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Assessment of archaeometallurgical residues from Ballyburn (13E045)

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Abstract

This site yielded a small assemblage (approximately 25kg) of iron working residues. The assemblage is dominantly formed of smithing hearth cakes (SHCs) totalling 20.7kg (of which 7.7kg were in the form of thirteen essentially complete examples and one larger example of around 80% completeness). The SHCs show a wide range of morphology and internal structure.

The SHCs are accompanied by a small, but persistent proportion of sherds from ceramic tuyères.

The combination of a wide range of SHC internal structure and the use of ceramic tuyères is a feature of Irish smithing assemblages from the 7th century but persisting in some areas into the late medieval (or even early post-medieval) period. In this instance, there are relatively local very close comparisons with assemblages from early medieval sites such as Parknahown and Blackchurch.

The assemblage is indicative of the end use of iron (blacksmithing) although, as is usual in early medieval Ireland, the SHCs are, on average, larger than would be typical for later assemblages. This is interpreted as being the result of the distribution of iron to blacksmiths during this period in a form that was not fully refined.

The assemblage was widely distributed across the site, but pit (1007) just to the NW of the entrance to the inner enclosure, can be interpreted as a smithing hearth and represents one centre of activity. The presence of residues in Area 4 suggests that other smithing hearths probably existed outside the enclosure. The assemblage is modest in size, despite the abundant sediment traps on the site, perhaps suggesting that blacksmithing was a relatively minor activity on the site.

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Methods

Background

The materials described and assessed here arise from excavations undertaken on land at Ballyburn Upper, Co. Kildare, by Rubicon Heritage Services Ltd in 2013 (McLeod *et al.* 2013), with site code BUCE12 and licence 13E045.

An assessment of archaeometallurgical residues from Ballyburn Upper was initially commissioned by Carmelita Troy of Rubicon Heritage Services Ltd in December 2013, but the project was put on hold after insolvency of the client. It was re-commissioned by Bruce Sutton of Rubicon Archaeology in December 2025.

Assessment

All submitted materials were examined visually in March 2026, using a low-powered binocular microscope where required. They have been catalogued (Table 1) and assessed. No instrumental analysis has been undertaken.

Results

General

The total submitted assemblage weighed approximately 25kg. All identifiable residues (>95% of the assemblage) were produced during iron working (smithing). There was no evidence for the primary smelting of iron nor was there any evidence for the working of non-ferrous metals.

Details

The various classes of material present in the assemblage (with the exception of natural stone) are described here, following the headings employed on Table 2:

Ceramic tuyères: approximately 380g of ceramic derived from tuyères was present. The pieces included examples from the rounded margin of the face of the face of the tuyère and the less-vitrified material from the curved sides of the tuyère. The present fragments were too small to provide significant morphological detail – so it was not possible to determine if the tuyères were cylindrical, 'D'-shaped or roundedly rectangular in section. No fragments showing the bore were present.

Smithing hearth cakes (SHCs): The assemblage is dominantly formed of smithing hearth cakes (SHCs) totalling 20.7kg (of which 7.7kg were in the form of thirteen essentially complete examples and one larger example of around 80% completeness). SHCs form from a mixture of a siliceous melt derived by melting of the area around the blowhole, which in Irish early medieval examples will be the face of the tuyere, with iron and iron oxides lost from the workpiece at a higher level in the hearth. The iron fluxes the melting of the ceramic into a fluid of lower melting point and higher fluidity, that sinks within the hearth until it cools, solidifying to form a convex-based slag cake – the smithing hearth cake (SHC).

The SHCs from Ballyburn Upper show a wide range of morphology and internal structure. Some subdivision was possible of the SHCs based on textural criteria, but where the pieces were complete or overgrown by secondary iron minerals, that classification was not possible: The classification employed here is that introduced by Young (2009a) when describing the large early medieval assemblage from Clonfad, Co. Westmeath.

Conventional and indeterminate SHCs: this category embraces those SHCs with a bowl of rather uniform, fine-grained microstructure with dispersed, often irregular, vesicles. This form is geographically widespread as a blacksmithing residue, hence being termed 'conventional'. The dense microstructure of the bowl may pass upwards into zones rich in charcoal (or moulds where charcoal formerly existed). The group also includes all those SHCs where the interior of the cake is concealed (through being complete, or encrusted), since the other categories are usually identifiable on external features.

Thin crust SHCs: this category includes SHCs where the basal dense crust of the bowl is very thin and the cake has a porous internal structure, often comprising a delicate mesh of medium- to large-sized olivine crystals. Such textures may become exaggerated through the weathering of any glass phase associated with the slag. They imply the trapping of gas within the solidifying slag formed by the olivine mesh at or near eutectic fayalitic composition.

Thick crust SHCs: this category includes SHCs with the bowl partly or entirely filled by a dense, olivine rich, slag puddle, often showing vertically-aligned tubular vesicles. The olivine grain size is often large, with 10mm vertical length being common, but lengths of over 30mm occur in one specimen here. The tubular vesicles may lead upwards to a zone of coarse tabular vesicularity just below the upper surface of the cake.

Draw-down of liquid slag during solidification may leave the upper surface (and/or the surface of the large vesicles just below it) with a micromorphology showing a surficial skin draped over the terminations of the olivine crystals in the slag below. The high and uniform temperatures within the base of the hearth implied by these textures, together with the common presence of small iron particles on the base of the cake (not observed in the examples from Ballyburn Upper), suggests that this form is mainly associated with the refining of iron.

Low density SHCs: this category includes material in which little iron has been incorporated into the slag, which remains strongly influenced by the originating melting ceramic of the tuyère. In some cases, such slag may form masses which approach the typical shape of an SHC, even if they comprise amalgamated flows of siliceous slag. When they show this form, the cermaic-influenced slags have been listed here, where they occur in less well amalgamated groups that may simply be adhesions to the face of the tuyere, they have been grouped with the indeterminate slags (see below).

Hearth slag: this category has been used in an informal sense, to describe the material present *in situ* in hearth (1007) (and also as an isolated single fragment in pit (827). This material comprised a dark indurated base, overlying a pale sediment (possibly with ash). The indurated base was overlain throughout by a zone of charcoal-rich concretionary material. This was extremely dark and hard and it is possible that a degree of secondary cementation by manganese oxides may be responsible. It was not possible to reassemble the fragments in the assemblage, but it was clear that induration and slagging increased towards one area in which the slag showed significant interaction with the substrate. This area will be that close to the air blast. If this zone can be identified in any photographs taken during excavation, then it may help determine the position of the tuyère and bellows. The material is compatible with having formed on the base of a smithing hearth. A single isolated fragment of similar material was recovered from nearby pit (827).

Indeterminate slag
Not all of the slag fragments could be attributed positively to an origin within SHCs. These were divided into two groups based on slag density:

*Dense smithing slag***:** not all of the iron-rich smithing slag necessarily becomes incorporated into a recognisable SHC and some SHCs were sufficiently fragmented that their component slag fragments could not be classifiable as from SHCs with confidence. These materials provided just 0.3kg (1%) of the total assemblage. In practice, most of this material is very likely to derived from SHCs.

*Low-density smithing slag***:** in contrast to the previous class, a similar proportion (0.7kg, 2%) of the overall assemblage was formed by particularly low-density slags, without good evidence for fluid flow and with blebby and often gritty textures. These slags represent material dominated by input from partial melting of the tuyère, without sufficient iron input to make them more fluid. In this instance, many such slags may have formed attached to the face of the tuyère, rather than being a part of the SHC.

*Debris and dust***:** this material includes the very fine slag particles and other debris preset in the bags of samples. They are two small for meaningful identification.

Iron ore: a fragment of a low-grade iron-bearing rock with large, euhedral pale crystal inclusions (calcite or baryte?) was present in the collection. This is not believed to be present for economic purposes and is likely to be an entirely natural occurrence.

Iron: a single piece of weathered iron (20g) was present. Although degraded, this lacked an obvious form and may therefore be a piece lost during smithing, rather than a fragment of an artefact.

Distribution

The assemblage was widely distributed across the site, but pit (1007) just to the NW of the entrance to the inner enclosure, can be interpreted as a smithing hearth and represents one centre of activity. Other features within the NE, SW and E sections of the area also produced examples of residues, with a total of 7.1kg from Area 1. Three complete SHCs (totalling 2182g) were recovered from Area 1, forming 31% of the assemblage.

A further 6.9kg of residues were recovered from the inner enclosure ditch (003). Eight complete SHCs (totalling 3022g) were recovered from this ditch, forming 44% of the assemblage.

Area 2 produced just a single 22g fragment of slag.

The outer enclosure ditch (004) yielded as total of 4.0kg of residues, including tow largely complete SHCs totalling 2.0kg (49% of the assemblage).

The presence of residues in Area 4 suggests that other smithing hearths probably existed outside the enclosure. The total recovered assemblage recovered from Area 4 was 6.4kg, of which 5.8kg derived from pit (1224). The location of this pit needs checking – it isn't listed in the preliminary report, but the number suggests a location in Area 4. This yielded a single complete SHC (477g), representing 7% of the material from Area 4.

The assemblage is modest in size, despite the abundant sediment traps on the site, perhaps suggesting that blacksmithing was a relatively minor activity on the site. The proportion of the assemblage present as intact SHCs was much higher for the two enclosure ditches than for the other areas – which is compatible with the expected taphonomy of the residues on such a site, with less degradation of those examples finding their way (directly or indirectly) into the major sediment traps.

Interpretation

The assemblage is characterised by smithing residues, in which a rather variable SHC morphology was developed during ironworking in hearths blown by bellows through ceramic tuyères. This compatible with the technology employed for smithing from the 7th century (tuyères were possibly introduced to Ireland in the 6th century, but the dating on early examples is not precise).

At this period raw iron probably circulated in the form of part-processed bloom pieces. The larger SHCs present on early medieval sites, even where no iron smelting is indicated, probably derive from the need to work that raw iron before its final incorporation into artefacts.

The relationship of the textures present in the larger SHCs, the thin- and thick-crust SHCs, to specific processes of iron refining is still not well defined. Some iron could have been refined simply by folding and welding, but other options included the hearth refining (remelting) following the same techniques later described by Evenstad (Evenstad 1790; Jensen 1968; Vike 2016, Wagner 1990). Research is on-going into how such techniques might be reflected in the Irish SHCs, but their use has been suggested for some examples that have been examined in detail (*e.g* some slag cakes from Woodstown and Camlin 3; Young 2009d, 2011).

Although the general style of technology survives into the late medieval period – and probably into the early post-medieval too, the supply of iron to blacksmiths appears to become more in the form of fully-finished iron, and average SHC weights fall in the later medieval period as a trade in finished trade iron developed (as seen for instance at Garryleagh, Table 3). The end of the use of this technology is marked by a further fall in the weights of SHCs from blacksmithing as ceramic tuyères were replaced by examples made of iron (as represented by in Table 3 by assemblages from Ballykillaboys and Gorteens).

Discussion

The assemblage is modest in size, despite the abundant sediment traps on the site, perhaps suggesting that blacksmithing was a relatively minor activity on the site. If the estimated average SHC weight (547g) is compared with the site total assemblage, it is only equivalent to approximately 46 smithing work sessions. Of course, only a small proportion of the overall slag production is likely to have survived and to have been retrieved.

There are relatively local very close comparisons with larger assemblages from early medieval sites such as Parknahown 5 and Blackchurch 48 (Table 3).

Parkahown 5 (Young 2009c) produced 100kg of slag. Although there was some evidence for smelting, this may have contributed only 5.5kg of the assemblage. 70% of the 89 SHCs recovered weighed below 490g (the Ballyburn Upper assemblage has 64% at 500g or less), and 79% at less than 850g (compared with 86% at Ballyburn) showing that much of the iron working was the end use of iron, rather than the initial processing of newly smelted iron. Tuyère fragments provided 1.4% of the assemblage (compared with 1.6% at Ballyburn). The majority of the assemblage derived from the inner enclosure ditch, probably indicating that the ironworking took place within the enclosure.

Blackchurch, Site 48, produced 110kg of slag (Young & Kearns 2010a), There were 70 intact SHCs, with 80% weighing less than 850g. Here the slag was focused on an area within a ditched field system apparently outside any main area of occupation. Despite the larger quantity of residues, the Blackchurch excavation involved examination of an extensive ditch system, so even if the distribution of the residues was focused, it was a small assemblage compared with the size of the site.

It is possible that the sites had much larger slag volumes that have been dispersed by subsequent agricultural practice, or that disposal was undertaken at some distance from the activity itself. The low frequency activity that is apparently suggested, might run rather contrary to the evidence from the variability of the SHCs, which suggests experienced smiths working across a variety of techniques (even if those techniques remain hard to determine with certainty). The evidence might therefore suggest the possibility that the smithing was undertaken at intervals by a visiting smith.

A situation with an visiting smith and a lack of any non-ferrous metalworking would be compatible with a site of modest social status.

Further work

No further investigation of these residues is recommended. That situation could be reviewed if further specific archaeological questions needed to be asked of the material, driven by other aspects of the developing site interpretation.

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Table 1: catalogue of submitted materials. Assm = assemblage of small particles. Weights in g.

C	S	notes	s wt	l wt	l no	notes
7	5006		24	22	2	fractured, slagged, oxidised ceramic
15	5003		629	543	1	80x105x55mm; deep, vertically-sided SHC (or fragment, but probably complete); upper part charcoal-rich; lower bowl just 20mm of probably denser slag; top rusty with some fuel impressions, but obscured
				75	1	irregular fragment of porous slag
38	5037	s.117 ab	232	14	assm	debris
				186	1	small complete SHC; base prilly with charcoal inclusion; dense middle layer; top messy finer slag sitting in dished bowl; 60x80x35(30)mm; slightly biconvex
				32	1	margin from small gritty lining-influenced cake; highly vesicular, even like fuel ash slag in places
38	5001		788	131	5	fragment of low-density vesicular slag that has exploded because of an iron inclusion
				261	3	fragments, possibly from a single example of a folded thin crust cake
				70	1	agglomerated mass of lining slag prills; no clear overall form
				75	1	extremely low density complete SHC formed of gritty lining slag; slightly dished smooth glassy top; 50x70x25mm; base irregular
				115	2	fragments of SHCs with 10mm lower crusts; rather messy above with rust
				132	assm	small smithing slag fragments and dust
38	5012		584	413	4	joining fragments of a dense SHC; basal crust 15mm; base smoothish, lumpy; top of bowl is a deep hollow with steep sides, partially filled by grey porous slag; at least 50mm deep; fraction of cake is unknown
				163	1	complicated slag, probably from near blowhole; large probably reddened lobes or folds on top; irregular base; possibly deformed
39	5011		107	41	2	2 fragments from margins of tuyère faces
				6	1	oxidised fired ceramic
				2	1	tuyère marginal fragment
				48	1	irregular angular fragment of hard, but highly vesicular, gritty slag
				10	1	fragment of porous, possibly coralline slag
39	5018		216	68	1	rusty vesicular slag attached to pale burr
				56	1	vesicular gritty lining slag attached to small area of ceramic
				11	1	gritty lining slag with small skim of ceramic - detached fom 68g piece?
				76	1	fragment of slagged tuyère face; mostly smooth but inner attached slag; ceramic pale pink, gritty

39	5025		958	827	1	complete classic EM SHC with raised, angled, lining slag pad; lower bowl with well-formed sediment(?) contact base; filled with charcoal-rich slag, then upstanding flowed pale slag, with then a top pad of grey finely prilly lining influenced material; 130x110x70(40)mm
				131	1	rounded (worn?) lump of highly vesicular slag; weathered; ow density
39	5033	s6 ab		15	1	dense vesicular grey slag
40	5010		478	37	1	fragment of lining slag attached to buff lining; broken in two
				27	1	oxidised fired fragment from margin of tuyère
				74	1	fragment from margin of small SHC; rich in charcoal, up to 20mm; concavo-convex
				259	1	highly vesicular slag with small area of burr-like contact; charcoal-rich on base; upper parts irregularly vesicular; c.50mm thick SHC
				5	4	bits
				66	1	margin of thin concavo-convex cake, with protruding U-shaped rod 30mm wide and 15mm deep extending 40mm on base, 20mm on top, from inclined bowl side
40	5014		1094	128	5	probably from a single cake; highly vesicular SHC fragments, some tubular vesicles at base where the slag is pale grey; above it is even paler, almost FAS-like
				412	1	very neat, dense, complete plano-convex SHC; 85x105x40mm; base and reddened top both fairly smooth; just very slight dished top
				89	1	fragment of moderately dense, thin SHC; low vesicularity with thoroughly glazed flat top; from margin
				9	1	small blebby prill of low-density, very rusty, slag
				129	1	fragment from centre of thin crust type SHC; irregular microprilly and microdimpled basal sheet, maybe to 8mm; overlain by 35mm of rather encrusted probably coralline type slag
				316	1	large piece of channel-like slag, probably from thin crust SHC; prilly basal sheet microdimpled; interior obscured; unclear if original shape or folded
50	5000		867	500	1	unusual double layer SHC; either formed as two layers or was broken and fused; upper surface(s) with fuel impressions in smooth surface; slightly dished; cakes thin, 30mm; lower 140x80mm, upper 80x55mm; upper is probably just a torn fragment; base smooth dense, interior conventional
				52	2	broken grey slagged tuyère fragment
				32	1	iron cemented coarse sandstone with large well-rounded grains to 2mm
				229	2	fragments of dense SHCs with few clues as to form
				45	assm	dust and small fragments
65	5002		210	210	1	complex mass of lining slag prills; glazed top, very irregular; probably not complete pro-tuyère mass
65	5004		710	85	1	probable fragment of pale SHC with maroon surface; base dimpled; charcoal internally; top variable, locally smooth haematised
				360	1	wide, flat, slab-like, complete plano-convex SHC; dense bowl 10-15mm thick; more charcoal-rich on top; upper surface smoothish with deep fuel impressions, some with fuel surviving; 75x125x35mm

				246	1	probably complete, dense SHC; possibly slightly folded on one side; base finely prilly; top smooth but irregular with large fuel impressions; one side raised; some adhering concretion on upper surface; 70x90x40mm
66	5017		58	23	1	grey porous slag large grey lobes on top; dimpled base; isolated nub
				32	1	dense worn lump; starting to show iron explosion
67	5005		851	416	1	irregular, but effectively complete, tabular SHC; 105x110x55mm; 15mm crescentic lower sheet fragment; then 15mm thick large slab; gently raised smooth upper surface
				426	1	deep irregular SHC; incomplete lower slab, then more porous, then denser upper layer, slightly dished
67	5035	s.32	31	31	1	flap of grey slag with microprilly structure and rusted inclusion
127	5007		639	281	5	rather chaotic fragment vesicular slag with some flow surfaces; probably from the near blowhole part of SHC
				124	3	denser slag fragments also showing flow lobes, all from smithing slags
				86	2	crude ceramic with vitrification and slagging
				43	2	sherds from curved tuyère surface, one well vitrified
				20	1	iron nub, corroding badly
				85	1	dense slag puck dimpled base; possibly reddened top; incomplete, worn
211	5036	s56 ab	22	22	2	grey porous slag, granular; porosity has high sphericity
249	5032	s80 ab	69	69	1	very dense rounded, worn, iron ore nub with reddened surface; contains euhedral pale crystals (calcite? baryte?) and has large voids surrounded by crusts
249	5023		136	55	1	open textured amalgamation of pale gritty flow slag prills
				80	1	dense fractured nub of slag; deeply convex dense crust with external dimples encasing porous charcoal-bearing slag; unclear if original so tightly-shaped (tool mark?) or if it has been folded into this form
348	5008		116	1	1	horizontal branched flow slag prill, dark glassy surface
				56	4	rottenstone fragments, natural
				41	1	gritty lining slag sheet
				11	6	tiny slag fragments
397	5024		574	569	1	two fragments from a deep dense SHC (around 30g probably missing); 125x80x55mm; base irregularly rounded - but not clear if these are toolmarks; top has smooth areas proximally, probably hematised but locally rich in charcoal; internally appears dense, few vesicles
805	5034	s170 ab	13	13	1	lobate piece of iron-bearing lining slag

806	5026	4047	1688	2	fractured and incomplete large low density cake; almost no basal curst; 180x190x100mm; deep, concavo-convex (strongly - could be slightly folded not not certainly so); slag pale, coralline/granular; base only dense at proximal end; base irregular with possible toolmarks; top strongly dished, leathery because of crystal terminations pushing though surface, otherwise smooth; larger vesicles just below top skin; basal 5mm more solid peripherally
			389	1	fragment from centre of base of very similar cake to large one above, but missing upper part
			137	1	fragment of small thin crust cake with charcoal-rich bowl fill
			285	2	broken small rusty SHC; 80x100x40mm; plano-convex; slightly concreted on top, smooth with depressions only proximally; base smoothly prilly; interior very rusty with small vesicles, but with larger examples just below top
			673	1	fragment from large thick crust SHC; crust to 30mm with tubular vesicles; bowl 50mm deep, inside and above to 75mm is coralline with charcoal moulds; top rough, microprilly; base microprilly/microdimpled with some elongate impressions
			209	1	small fragment from deep crust SHC; probably towards burr; crust to 35mm; only thin layer of coralline texture preserved above
			224	1	fragment of thin crust cake with 70mm spike extending off base; surface finely prilly on spike, but coarser near its root; no crust; coralline interior
			324	16	fragments with coralline texture
			33	1	fragment with 11-5mm crust
			85	assm	dust and bits
830	5020	35	35	1	fragment from oxidised rounded\angle of tuyère; deep purple-red internally; thick glassy smooth slag externally
980	5021	62	19	1	soft bowl base fragment; sediment on base; dark rather fragmental looking material cf #1060
			5	3	tiny slag fragments
			36	1	pale glassy vesicular lining slag; smooth bulbous top; base rougher and probably fractured
1060	5022	2309	2309	c80+bits	probable in-situ hearth; large, ashy clay base, locally gravelly with thin layer of indurated charcoal (Mn?) through to slag skim; wide burr area with shallow thin slag, reddened and charcoal-rich in front; lots of powdered debris; only limited retro-fitting possible, so size uncertain, but probably >300mm across
1402	5027	509	142	1	weathered fragment from base of thin crust cake, almost no crust; interior coralline, with big olivine crystals; base has some moderately large charcoal
			106	1	fragment of SHC with variable internal texture, probable y conventional
			165	1	fragment from small dense SHC; top not preserved; base microdimpled; locally has abundant charcoal; top appears void rich, but otherwise conventional
			89	1	fragment of lining based SHC; upper disc is grey glass, below is pale and more prilly; incomplete
1407	5028	1500	175	1	mass of poorly amalgamated lining slag flows and sheets; probably crudely dish top; base very irregular; gritty
			64	1	smaller piece of similar lining slag to 175g piece
			654	1	dense, probably worn SHC, with few edges missing; dense, deep, 80x110x65mm; base obscured; some coralline above crust, but then charcoal-bearing to top; plano-convex
			318	2	fragments from pale SHCs with vesicularity throughout; rather conventional; smooth fuel impressed top

				126	1	angular fragment, perhaps from burr end of a thick crust cake
				145	1	fragment from a small cake (probably) with a dense crust, almost puddle-like; very irregular, rounded, lumpy base; top shows crystal terminations; fractured
1442	5039	s 3158	1490	985	1	135x160x60mm; weathered SHC; deeply impressed lobate, fuel impressed dished top; base well formed but probably prilly below the weathering; upper prilly layer differentiated from bowl
				443	1	fragment of SHC with thin basal crust; core and top porous charcoal-bearing and finely prilly; rusted; biconvex
				62	assm	debris - partly distinct fragments, partly from major pieces
1605	5031	bag 1	4164	477	1	complete SHC; 90x110x50(25)mm; low bowl with thick charcoal-rich layer on top; then denser flat surface with slightly lobate margin and some impressed fuel
				905	2	2 pieces from a heavily fragmented large SHC; 120x110x70mm; plenty missing; crust to 15mm, very coarse olivine; interior charcoal-rich; top appears smoothish with very deep impressions
				230	2	joining fragments from base of similar to the above; shows olivine to over 30mm, but little further detail
				1233	7	fragments from thin crust cakes; mostly passing up into vesicular slag but some to coralline
				135	1	part of a biconvex SHC with a raised smooth brown glassy? top over a prilly lower section; some rusty accretion
				180	1	fragment from cake with 15mm crust, overlain by coralline material
				235	1	distal part of a biconvex thin SHC; raised smooth grey glassy top, over prillier lower parts; 35mm thick; interior slightly vesicular; conventional appearance
				393	1	fragment from the centre of a cake with thick crust; deeply impressed charcoal surviving on the upper surface; no other details
				284	1	worn fragment from a thick crust cake; very dense; rusty; no details visible
				48	1	pale lobate slag with dark surface; covered in iron-rich accretion
				6	1	tiny fragment of slightly glassy lag - top of SHC?
1605	5031	bag 2	1662	1435	12	fragments of SHCs with dense basal crusts overlain by porous bowl fills; often coralline with large plates of olivine exposed; size of cakes unknown; dense layer mostly 10-15mm
				135	1	fragment of SHC similar to the above material, but from near blowhole; has maroon surface slag flowed down exterior and rusty charcoal-rich slag on top of bowl
				14	1	crude flow-lobed maroon surfaced slag,
				54	4	small fragments from similar slag cakes

Table 2: distribution of residues by context, structured by area of site. The residue total is the sum of material excluding the iron and iron ore.

Context	Tuyère	SHC				Hearth	Indeterminate. slag		Iron	Iron ore	Residue total	
		Conv & indet	Thin crust	Thick crust	Low-density		Dense	Low-density				
Area 1												
15		543					75				618	surface
397		569									569	fill of posthole on E side
830	35										35	Fill of posthole (826), Structure 1
980						19		36			55	Fill of rectangular pit (827)
1060						2309					2309	Fill of circular hearth (1007)
1442		1428									1428	Fill of posthole (1440), SW Structure 1
249		80						55		69	135	Fill of souterrain (321)
1402		271	142		89						502	Fill of pit (1397), near souterrain
1407		972	145	126	239						1482	Fill of pit (1397), near souterrain
	35	***3863***	***287***	***126***	***328***	***2328***	***75***	***91***		***69***	***7133***	***Area 1 total***
Inner enclosure ditch (003)												
38		877	261		107			201			1446	Slot 2
39	125	837					15	314			1291	
40	27	1028	445					46			1546	
50	52	729									781	Slot 8
65		691			210						901	Slot 6
66							55				55	
67		842					31				873	
	204	***5004***	***706***		***317***		***101***	***561***			***6893***	***Inner enclosure ditch total***
Area 2												
211							22				22	Pit (024), S of entrance
							22				***22***	***Area 2 total***
Outer enclosure ditch (004)												
7	22										22	
805							13				13	
806		318	2762	882							3962	
	22	***318***	***2762***	***882***			***13***				***3997***	***Inner enclosure ditch total***
Area 4												
127	129	491							20		620	Curvilinear ditch (126)

348					1	41		42	Fill of pit (129)
1605		847	2983	1812	68	48		5758	Fill of pit (1224)
	129	***1338***	***2983***	***1812***	***69***	***89***	***20***	***6420***	***Area 4 total***

*Table 3: Comparison of the overall weight-frequency distribution of the SHCs from Ballyburn Upper with that of other selected smithing assemblages from Ireland, ordered by mean weight. Weights in gram. * for Ballyburn Upper the largest SHC was incomplete; the cited mean is a minimum (for instance if 1688g partial SHC actually weighed 2000g, the mean would rise to 569g).*

Site	**Ballykillaboy**	**Gorteens**	**Garryleagh**	**Coolamurry**	**Gortnahown 2**	**Ballyburn Upper**	**Carrigoran**	**Parknahown 5**	**Blackchurch 48**	**Ballyellin 1**	**Ballykilmore 6**
County	**Kilkenny**	**Kilkenny**	**Cork**	**Wexford**	**Cork**	**Kildare**	**Clare**	**Laois**	**Kildare**	**Wexford**	**Westmeath**
Age	**16th-17th**	**17th-18th**	**13th-14th**	**12th-13th**	**6th-7th**		**e-med**	**e-med**	**7th - 9th**	**9th - 10th**	**e-med/med**
minimum	50	52	84	62	78	75	124	86	108	143	80
maximum	478	748	802	2588	3450	1688*	3866	2898	2450	1525	4033
% <500g	100%	93%	76%	80%	68%	57%	72%	70%	53%	33%	52%
% <850g	100%	100%	100%	93%	87%	86%	89%	79%	80%	67%	71%
% >1kg	0%	0%	0%	5%	8%	7%	11%	16%	19%	24%	24%
% >3kg	0%	0%	0%	0%	2%	0%	6%	0%	0%	0%	7%
mean	134	206	316	386	498	547*	553	564	629	684	887
count	106	27	25	41	98	14	18	89	70	33	42
smelting?	no	no	no	no	yes	no	yes	trace	no	no	yes
Reference	Young 2010	Dabal & Young 2011	Young 2009f & 2019	Young 2008a	Young 2009e & 2019	This report	Young 2006	Young 2009c	Young. & Kearns 2010a	Young. & Kearns 2010b	Young 2009b & 2012

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