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Evaluation of Archaeometallurgical Residues from the M8/N8 Cullahill-Cashel: AR36 (E2941)

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Abstract

This site yielded a large assemblage of archaeometallurgical residues, principally an extremely important collection of large smithing hearth cakes (SHCs). This assemblage can be interpreted as representing the waste of a specialist bloom-smithing operation. The hearths appear to be part of the same period of activity (despite the 14C date to the contrary), being linked by an early medieval style of macro-residue assemblage.

The assemblage is also important for the details it provides on the manner in which the various residue components are linked, both physically in term of hearth construction, and chemically, in terms of the slag generation pathways. The existence of what are interpreted to be the bloomsmithing hearths and their contained micro-residues provides another significant feature of this site.

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Methods

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

Results

General nature of the assemblage

The assemblage was collected from two separate suites of contexts: firstly within the major ditches (c90/c127) and secondly from eleven cut features interpreted to be of metallurgical origin.

The ditches yielded a total of 198.3kg of archaeometallurgical residues of which 93% was identifiable as being slag from smithing hearth cakes (SHCs), 3% from pro-tuyère slag tongues, 1% were other forms of smithing slag and 3% were indeterminate slags. Less than 1% was comprised by sherds of ceramic tuyères.

The metallurgical features yielded only 4.8kg of slags in roughly the same proportions by class as that rom the ditch. One pit contained 10.9kg of what appears to bog iron ore.

Description of the residues

The abundance of smithing residues has permitted a good deal of integration of the interpretation of the various residue classes.

The air blast was conducted into the smithing hearth through ceramic tuyères. About 0.9kg of tuyère sherds were recorded, together with the imprint of tuyères on adjoining slags. The typical tuyère employed on the site appears to have had a rather flat lower margin, probably giving the face an overall oval shape, with an overall width of probably 200mm in many cases. The bore was 20mm on measured examples.

Melting of the tuyère tip led to slag generation and various forms of slag are found associated with the tuyère ceramics. The most important form is the pro-tuyère tongue. These slags have been described previously from Clonfad (Young 2009a) and Woodstown (Young 2009d). The tongues typically have a planar upper surface with the uppermost layer of the slag being glassy, and commonly blue or green on colour. The lower part of the slag tongue has a morphology of descending prills, often of a dense, iron-rich slag. Tongues range in weight from about 50g to 250g, but most examples are in the 150-200g range.

The generation of fluid slags close to the tuyère may lead not just to the generation of the prills under the tongue, but also to slag flows which may track along the underside of the tuyère. These flows thus have a morphology of thin flow lobes with an upper surface which is concave (sometimes with ceramic from the tuyère attached, but usually this is a non-wetting contact).

One exceptional specimen (from s68, c85, bag2) shows slag formed in a system where the tuyère tip lay at the top of a gently inclined slope leading down to the zone of accumulation of the main SHC. On this slope there are lobate, clearly fluid, slags, related to the prilly facies on the base of the tongue.

In a simple smithing situation, the slag tongue develops into an SHC, and on many sites where there are small SHCs from blacksmithing these may be directly attached to the tuyère front. In assemblages of large SHCs such as this (as well as sites such as Clonfad and Woodstown), the tongue acts as a point of origin for the iron-rich slags, but these descend to accumulate in a large SHC lower in the hearth.

The SHCs from AR36 are unusually large (mean weight 1618g). The statistics of the assemblage (Table 2) are given in Table 3. The high proportion of SHCs with weights over 3000g is particularly noteworthy.

Two of the determinable SHCs were from hearths (one each from c70 and c72); these were moderately large and appeared similar to SHCs from the assemblage from the ditches.

The SHCs from AR36 show a similar wide range of textures to those from the assemblages at, for instance, Clonfad and Woodstown. Three broad and inter-related textural variants are distinguished – a "conventional" texture in which the lower part of the SHC is of a dense slag, commonly vesicular, sometimes, but not always, with a differentiated upper section with a high content of charcoal fragments. The top of the cake may be acted upon directly by the air blast leading to a smooth surface.

In "thick crust" cakes a substantial puddle of liquid slag gives rise to a coarse grained deep dense crust, often with a "draw-down" texture at the top exposing the upper ends of the coarse olivine crystals. The upper parts of "thick crust" cakes are often of a charcoal rich slag – sometimes with a substantial void between the upper layers and top of the crust.

In "thin crust" cakes the slag has an open texture, typically rather coarsely crystalline, but with substantial porosity. Only a thin crust of denser slag forms the base of the slag bowl. The upper surface of "thin crust" cakes is often formed by a concentrically ridged structure.

At this site many of the medium sized SHCs are strongly deformed, sometimes to the extent of appearing to have been folded or rolled-up. This deformation must have happened when the slag was hot, and marks a particular approach to the issue of hearth clearance.

The indeterminate slags are mainly pieces of slag of the various types that is too small for firm identification. Small rounded lumps of smithing slag may be recorded as separate to the SHJCs and these for the "other smithing slags" category.

The micro-residues from the hearths include a variety of particle types. Planar micro-residues include flake hammerscale (essentially planar sheets of iron oxide formed by oxidation of the surface of the workpiece), slag flats (similar, but more silicate-rich and typically thicker) and blisters (flats with voids developed locally between the slag and metal). Spheroidal particles include spheroidal hammerscale (slag spheroids expelled at high speed during forge welding) but also slag droplets (often of dimpled, "coffee bean" morphology) which are generated by slags dripping through the fuel bed in the hearth.

Comments on residues from metallurgical features

Eastern Group:
[c67] 1.25 x 1.00 x 0.29 (c81 lower, c66 upper fill)
[c65] 1.50 x 0.90 x 0.26 (c64 fill)

[c66] has a good assemblage of smithing fines and some tuyère-related materials. There were no samples from [c64].

Southern Group:
[c77] 1.16 x 1.02 x 0.22 (c76 fill)
[c79] 0.58 x 0.55 x 0.10 (c78 fill)
[c75] 1.0 x 0.93 x 0.33 (c74 lowest, c73 mid, c72 upp.)

There were no samples from [c76].
[c78] has a good assemblage of smithing fines.
[c74] yielded no residues and [c73] was dominated by fired clay. [c72] yielded some hearth floor fines, slag fragments, an almost complete thin-crust SHC, a possible bloom fragment and the face of a large tuyère.

Group by enclosure ditch:
[c71] 0.74 x 0.49 x 0.10 (c70 fill)
[c69] 0.25 x 0.25 x 0.4 (c68 fill)

[c70] had a good assemblage of hearth fines, as well as slag fragments (including both thick and thin crust SHC types) and a sherd of tuyère.
[c68] yield a good assemblage of hearth fines and some SHC fragments. This may just be the basal part of a truncated smithing hearth.

Close to linear ditch:
[c116] 0.45 x 0.35 x 0.10 (c115 fill)
[c118] 0.35 x 0.35 x 0.05 (c117 fill)
[c120] 0.35 x 0.27 x 0.11 (c119 fill)

None of these features has associated archaeometallurgical residue samples. These features are small, and therefore should be considered as possible basal pits of slagpit iron smelting furnaces. However, the lack of smelting slags from the pits or from the adjacent ditch might argue against this.

Isolated pit:
[c98] 0.43 x 0.36 x 0.11 (c97 fill)

This deposit yielded the curious plano-convex mass which appears to be globules of bog iron ore. It may therefore have been an ore storage pit rather than a hearth row furnace.

In general the hearths appear to be variable in size, but fall broadly into the same size range as the blacksmithing hearths from Coolamurry (Young 2008a).

Interpretation

The weight-frequency distribution of the SHCs places the AR36 assemblage very firmly with those sites for which the occurrence of large SHCs has been linked to bloomsmithing. Chemical evidence for the linkage has been now been put forward for Clonfad, Ballykilmore and Woodstown (Young 2009a, b and d respectively). At AR36 it would appear that a very high proportion of the smithing work was involved with bloom refining, although the relative abundance of 200-300g SHCs may suggest something was being undertaken with finished iron too.

The importance of the AR36 assemblage lies in the additional information it provides on two issues:

Firstly concerning the nature of the tuyère-SHC linkage: the relationships are broadly those previously proposed for the manner in which the tuyères were employed, but the new evidence shows the possibility of a significant lateral gap between SHC and tuyère, in which fluid slags may be developed. These may cool into a variety of prilly or flow-lobed geometries, depending on the angle of the slope between the tuyère and slag accumulation. Such slags have proved difficult to interpret in some assemblages, having textures similar to the margins of a smelting slag "furnace bottom", but occurring in smithing assemblages. A variety of flow-lobed slags in smithing settings may now be reinterpreted. These slags must play a significant intermediate role in the generation of the final SHC slag composition.

Secondly, there are six isolated hearth features which have macro- and/or micro-residue evidence linking them to the production of the smithing slags. These are amongst the clearest examples yet, where a good case can be made for the identification of bloomsmithing hearths on an early medieval site. There is a problematic (Iron Age) 14C date from one of the hearths, but the associated residues appear to be much more likely to early medieval than Iron Age (presence of tuyères, large size of SHCs...).

In summary, AR36 appears to be a good example of a specialist iron production site, although not directly involved in smelting itself. Comparison can be made with the site of Lismore-Bushfield 1 which was probably undertaking similar activities at a broadly similar date.

Evaluation of potential

AR36 has the potential to help develop understanding of the procces of bloomsmithing as undertaken in early medieval Ireland. The importance of the assemblage is such that it is recommended that it is retained in its entirety. Analytical investigation is recommended of examples of the bloomsmithing slags (involving the slags associated with the tuyères as well as those in the main cakes), together with the associated micro-residues. The analytical programme should be accompanied by a careful reappraisal of the field evidence for the nature of the smithing hearths.

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f	s	c	label	wt	no	notes	propn	orig
	132	66	met waste	52	1	tiny tongue?		
				36	1	dense slag with tuyère contact - can see the reaction of fragments into slag		
	132	66	hs	45	assm	assemblage rich in flake and spheroidal hammerscale, slag debris and slag flats		
	73	68		306	2	SHC fragments with fairly thin crusts, one with tubular vesicles, internally coarsely crystalline slag in open clotted texture		
#5		70		578	2	thin crust cake fragments		
				474	2	broken piece of a cake with a dense crust, (80)x(110)x50mm (of which bowl 30mm). About 50% of SHC with microdimpled base, coarse crust possibly with open clotted textured top in centre, margins deeply dimpled	50	948
	135	70	metal fragments	134	21	spiky slag fragments		
				4	1	vitrified clay- probably tuyère sherd		
				19	2	dense slag flows with concave shiny non-wetted surface - probably from sub-tuyère flows		
				46	4	dense slag blebs/flow lobes		
	135	70		106	assm	spiky slag material plus a few blebby lobes, 2 pieces probably sub-tuyère slags		
				400	assm	good collection of hearth fines, coffee beans, flake hammerscale, some spheroidal hammerscale, slag flats, stone, slag, blebs etc		
#3		72		1390	1	(140)x170x80mm 80% of thin crust cake with concentrically structure coralline crystalline interior, crust to 20mm, plano-convex	80	1738
#4		72		1375	11	fragments of a large thin crust porous slag		
				132	1	large tuyère sherd suggestive of approx 200mm diameter		
				272	1	iron-rich lump - probably a lost bloom fragment coated in slag		
	136	72	met waste	40	3	like material from (73) - porous probably fired ceramic - gravelly in places		
				191	assm	fines similar to above and lots of finely blebby brown material: could be furnace floor fines		
	137	73	met waste	530	assm	soft porous grey material probably fired clay, reduced fired, contains at least one natural rottenstone pebble		
	137	73	hs	300	assm	mainy fines of grey fired clay, some slightly more slaggy pieces and one or two prills and coffee beans - could be furnace floor sinter?		
	138	74	hs	46	assm	small bag with two pieces of organic material (fish bone? beetles?)		
					assm	larger bag has lots of very magnetic slag blebs, but no real hammerscale		

f	s	c	label	wt	no	notes	propn	orig
	140	78	filings	9	assm	flake hammerscale, slag flats, slag blisters, slag fragments, small amount of possible spheroidal hammerscale		
	67	82	bag 1	828	13	various smithing slags and indeterminate materials		
				460	1	curved slag block - probably a rolled up SHC, but unclear if it is complete		
				804	1	(100)x(120)x65mm thick crust SHC fragment with bowl with a parallel-sided gutter-like form - probably transverse, ends missing so size not easily determinable, but probably about 60%	60	1340
				172	1	well flowed lobate slag block with fragment of lower tuyère margin preserved on top		
				574	1	irregular low density slag block, possibly a deformed large tongue - base appears prilly		
				178	1	65x95x50mm tongue, standard low density type		
				976	1	block from centre of inclined 2 layer cake, >75mm thick, size not determinable		
				24	1	possible tuyère ace slag fragment		
				102	1	vitrified face edge from large diameter tuyère, very gravelly fabric		
				216	1	65x75x60mm small dense tongue attached to tuyère face, tuyère base appears oval and may be 160mm wide?		
	67	82	bag 2	464	1	lump from large thin crust cake		
				598	1	lump from large thin crust cake		
				1205	1	130x160x80mm, dished-top SHC, fairly conventional appearance, has crust of uncertain thickness with charcoal filled bowl and smooth blown top	100	1205
				1285	1	140x160x60mm transverse fairly conventional SHC with charcoal-rich base, denser above, slightly dished top	100	1285
				1056	1	125x170x100mm, upper wide moderately dense conventional SHC resting on inclined earlier charcoal-rich slag lump	100	1056
				428	1	80x120x60mm dense transverse SHC	100	428
				208	1	130x70x45mm transverse low-density tongue		
				102	1	fragment from low-density prilly tongue		
				90	1	fragment from small SHC		
#30		82		5825	1	200x260x180mm of which bowl 80mm, dense bowl with high piled more porous material with layers and some concentric build up, although edges not well preserved	100	5825
#37		82		980	1	irregular SHC - probably twisted and broken on extraction so unclear how much is here, probably 85%, somewhat blown top, microdimpled base	85	1153
	72	84	bag 1	1940	1	170x180x110mm rather irregular and slightly double layer SHC, thickest at proximal side, good organic preservation on top	100	1940
				538	1	110x80x75mm (of which bowl 40mm) neat bowl shaped SHC with wedge on top, dense conventional	100	538
				640	1	85x120x70mm very irregular mass with side by side neat bowl and more irregular mass - possibly deformed?	100	640

f	s	c	label	wt	no	notes	propn	orig
				526	1	90x120x40mm (of which bowl 25mm) flat wide SHC with remains of wedge on top	100	526
				464	1	deformed SHC material - not clear If this is a whole SHC		
				372	1	80x80x50mm irregular mass, probably a tongue		
				308	1	80x100x45mm semicircular SHC with granular slag and dished top	100	308
				462	1	block from a very dense thick SHC		
				366	1	90x70x70mm (of which bowl 35mm) slightly prilly, charcoal-rich small SHC	100	366
				248	1	SHC fragment		
	72	84	bag 2	844	1	(100)x140x77mm slightly dished-top semicircular SHC deepest at proximal side, very slightly prilly around margins	100	844
				1240	1	120x120x100mm (of which bowl 40mm) well-formed shallow bowl with charcoal-rich slag on top surmounted by lining-rich, slightly flow-topped slab, inclined top surface coated in rust	100	1240
				1230	1	100x180x75mm probably transverse deep SHC, charcoal dimpled base, core unknown, well-formed smooth top slab	100	1230
				1180	1	140x130x70mm, medium-sized SHC with fragments of a second around and to one side - probably 90%	90	1311
				280	1	fragment from small SHC, thin flat crust with pile of slag on top		
				86	2	sherds from slagged tuyère tips		
				396	1	fragment of very dense thick crust cake		
	68	85	bag 1	26	1	tuyère sherd with part of margin of 20mm blowhole		
				492	1	probably most of small SHC, bent on extraction		
				838	1	110x120x80mm (of which bowl 50mm) concave top SHC with one side folded up, slightly irregular, smooth blown top	100	838
				18	1	tuyère sherd with margin of face		
				24	1	reduced fired clay		
				64	1	prilly slag from below tuyère, with reduced fired clay adhering to top		
				22	3	small slagged tuyère sherds		
				188	1	pyramidal tongue 70x90x40mm		
				1220	12	SHC fragments		
	68	85	bag 2	1490	1	slag block with part of SHC bowl at base, then very prilly intermediate areaa, leading up to contact with tuyère at top. This is an important piece. Shows lobate slags on gently inclined margin at top - similar to smelting slag, tuyère base only very gently curved. SHC 140mm wide x 40mm deep, top of bowl 65mm below tuyère base, slag lobes go back 30mm behind tuyère front. slag drops from tuyère to SHC over 90mm with a slightly convex profile margin. Slag attachment to tuyère 130 wide, 20mm depth of tuyère seen		
				178	1	fragment of crust of thin crust cake with open-textured clotted interior		
				984	1	150x110x60mm c80% of very dense SHC with smooth maroon top,	80	1230

f	s	c	label	wt	no	notes	propn	orig
	68	85	bag 3	2110	21	assorted SHC fragments		
				142	1	80x60x20mm dense lobe of slag with dimpled base and convex top - probably not an SHC but indeterminate		
				444	8	slabby iron-rich material on clay - could be floor, or could be a natural deposit		
				202	1	90x60x35mm small conventional SHC, c85%	85	238
				208	1	dense slag 90x75x30mm, probably a small SHC	100	208
				214	1	fragment of very prilly shallow SHC, proportion not determinable		
				360	10	fragments (some feshly broken) from a large well-slagged tuyère tip, one piece has blowhole margin with 20mm diameter		
	68	85	bag 4	1495	1	large block (possibly 50% of thick crust cake, dense bowl to 50mm, has inclined wedge to 25mm on top, overall top is smooth blown, base of very irregular form but fairly smooth	50	2990
				526	1	probably most of dense granular SHC, but rolled up so size and completeness uncertain		
				150	1	very highly vitrified sherd from large tuyère		
				520	1	block from centre of thin crust cake with 10mm crust overlain by 50mm of open textured slag		
				358	1	fragment from margin of large conventional cake		
				56	1	amalgamation of viscous low-density flow lobes		
				242	1	small cake fragment formed of coalesced prills, probably an SHC, but technically indeterminate		
				300	1	twisted elongate SHC fragment		
				1020	12	SHC fragments		
	68	85	bag 5	1295	10	pieces of SHC - several show evidence for folding		
				14	3	vitrified clay - probably single broken piece		
				74	1	slag from front of tuyère		
				112	1	rounded mass of slightly flowed slag - probably deformed, but different to SHC material		
				406	1	SHC fragment,		
				750	1	SHC fragment, probably less than 25% of cake		
				94	1	side of SHC? With c18mm diameter slag rod extending out of side		
				706	18	smaller slag pieces - indeterminate		
	68	85	bag 6	2205	23	SHC fragments		
				206	2	dense slags in pieces with long spikes/rods - probably the result of deformation		
				278	3	dense lobate slightly flowed material - probably fragments from fluid SHCs		
				160	1	prilly tongue, moderately dense but pale glassy surace		
				316	1	grey bowl 25mm with 50mm of friable slag piled on top		
				720	1	probably 45% of deep SHC 80x130x75mm	45	1600
				542	1	110x85x70mm (of which bowl 20mm) small SHC with material wedged up on one side of bowl, overall a smooth blown top	100	542

f	s	c	label	wt	no	notes	propn	orig
	68	85	bag 7	940	1	large 3 pointed block of slag with smooth blown surface - possibly blown and remelted after partial clearance - otherwise very irregular SHC, 130x150x75mm		
				568	1	130x110x40mm flat plano-convex SHC with various rod-like protrusions and very charcoal -rich upper surface	100	568
				202	1	fragment from very large almost straight-edged tuyère		
				2655	30	assorted SHC fragments and associated materials		
	68	85	bag 8	2084	34	assorted SHC fragments		
				116	1	fragment from small very dense SHC or tongue		
				154	1	75x70x35mm (of which bowl 15mm) small dense SHC with charcoal pressed into top, base fairly smooth	100	154
				230	1	70x80x40mm highly iregular lump - possibly a very thin small SHC with substantial upper wedge		
				286	1	75x75x35mm dense plan-convex rounded lump - probably a small SHC	100	286
				220	1	79x90x40mm low density plano-convex charcoal-rich SHC	100	220
				356	1	block with two juxtaposed bowls of opposite orientation - not clear If one cake folded or welded onto older piece		
				330	1	large part of a flattish conventional SHC		
				404	1	block from a thick crust cake with wedge-shaped upper layer - almost a distinct top cake but all gradational		
				130	1	low density slightly flowed large puffy slag lump		
				64	2	tuyère sherds		
				140	1	irregular blebby C-shaped piece of clinkery slag - possibly a tuyère beard		
				32	1	C-shaped slag film - possibly from a tool		
				470	3	rounded slag lumps - probably parts of rolled SHCs		
	68	85	bag 9	1245	34	small fragments - probably all SHCs or other smithing slags		
				34	1	dense well-flowed slag film from base of tuyère		
				420	1	dense SHC fragment, proportion unknown		
				350	1	70% of (70)x110x35mm plano-convex SHC, slightly concentric top, smooth, burr-like base	70	500
				76	3	tuyère sherds		
				412	7	dense slags n poorly developed flow lobes - probably from sub-tuyère area		
				190	1	70x55x40mm small dense plano-convex block - probably an SHC, slightly prilly on edges	100	190
				178	1	desne but vesicular SHC in gutter-like form - neither end preserved		
				130	1	corroded plano-convex block - could be SHC but not certain, 75x60x30mm		
				238	1	fragment from dense conventional SHC		
	68	85	bag 10	1135	1	massive rounded slag block, probably, but not certainly a rolled up SHC		
				854	1	large incined slab from below tuyère - unclear If this is an SHC in its own right, but probably not		
				142	1	slag around corroding iron fragment		
				264	1	twisted slag piece probably a highly deformed SHC but unclear If complete		

f	s	c	label	wt	no	notes	propn	orig
				114	1	probable tongue - one smooth surface one prilly, rusted so unclear If complete		
				46	1	vitrified tuyère tip		
				558	8	various pieces of SHC		
				16	1	curved flowed lobe		
	68	85	bag 11	1155	9	fragments of small SHCs, proportion not determinable		
				912	26	pieces of iron slag, all indeterminate, but all could be SHC or related materials		
	68	85	bag 12	2305	1	very large block of porous friable slag - probably part of the thin crust cake, but proportion not identifiable		
				1245	1	very irregulr block - probably two cakes each 100x100x40mm welded together into a smooth shape		
				312	1	block of dense crust with tubular vesicles		
				50	7	small fragments of slag - mainly pieces of a slag sheet - possibly from tuyère or possibly from cake wth cavernous core?		
	68	85	bag 13	984	1	170x(100)x90mm of which 50mm bowl, interior of bowl is coralline granular coarse slag, bowl top piled here with vesicular slag - just possible some of this is the missing part scraped up	85	1158
				722	1	130x100x60mm deep SHC with concentrically-ridged top and slightly microprilly base	95	760
				100	8	8 slag fragments		
	68	85	bag 14	450	1	eroded double layer cake, poorly developed bowl with thin crust, charcoal-rich fill to bowl and flow-lobed slab top 50mm above bowl, 70x120x65mm	100	450
				720	1	fragment from edge of thick crust bowl with charcoal-rich slag piled up high on top on the edge, bowl to 45mm, slag 40mm above		
				300		open textured slag - probably from thin crust cake		
				612		70x115x65mm dense slag lump - possibly an SHC folded in half?		
				210		70x90x60mm (of which bowl 40mm) tiny SHC with well-differentiated crust from bowl fill but still smooth on top	100	210
				714		140x85x65mm probably a complete dense SHC with dished top with bits adhering, complex shape	100	714
	68	85	bag 15	2050	9	large pieces from SHCs - mainly open texture thin crust, but two pieces show dense crusts		
	68	85	bag 16	1330	17	assorted SHC fragments		
				278	1	small dense highly irregular SHC 100x60x35mm	100	278
				442	1	fragment from large conventional cake with smooth blown maroon top		
				408	1	probably 70% of irregular but conventional cake,	70	583
				912	1	(85)x150x100mm (of which bowl 65mm) 50% of very dense thick crust cake, some slag piled on top, lower part of bowl has tubular vesicles, but all very massive	100	912
				460	1	130x150x45mm palmate SHC formed of granular slag, very irregular	100	460

f	s	c	label	wt	no	notes	propn	orig
	68	85	bag 17	704	1	large block of slag, probably a piece of slightly granular crust folded in half		
				396	1	irregular block - possibly two SHC fragments welded together		
				1605	19	various slag fragments - probably all SHC related		
				34	1	tuyère sherd - apparent diameter 190mm, but small fragment		
	68	85	bag 18	1690	1	large block from thick crust cake, exposed crystal terminations, 45mm thick, 2 pieces, originally 200x170x70mm, toolmarks on base	55	3073
				1325	1	large block from rough concavo-convex cake, probably c170mm diameter originally x 80mm deep, pointed conical base	70	1893
	68	85	bag 19	1026	1	fluid slag in curved sheet resting on irregular prilly base, sheet margins broken so hard to judge original size but most present, 130x180x80mm, possibly the curve is bending on extraction	90	1140
				1055	1	170x140x80mm of which bowl 40mm, smooth blown dished top, raised lump one end, rough base	100	1055
	68	85	bag 20	554	1	fragment of crust of thin crust cake showing outer contact with wall and abrupt wall base angle?		
				674	1	(100)x130x60mm (of which bowl 25mm) part of flat wide dense conventional cake probably 80%	80	843
				784	1	160x(100)x60mm (of which bowl 45mm) part of dense cake, dense bowl some charcoal-rich fill, some coralline open-textured slag, deeply dimpled smoothish top 65%	65	1206
				360	1	fragment of SHC with very dense but fairly thin crust, also second earlier crust below at angle		
				348	1	thin crust fragment with porous slag showing marked floor wall angle		
				280	1	thin crust fragment with charcoal-rich slag piled up 55mm above low bowl		
	68	85	bag 21	404	1	80x120x50 conical SHC with depressed top and very asymmetrical base - probably deformed on extraction, complete	100	404
				654	1	margin of thin crust SHC with well-flowed lobes of lining-rich material on top - just possibly a smelting slag		
				536	1	part of a thin wide SHC with deeply dimpled margins and a coralline centre with exposed crystals		
				1500	1	curious block with two part SHCs welded together - probably an incomplete hearth clearance - but since neither is complete it is possible this is one broken on extraction		
	68	85	bag 22	672	1	block from thin crust SHC		
				676	1	block from two layer cake - 20mm maximum thickness of thin bowl, then 50mm charcoal-rich then 10mm top slab, from centre so proportion not determinable		
	68	85	bag 24	194	12	SHC fragments		
				252	1	dense tongue like slag - smooth top, pendant prilly base 110x70x30mm		
				252	1	block from lip of thin crust cake with lobed top - just possibly smelting as bag 21		
				320	1	very dense tongue-like block, smooth glassy top, prilly base, but very dense 70x80x35mm		
				126	2	very dense tongue or small SHC fragments		
				210	1	rounded indeterminate slag lump		

f	s	c	label	wt	no	notes	propn	orig
				436	1	block from margin of a large cake, has some prilly parts, probably from a rather deep SHC		
	68	85	bag 25	1360	1	irregular lump - probably most of slightly cavernous SHC strongly curved, but set inside much larger diameter crust extending out both sides		
				522	1	rounded slag lump		
				822	1	c50% of deep very thick crust SHC with blown top, with slightly wedged upper deposit to 22mm, deep bowl to 55mm,	50	1644
	68	85	bag 26	2680	1	190x215x85mm of which 70mm bowl, top smooth slightly dished, base fairly smooth, probably just about 65% of this thick crust cake, crust up to 50mm	65	4123
	68	85	bag27	1230	1	fractured block from large SHC, with deep vesicular bowl, slightly clinkery-looking top with medium charcoal moulds, rough base		
				1080	1	170x130x110mm probably originally 70mm deep with end folded up on extraction, very rubbly looking SHC, irregular	100	1080
				94	1	well flown large rounded lobe, with internally porous coralline slag		
				88	1	SHC crust fragment		
				76	1	very dense slag fragment		
#2		84		3600	1	190x220x100mm (of which 60mm bowl), well developed crust to about 40mm centrally, deeply dished bowl with smooth surface where exposed, but one side has linear band of deep fill, also locally with smooth top, probably c85% since edges of crust are missing	100	3600
#7		85	bag 1	4115	1	200x210x100mm dished top SHC with half of hole filled, open part of hole is blown smooth, base is smooth and very slightly flowed in places, interior not seen	100	4115
#7		85	bag2	2135	1	150x200x100mm fairly low density cake with rubbly appearance with slightly flown bits in the top, microdimpled base - probably cracked on extraction - this is probably most of the cake but too irregular to be certain	100	2135
#8		85		3635	1	130x235x140mm, large triangular SHC with deeply dished charcoal-rich top, base slightly prilly	100	3635
#9		85		3215	1	190x220x65mm dense large dished-topped SHC. Top looks like dimples that have been smooth by blowing, base smooth, internally not seen	100	3215
#11		85		3250	1	150x210x105mm, neat lower microdimpled bowl to 45mm, inclined upper parts lead to raised edge of bowl on one side, top charcoal-rich and rusty	100	3250
#12		85		2020	1	rather clinkery-looking cake with blown top (rusted) 180x170x80mm of which vesicular crust is about 30mm, top hollow 30mm	90	2244

f	s	c	label	wt	no	notes	propn	orig
#13		85		3720	1	half of a very large SHC, has strongly vesicular bowl to 85mm overlain by charcoal-rich material with concentric top structures, base rough to microdimpled. 270mm diameter 130mm deep, plano-convex	50	7440
#13		85		2905	1	200x200x75mm, deep bowl shaped SHC deeply dished top with internal smooth blown surface, base shows some sediment contact all around proximal end, other wise rough microprilly, bowl hollow 30mm deep	100	2905
#14		85	bag 1	1615	1	120x140x80mm unusual SHC with double layer, lower is neat 30mm deep bowl, then charcoal-rich, top slab is extremely dense slag puddle with very smooth flow-like top except or slight hollow (blown?)	100	1615
				2025	1	170x180x90mm (of which bowl 50mm) neat plano-convex smooth topped bowl raised on proximal side, base smooth - almost non-wetted flow-like surface in places	100	2025
#14		85	bag 2	656	1	110x125x45mm very neat discoidal plano-convex SHC, quite a lot of charcoal inclusions	100	656
				1840	1	(120)170x100mm, double layer cake, thickish crust lower crust to 30mm, with tubular vesicles, then charcoal-rich slag, then upper dense cake 90x90x20mm steeply inclined, charcoal-rich but with glassy top, 90%	90	2044
#16		85		632	1	fragment of fairly thin crust cake with smooth blown dark top suspended over charcoal-rich porous material		
#17		85		858	1	neat subcircular SHC, bowl has rough charcoal-rich fill extending above lip and twist of lining slag in centre of top, 135x120x70mm bowl 50mm	100	858
#18		85		1410	1	very prilly cake below, several large flows on base and cavernous above, 170x140x70mm,	100	1410
#19		85		1095	1	entire thin crust SHC with corroded organics on top, 170x150x50mm	100	1095
#20		85		4715	1	large slightly folded SHC, similar to #21, in smooth top (flowed away from bent part) and partial crusts 150x200x140mm bowl 85mm	100	4715
#20		85		4085	1	200x210x100mm large slightly dish topped SHC of neat shape but rubbly texture base and top with lots of charcoal and some gravel	100	4085
#21		85		2155	1	large transverse SHC, smooth top with some rusty residue, base shows partial crust in contact with sediment - but doesn't cover whole base, 140x180x85 p-c	80	2694
#23		85		3385	1	170x150x110mm deep dense bowl, lower part has tubular vesicles but all slightly vesicular, concentric on top, piled above coralline material, both horizontal dimensions broken	80	4231

f	s	c	label	wt	no	notes	propn	orig
#23		85		908	1	small neat SHC with cavernous centre and part remaining of raised hood 120x135x90mm of which bowl 40mm, height large because block of charcoal rich slag stuck to base	100	908
				1495	1	200x100x70mm which bowl 40mm, very strange SHC - probably a bit squeezed in which the top doesn't really overlie the bowl	100	1495
#24		85		326	1	slag beard from front of very large tuyère. Hard to give dimension but probably at least 200mm across and maybe much more		
#25		85		1070	1	130x170x60mm transverse cake, bowl 40mm thick, conventional appearance, slightly dished top with charcoal impressions	100	1070
				2445	1	180x140x65mm cake with deep hollow, second fragment attached to base (100x70x50mm) base has charcoal dimpled too	100	2445
#26		85		778	1	part of a large rather conventional SHC - proportion not determinable, 45mm thick good organic preservation on top		
				2160	1	large rather friable SHC with dished top 160x190x100mm, proximal side appears to be in contact with ceramic, probaby a tuyère tip about 160-180mm wide, but shallow, elliptical ?	100	2160
#27		85		1785	1	135x175x80mm of which bowl 55mm, hollow 45mm deep, irregular SHC, complete, microdimpled base possibly with sediment contact on one side	100	1785
#28		85		3805	1	200x240x100mm, dished top concentric structure, clotted texture SHC, rather weathered, probably this sub semicircular shape is original	100	3805
#29		85		828	1	(90)x130x60mm part of medium sized SHC,	50	1656
				416	1	120x80x40mm extremely dense piece, slightly flowed, probably a small SHC	100	416
				268	1	90x100x60mm, bowl 40mm, small SHC, slightly flowed base, charcoal rich	100	268
				382	1	SHC fragment - just possibly whole triangular SHC	100	382
				354	1	angular lump of clotted dense slag - probably part of a hot broken SHC		
				88	1	SHC fragment		
				104	1	SHC fragment		
				228	1	cube of prilly slag with lobes between medium charcoal - possibly a smelting slag		
#34		85		2715	1	170x235x70mm dished top SHC with smooth top with rusted accretion of stone (and bone), proximal side has crust which is fairly planar, but only bowl contents extend on distal side	100	2715
#35		85		4825	1	210x210x110mm, concentric ringed (but asymmetric) top, looks thin crust but probably not - dense, 210mm diameter 110mm deep	100	4825

f	s	c	label	wt	no	notes	propn	orig
#36		85		1025	1	large block from a thin crust cake - size not deteminable, some sediment and flat base hint at contact with substrate in centre		
	71	88	bag 1	1960	7	SHC fragments		
				254	1	fragmet of a dense but thin SHC with very smooth blown top		
				234	1	70x70x40mm charcoal rich and slightly prilly mass which may be a small SHC	100	234
				1030	1	large block from centre of a double layer cake with large angle between base and top, size not determinable		
				600	1	folded thin dense crust - could be an entire very thin SHC, but probably lacking its upper parts		
				192	1	ball shaped prilly mass - probably a sort of small tongue?		
				186		rather deformed but probably complete low density tongue		
				202	2	large block from side of vitrified tuyère front		
	71	88	bag 2	332	1	90x120x50mm rather irregular small SHC with organics on top - not clear I it has an earlier crust attached to base or if the slag has collapsed into a central void, upper part quite platy, flattish top	100	332
				168	1	charcoal rich slag mass attached t0 tuyère tip - curvature suggests 250mm diameter		
				490	1	very strange, very dense very well flowed slag, probably a thick crust SHC but has odd flanges, also surface is smooth and rounded - suggests slag exhumed and blown		
				140	3	possible mediumly dense tongue fragments, variably prilly		
				914	5	SHC fragments		
				1170	25	indeterminate smaller slag fragments		
				52	2	well flowed and dimpled slags around small charcoal moulds- technically flow slags - possibly from sub tuyère area?		
				24	2	small fragments of slagged tuyère		
#6		88		1245	1	75% of SHC (120)x160x70mm, fairly thin crust cake with lots of large voids	75	1660
#32		91		2750	1	elongate SHC with charcoal-rich slag filling plano-convex bowl, several other older crust fragments attached to main cake 230x160x100mm of which last cake is upper 60mm	100	2750
	69	91 s2		770	1	very irregular slag block - probably has two SHC parts each rolled, welded together - not clear If this is originally a single SHC		
#31		97	bag1	2735		plano-convex bowl apparently formed of bog iron granules - this is very important, up to 100mm thick and approximately 340mm diameter total weight 10.88kg		
#31		97	bag2	2535		ditto		
#31		97	bag3	5610		ditto		

Table 1. Summary catalogue of material by bag, ordered by context. Assm = assemblage from flot sample. Prop. = estimated surviving proportion of SHC, orig. = estimated original weight

100g class	count	500g class	count	1000g class	count
0-100	0				
100-200	2				
200-300	8				
300-400	4				
400-500	5	*0-500*	19		
500-600	6				
600-700	2				
700-800	2				
800-900	4				
900-1000	3	*500-1000*	17	*0-1000*	36
1000-1100	5				
1100-1200	3				
1200-1300	6				
1300-1400	2				
1400-1500	2	*1000-1500*	18		
1500-1600	0				
1600-1700	5				
1700-1800	2				
1800-1900	1				
1900-2000	1	*1500-2000*	10	*1000-2000*	28
2000-2100	2				
2100-2200	2				
2200-2300	1				
2300-2400	0				
2400-2500	1	*2000-2500*	6		
2500-2600	0				
2600-2700	1				
2700-2800	2				
2800-2900	0				
2900-3000	2	*2500-3000*	5	*2000-3000*	9
				3000-4000	6
				4000-5000	6
				5000-6000	1
				6000-7000	0
				7000-8000	1

Table 2: AR36 - Summary of distribution of smithing hearth cakes (SHCs) by weight. Each weight class in inclusive of its lower limit and exclusive of its upper limit.

	Coolamurry	Navan	Moneygall	Carrigoran	Parknahown 5	Trumra 4	Clonmacnoise (NG)	Ballykilmore	Woodstown 6	Clonmacnoise (WWS)	Clonfad	AR36 Borris	Lismore/ Bushfield 1
date	C10-12	E. Med.	E.Med-Med.	C10?	C5-C10?	C5/6	C7-10	C10-15?	C9-10	C10?	C7-9	C7-9?	E. Med?
SHC count	41	17	22	18	89	57	117	30	140	38	381	88	23
SHC min. wt		60	114		86	92	100	94	68		60	154	426
SHC max. wt	2588	2990	1800	3866	2898	3163	7815	4033	6310	5540	11000	7440	4390
SHC mean wt	386	507	527	553	567	727	843	1022	1060	1087	1302	1618	1737
% <500g	83%	82%	55%	72%	70%	47%	50%	47%	40%	39%	30%	22%	4%
% <1000g	95%	88%	95%	89%	84%	75%	78%	73%	71%	68%	61%	41%	39%
% >1000g	5%	12%	5%	11%	16%	25%	22%	27%	29%	32%	39%	59%	61%
% >3000g	0%	0%	0%	6%	0%	2%	3%	10%	7%	8%	9%	16%	13%
Modal 100g interval	100-200	100-200	200-300	100-200	400-500	100-300	400-500	200-300	200-300	300-400	300-400	200-300	500-600

Table 3. Comparison of the AR36 SHC assemblage with other Irish smithing assemblages.

Assemblages ordered by mean SHC weight.
Coolamurry from Young, 2008a; Navan Site 1 from Young 2007; Moneygall from Young 2008b; Carrigoran from Young 2006; Parknahown 5 from Young 2009c; Trumra 4 from Young 2008d, Clonmacnoise New Graveyard site from the author's work in progress; Ballykilmore from Young 2009b; Woodstown from Young 2009d; Clonmacnoise Waste Water Scheme from Young 2005; Clonfad from Young 2009a; Lismore/Bushfield 1 from Young 2008c.

The assemblages from Coolamurry, Navan, Moneygall, Carrigoran and Parknahown are interpreted as being dominantly blacksmithing residues. The assemblages from Trumra, Clonmacnoise, Ballykilmore, Woodstown, Clonfad, AR36 and Lismore/Bushfield are interpreted as including bloomsmithing residues.

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