-12000	1

Table 1. Distribution of smithing hearth cakes by weight (g). Each class interval runs from the lower limit up to, but not including the upper figure. 1000g class intervals are shown for entire assemblage, with additional detail for the smaller SHCs.

n	513
min	60g
max	11000g
average	1153g

	number	*%*
<500	151	29%
<1000	328	64%
>1000	183	36%
>3000	35	7%

Table 2. Summary statistics for the 513 smithing hearth cakes for which the total weight could either be measured or estimated.

	<500	*<1000*	*>1000*	*<3000*	*max*	*n*	*mean*
1	29%	64%	36%	93%	11000	513	1153
2	51%	74%	26%	93%	4033	43	898
3	39%	68%	32%	92%	5540	38	1087
4	83%	95%	5%	100%	2588	41	386
5	77%	100%	0%	100%	824	30	333

Table 3. Comparison of summary statistics for smithing hearth cake size from Clonfad (1), with Ballykilmore 6 (2; Young 2006b), and Clonmacnoise (3; Young 2005b) for which the assemblages are rather similar, together with Moneytucker site 7 (4; Young 2006a) and Marsh Leys Farm (5; Young 2005a) which have more conventional blacksmithing assemblages.

interval (67%), forming 36% of the interpreted SHCs by weight. Only 71 SHCs exceed 2kg (14% of the collection), but these weigh 250kg, or 42% of the interpreted SHC assemblage by weight.

The overall size distribution of SHCs is very similar (Table 3) to two other sites currently under investigation, Clonmacnoise (material from the water treatment plant; Young 2005b) and Ballykilmore 6 (Young 2006b). At Clonmacnoise the assemblage includes smelting slags as well as the SHCs, so the collection appears likely to be the result of production from raw blooms to bar iron or to artefacts.

As well as typically being of large size than on conventional blacksmithing sites, 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.

Tuyères

As well as, and in association with, the SHC material, the assemblage includes a large number of pieces of tuyère, with 300 sherds weighing 17.5kg identified.

The tuyère material suggests, although much more detailed investigation remains to be undertaken, that their outside diameters apparently ranged from 110-200mm. The smallest measured tuyère had a bore of just 18mm and the largest 40mm diameter. Typical material probably has an outside tip diameter of 140mm and a bore of about 26mm.

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 an essential component of an iron-working technology that also produced the abnormally large SHCs.

The collection contains some important specimens showing the linkage between the tuyère and main slag cake. A characteristic slag morphology of flowage up along the underside of the tuyère tube was noted, as was a particular class of slag mass in front of the tuyère at a high level above the main slag cake. The meting of the tuyère must have been one of the main sources of silicate for slag generation and modelling of this will be important to enable the recognition of any additional sources (e.g. a welding flux).

Evidence was found for the use of stones to help reduce erosion of the pit wall below the tuyère tip during retreat of the tuyère face due to melting. No evidence (*contra* Ballykilmore, Young 2006b) was found for lateral tuyère supports.

Brazing shroud

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 or shroud, placed over a workpiece to be brazed. The largest pieces clearly show on the inside 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 (Burke 1980, 1986). The most significant group of these clay pieces comes from a single pit [c464], but smaller fragments occur in at least 5 other contexts. It is not clear whether all the pieces from [c464] are from the coating of a single bell, but this appears likely. One piece shows much more iron contamination of the external glaze than the others, however. A collection from [c508] 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). Some of the material from the main assemblage [c464] may also possibly show fabric impression, but this awaits further investigation.

This style of brazing, involving attaching of brazing metal to the iron object (perhaps as sheets or alternatively as filings, maybe attached to the binding cloth rather than directly to the workpiece), 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, of broadly similar size to the example indicated by the brazing residues, 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 as 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.

Crucibles

23 sherds of pyramidal crucibles were recovered from the outer enclosure ditch in area B. The collection appears to form a homogeneous collection of vessels of similar form and fabric. This material is indicative of non-ferrous metalworking, but the limited geographical and stratigraphic distribution of the material suggests that either non-ferrous metalwork was not a normal component of activities on the site, or that the main focus of that activity (or at least disposal of its residues) has not yet been located.

Interpretation

It is envisaged that detailed analysis of representative material from this important assemblage will provide significant new evidence for the nature of Early Christian ironworking; over-interpretation of the assemblage at this stage would therefore be unwise. It seems likely however, that the large size of the SHCs may be indicative both of a technology in which the smithing hearth was cleared of slag on a slightly less frequent basis than is usually considered normal, and also that the processes being undertaken include bloomsmithing (the working-down of the raw bloom produced in the smelting furnace to usable bar-iron).

If bloomsmithing is responsible fro the large SHCs then it should be possible to use this to provide some evidence for the size of blooms being worked. An additional line of evidence or the size of blooms being produced may be provided by the handbells. These are amongst the largest iron objects of their period, and have not yet provided any indication of production from a piece of sheet iron produced by welding smaller pieces. The production of suitable iron sheet would be a very skilled task, and any flaws in the iron would cause great problems in thinning the iron to sheet. It would seem highly likely hat the raw iron in each sheet might have been produced in a single bloom. Production and working of blooms of this large size would have been a very specialist task.

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 Ednam Bell probably has approximately 5.5kg of iron sheet. 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 unworked 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 abundance of SHCs in the sub-kg range indicates that blacksmithing was important as well as iron billet production. This is consistent with the evidence for production of artefacts as evidenced by the handbell manufacture.

The evidence for brazing is of great interest, both for the evidence it sheds on the construction of the handbells, but also for the development of the technique. Brazing within a clay coat was described by Theophilus in the 12th century, and has been widely attested in the Viking period (particularly in the fabrication of padlocks), but is rather poorly known prior to this.

Evaluation of potential

The Clonfad 3 slag assemblage, whilst not quite as large as originally believed by the excavators, amounts to approximately 1.5 tonne of residues. This is an exceptional assemblage, and comprises material for which the detailed interpretation is highly significant for understanding of iron-working technology of the Early Christian period in Ireland.

This assemblage cuts to heart of the old problem of the interpretation of the large slag cakes found on Irish Early Christian sites. With the recent recognition of certain iron smelting slags on sites of this age, the large SHCs would all appear to be from smithing, despite their large size and their very variable texture. This leaves the enormous question as to why the SHCs are so variable. This assemblage includes well-preserved slags of both "puddle" and "porous" textures across a wide range of sizes from conventional sub-500g blacksmithing slags, up to 11000g examples.

The key issues to be addressed by more detailed analysis during the post-ex studies are:

1. the definition of 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? 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)?

2. the interpretation of the SHC types in terms of overall process (e.g. bloomsmithing and blacksmithing).

3. thorough analysis of both macroscopic and microscopic residues to attempt to provide linkage between the production of the two classes of materials.

4. clarification of the overall form of the tuyères, and an integration of their function with the archaeological evidence for the nature of the iron-working hearths.

5. the characterisation and clarification of the brazing process, including analysis of the surface of the clay coating to determine the alloy used in the brazing and any possible fluxing agent.

6. investigation of the metal being worked in the crucibles.

Future investigation

A collection of specimens providing full coverage of the range of variability in SHC texture and size has been separated from the main collection and will form the focus of the second stage of analysis. This collection comprises:

26 slag pieces, total weight 62.84kg
300 tuyère sherds, total weight 17.5kg
23 crucible sherds
59 pieces of clay brazing shroud
19 bags of sieve residues, total weight 2.16kg

A detailed programme of work to be undertaken on this collection has already been outlined in a separate submission. Given the anticipated significance of a concentrated analytical investigation of the assemblage, conservation of a larger pool of material as a resource for any future re-evaluation would be desirable, and a suggested list of contexts for preservation has been presented.

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