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Assessment of archaeometallurgical residues from Aghavea, Co. Fermanagh

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Abstract

This report outlines an assemblage of approximately 47.4kg (1328 pieces) of metallurgical residues recovered during excavations at Aghavea, Co. Fermanagh.

The residues are mainly associated with a distinct 'industrial area', although a sparse assemblage of residues does occur in other features and contexts. This area includes a smithing hearth with an associated slag dump, of degraded, probably trampled, residues, in part associated with a terraced platform.

Despite a few ambiguous pieces, the assemblage is probably entirely from iron working (smithing). The smithing hearth cakes (SHCs) are well-formed and comprise a very dense slag, probably partly due to the fluxing action of the quartz-rich tuyère ceramic. The SHCs show a weight distribution with a modal weight of approximately 220g, but with a few cakes as heavy as 1300g, giving a mean SHC weight of 403g. 11% of the SHCs weighed over 1kg. This distribution is similar to that seen in assemblages from other medieval smithy sites, such as Coolamurry (12th-13th century). The general style of deposit can also be closely matched at Coolamurry. The assemblage differs from the 'high status' metalworking evidence from major early medieval monastic centres, the studied examples of which both tend to be involved in the production of iron (rather than simply its use) and also to be involved in the working of the non-ferrous metals. The Aghavea evidence suggests activity compatible with a typical rural or urban smithy, rather than as a centre of industrial production.

The main analogues for the residue assemblage are medieval. This may mean that the assemblage is younger than currently interpreted, but equally it may simply be an earlier example of a site-type that is only currently documented for this lightly later period.

The residues have little potential for providing significant extra information through further detailed analysis, so no further analysis is recommended, although retention of the assemblage for deposition with the site archive is strongly advised.

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Methods

All materials were examined visually with a low-powered binocular microscope where required. As an evaluation, the materials were not subjected to any high-magnification optical inspection, not to any form of instrumental analysis. The identifications of materials in this report are therefore necessarily limited and must be regarded as provisional. The summary catalogue of examined material is given in Table 1.

Stratigraphic information quoted in this report is derived from Ó Baoill (undated).

This project was commissioned by Sarah Gormley, of the Centre for Archaeological Fieldwork, Queen's University, Belfast.

Results

Distribution of materials

The residues were recovered from 38 stratified contexts (total 27.1kg) with a further 18.2kg of slag as 'surface finds'.

Within those features currently identified as probably being of early medieval age some 23.4kg of residue was recovered, 1.4kg from ditches and 22.0kg from the 'industrial area' (from hearth [278], gullies [90] and [354], together with the spread on terrace [361]). Thus the 'industrial area' provided 81% of the stratified residues.

A further 1.3kg of residues were recovered from the path [6] and metalled area [94], and these may well have been derived from the underlying deposits.

Features currently interpreted as being of medieval age yielded only 0.3kg of residue.

Undated features provided a further 2.0kf of residues.

'Surface finds' and the fill of a modern drain yielded the remaining 19.2kg of slag.

Metallurgical features

The excavators identified two features as of metallurgical origin: 'bowl furnaces' [278] and [38]. The term 'bowl furnace' is not an appropriate term for such structures. The bowl furnace is strictly a smelting furnace that is broader than it is tall. The Irish 'bowl furnace' of Scott (1990) and other earlier authors has now been largely rejected in favour of an interpretation of the 'bowls' as simply the basal pits of non-slag tapping shaft furnaces (Young 2003; Carlin 2008).

The present features do not, however, show any of the characteristic residue assemblage of iron smelting furnaces. Neither feature shows any evidence for *in-situ* residues; hearth [38] contained no archaeometallurgical residues at all, and the fill of hearth [278] comprised a large quantity of smithing waste which would have been deposited into the feature after its abandonment.

Feature [278] was slightly deeper than is typical for a smithing hearth, but the overall diameters (1.1m for [278] and 0.8m for [38]) are typical for floor level hearths of the period.

Possible pit [12] was not discussed in detail in the DSR, but its fills contained almost 800g of smithing residues, including hammerscale-bearing concretions, suggesting that this feature too was intimately associated with the smithing activity.

Description of materials

Possible iron smelting slags:

The slag assemblage was dominated by materials from iron working (smithing; see below). A very small proportion of the residues are morphologically compatible with an interpretation as being from iron smelting

These include 626g of dense flow slags from hearth [278], 142g of dense flow slags from ditch [103], a lip of a slag cake (88g) also from ditch [103], a prilly, charcoal-rich slag (5 pieces, 546g) from [268], and a lip of a slag cake (136g) with a long charcoal fragment parallel to the margin from [289].

None of these pieces need necessarily be from iron smelting. In the absence of pieces of definite smelting slag, the lack of evidence for a smelting furnace and the association of several of these pieces with the area around smithing hearth [278], then an origin in smithing is extremely likely.

Iron working (smithing residues)

The evidence from the site was overwhelmingly for iron working. The residues may be divided into several categories:

Smithing hearth cakes: smithing hearth cakes (SHCs) provided 26.4kg of the total assemblage (59%). In addition, the 'indeterminate slag' category (see below) will, in practice, have comprised a very large proportion of fragments from SHCs that were too small to be identified as such.

Thirty eight SHCs were complete (or almost so). Their weight-frequency statistics (Table 3, Figure 1) show a predominance of examples in the range of 80 to 300g. Sporadic examples are heavier, although some of these are amalgamated SHCs caused by a slag from a previous phase of activity being pushed down into the hearth rather than being removed, and then becoming fused to slag formed during a second period of activity.

These SHCs showed a range of forms, but were mainly rather neat, typically around 80mm by 60mm and 35mm deep with a slightly concavo-convex form. The SHCs were dense, with a relatively low degree both of vesicularity and of charcoal inclusions. A few lighter examples were of the form described as 'tongues', which have an iron-poor glassy surface top and an iron-rich prilly base.

Several of these smaller SHCs show tool marks on their bases, caused either by the tool used in the extraction, or more likely as a result of preparation of the ash bowl below the charcoal fuel before the commencement of smithing.

In some instances the base of the SHC incorporated small amounts of well flowed slag, indicating that leakage of fluid slag from the main SHC was capable of generating flow slags within the hearth (see below).

A distinct group of SHCs were larger and weighed approximately 1.3kg each. These showed a thick lower crust within the bowl part of the cake, with a thickness of up to 40mm and with well-developed tubular vesicles. The upper parts of these cakes were also dense.

Flow slag: several contexts produced moderate to small quantities of flow slag. In total approximately 1kg (2% of the assemblage) of such flow slags were identified. The possibility of some of these having been produced during iron smelting has been raised above, but it is more likely that they can be interpreted as flows generated within the smithing hearths. The incorporation of small pieces within the bases of SHCs and the dense, presumably originally very fluid, nature of the SHCs suggests that the generation of flow slags within the hearths is a reasonable proposition.

Lining slag: lining slags (that is to say slag formed by melting of the hearth ceramics, with little or no influence from the iron) were rare in the assemblage, although some large, chaotic prices were recovered from the fill of hearth [278]. The lining slags were very rich in partially melted sand and gravel (thereby resembling the ceramic seen in the tuyères, see below) and some of the larger pieces may indicate the catastrophic failure of a tuyère.

Indeterminate slag: those dense slags without any diagnostic features have been grouped into this category. These pieces include small fragments of smithing hearth cakes that cannot be positively identified as such, together with other slag materials that did not get incorporated with the SHC – perhaps as isolated hearth slags or as slag adhering to the tuyère or wall.

Approximately 37% of the overall assemblage by weight was strictly of indeterminate origin.

Vitrified ceramic: vitrified (and sometimes slagged) technical ceramic comprised just 1.5% by weight of the overall assemblage. Most of the fragments were small and provided no clues as to detailed origin. Just five fragments provided good evidence for their identification as fragments of tuyères. Three of these fragments came from the 'industrial area' in and around hearth [278], one from an early ditch [24] and one from an undated feature (pit [12]). In addition two examples of SHCs preserved evidence for the formation in contact with the tip of a tuyère (examples from (145) and the surface finds).

The evidence from this small dataset suggests the use of tuyères of possibly elliptical cross section. Examples of possible tuyère bases include one example with a distinct curvature, but the other appears flatter. The overall width of a tuyère impression on a SHC from context (145) was approximately 150mm, with the point at which the sides reached a vertical orientation being approximately 60mm above the base. Such dimensions would appear typical of the earlier medieval; by the late medieval and into the early post-medieval period there is evidence for the use of larger tuyères (e.g. at Ballykilmore, Young 2012a)

The tuyère sherds and other pieces of vitrified lining were all in a very coarsely tempered fabric, with both abundant sand and angular gravel of up to 10mm in size. In some of the tuyère face material, the partial melting of the ceramic had produced a concentration of these quartzose clasts – locally to the point of an almost continuous layer. The abundance of this siliceous material may have facilitated the development of both the dense homogenous type of SHCs in the assemblage and the occurrences of dense flow slags.

Other fired clay: there were just a few fragments of clay of a different nature to that of the hearth ceramics described above. These were not diagnostic of origin, but one small piece of pale grey low-fired clay had narrow voids suggestive of the use of a hair temper (context (13)).

Slag droplets: discrete droplets of slag are closely related to the flow slags described above, but are more common elements of assemblages of both smelting furnace and smithing hearths. At Aghavea they occurred in two contexts, both in conjunction with good assemblages of smithing residues (contexts (13) and (75)).

Smithing floor concretion: the presence of smithing floor concretion (a concretion typically containing fine slag fragments and charcoal alongside abundant hammerscale) may be indicative of concretions developed within the fine-grained debris on a smithy floor or on a smithy waste deposit. They may be a good indicator contexts containing hammerscale in the absence of direct sampling. In this assemblage such materials were not well-developed, but an example was recovered from fill (260) of pit [12].

Interpretation

The assemblage appears strongly linked to a discrete phase of activity involving a smithing hearth [278], an associated levelled working area and dump [361] and some gullies ([90] and [354]). The residues indicate iron working (smithing) involving the use of a simple hearth and a ceramic tuyère. This is the ubiquitous smithing technology of medieval Ireland, and is quite distinct from contemporary Britain, where a clay-walled hearth with a simple blowhole was general.

The SHCs are typically small (with a modal size of approximately 220g), although a proportion of larger SHCs was also present, raising the mean SHC weight to 403g. Just 11% of examples of SHCs had recorded weights of over 1kg, and these clustered around a weight of 1300g.

A significant number of SHC assemblages of the general period are now known, enabling comparison between sites.

The weight-frequency distribution of the SHCs at Aghavea is rather unusual. Assemblages of most early medieval sites that have been examined contain a significant proportion of very large (>2000g) SHCs, that have been interpreted as being indicative of the processing of iron as part of the *chaîne operatoire* of iron making, rather than simply the end use of iron (i.e. blacksmithing).

The prevalence of these large SHCs decreases through time, and it has been argued that this indicates a progressively increasing use of iron that has been produced elsewhere and traded as a finished product (e.g. bar iron), rather than as past-processed blooms. In the earlier medieval period, iron appears to have reached end user smiths in an incompletely refined form, requiring further processing. Pleiner (2000; p241-242) described a similar trade in medieval and early post-medieval Denmark. Thus even minor early medieval rural sites such as Navan (Young 2007a), with what was probably a short-lived episode of smithing within a boundary ditch, show large SHCs ranging up to 3 or 4kg in weight. In contrast, later medieval smithies, such as Garryleagh (Young 2009) may show no SHCs of more than 1kg in weight.

It is possible that the end-users of iron, the blacksmiths, have been under-represented in recent excavations, particularly with the large number of iron working sites located during the construction of motorways that have skirted the iron resource-rich areas around the midland bogs.

Nonetheless, the most similar weight-frequency profiles to the present assemblage, are the dominantly end-user blacksmithing sites of medieval and even post-medieval age such as Ardreigh (medieval; Young 2012b), Coolamurry (12^{th} – 13^{th} century; Young 2008a, McCullough & Young in review), Mucklagh (post-medieval; Young 2008b), an undated, but probably medieval to the west of Clonmacnoise (author's unpublished data) and Garryleagh (Young 2009; 13^{th}-14^{th} century).

In terms of the nature of the site, with spreads of highly broken smithing debris and associated circular hearths, the site at Coolamurry (of 12^{th}-13^{th} century age; Young 2006, McCullough & Young in review) provides a close analogue. This site is an apparently isolated smithy and has slight structural evidence in the form of drip gullies to suggest associated buildings, perhaps of cob construction.

Other excavated smithing hearths of the period have tended to be more elongate:

Killeany 1 (Young 2008c)
- (F237): 1.37m x 0.9m and 0.16m deep
- (F264): 1.49m x 0.94m and 0.17m deep

Dunlo (cal AD 985-1028; Young 2010).
- (C16): 1.35m x 0.95m and 0.18m deep

Coolamurry (12^{th}-13^{th} century; Young 2008a)
- (C27): 1m x 0.9m and 0.2m deep
- (C59): 0.92m x 0.82m and 0.30m deep.
- (C100): 1.2m x 0.8m

Garryleagh (cal AD 1283-1318 & 1352-1390; Young 2009)
- (C13): 0.9m x 0.87m and 0.15m deep.

Cornamucklagh (cal AD 1044–1218; Walsh 2013, Young 2014)
- (C66): 0.82m by 0.54m by 0.11m deep
- (C68): 1.46m by 0.99m by 0.21m deep

At Cornamucklagh and Coolamurry tuyères were absent from the assemblages, but although it may be tempting to view these south-eastern assemblages as exhibiting Anglo-Norman influence, it is perhaps more likely that the sherds of ceramic tuyère became rapidly degraded and destroyed within the trampled spreads of residues on these sites, as opposed to the common preservation of tuyères on sites where residues were deposited into large dumps or into ditches (Young 2014, 2). Such an argument would certainly be compatible with the evidence at Aghavea, where there are trampled spreads of broken smithing slags and a very low proportion of tuyère remains.

In summary, the archaeometallurgical evidence suggests that the activity in the 'industrial area' was blacksmithing, the end use of iron to fabricate or repair artefacts. The scope and scale of the evidence is similar to that from other smithies both in rural (e.g. Coolamurry) and urban (e.g. Ardreigh) settings. The style of evidence is, however, markedly different from that at major metallurgical centres of both ecclesiastical and secular nature; at these iron production is commonly a major activity and they also show the working of non-ferrous metals. The closest analogues for the present material would be found in sites such as Coolamurry (12^{th}-13^{th} century), Ardreigh (medieval) and even in some conservative post-medieval sites (e.g. Mucklagh of the 17^{th}-18^{th} centuries).

Sites where ironworking is associated with a medieval ecclesiastical enclosure are known, with that at Ballykilmore (Young 2012a) being one of the more fully investigated. At Ballykilmore, the ironworking, including both smelting and bloom processing, appears to have distributed around various sections of the enclosure to the S and SW of the church in the medieval period, although some activity occurred near the eastern entrance very early (5^{th}-7^{th} century) in the history of the site, prior to construction of the church.

Whether the assemblage from Aghavea represents an earlier development of the medieval smithy as seen elsewhere, or whether the smithy is slightly later in date than currently envisaged, would require further detailed dating of the 'industrial features'.

Evaluation of potential

The residues have little potential for providing significant extra information through further detailed analysis, so no further analysis is recommended, although retention of the assemblage for deposition with the site archive is strongly advised.

The significance of the conclusions reached in the this report will vary depending on the determination of the dating of the metallurgical activity. The report may need some revision in the light the results of any such dating campaign when they become available.

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Glossary

Blacksmithing: the working of iron and steel. Often restricted to the secondary smithing – i.e. the smithing of iron to produce or repair artefacts, as opposed to the smithing involved in the production of billets or bar iron from raw iron blooms.

Bleb: a small rounded particle or textural component, often a droplet or prill.

Bloomery: a furnace for smelting iron from ore in which iron is produced as a solid material. The bloomery process was employed mainly prior to the introduction of the later blast furnace from the late 15th century.

Bloomsmithing: The process of reworking a raw bloom, through repeated reheating and hammering, to reduce its content of slag, to remove unwanted inclusions and to draw out the remaining slag into elongate inclusions. The end product may be a bar or billet. Usually taken as an alternative term for bloom-refining.

Blowhole: A hole through a furnace or hearth wall through which air is blown.

Burr: the zone of interaction between slag and the hearth or furnace wall just below the tuyère/blowhole. Typically seen as a dense lunate slag, with attached highly indurated ceramic, forming a protuberance on the margin of an SHC or FB.

Flake hammerscale (FHS): flake-like particles formed by the surficial oxidation of hot iron in air (Young 2011c). The iron oxide layer will detach from the workpiece because of differential thermal contraction or during deformation of the workpiece when hotworked at the anvil. The thin scales fall from the workpiece and will accumulate mainly close to the anvil (although some will be lost elsewhere in the forge and even in the hearth). Flake hammerscale has planar surfaces, one of which is typically very smooth and reflective, the other only slightly less so.

Flow slag: slag that has been very fluid and mobile, but which has stayed within the furnace (or hearth) and has not been tapped out of it.

Fuel Ash Slag (FAS): slag formed by the partial melting of hearth wall or substrate under the fluxing influence of the ash (inorganic component) of the fuel. Fuel ashes are often very rich in alkali and alkali earth elements that may lower the melting point of silicates.

Lining Slag: Slag formed from the complete or partial melting of hearth or furnace lining.

Prill: a small aggregate of a material, either a spheroidal droplet or a runnel, formed from a melted liquid and either occurring as a discrete particle or as an inclusion within another material.

Slag spheroids: sub-spheroidal particles, often dimpled (coffee bean spheroids), dull in lustre, and less perfectly spherical the spheroidal hammerscale. These spheroids are typically up to about 10mm in diameter. These are mainly slag droplets formed by the dripping of slag within the fuel bed of the hearth. Isolated spheroids may form in non slag-tapping smelting furnaces as a variety of sparse flow slag, but are more common in smithing hearths.

Smithing: the activity involved in forming a metal object, including, but not limited to, forging metal and joining metal by welding.

Smithing hearth cake (SHC): the slag cake formed in a smithing hearth by reaction of iron oxides lost from the workpiece with silicate material from hearth ceramic and/or fuel, below and in front of the tuyère/blowhole. They are very variable in form, but are typically plano-convex in shape (although concavo-convex and biconvex forms are common), frequently with a dense lower crust and a less well consolidated upper part. In some cases the top is formed of glassy slag.

Vesicle: a void or pore, usually rounded and formed as a preserved gas bubble in a solidified melt.

Table 1: summary catalogue of archaeometallurgical residues and associated materials, by bag. Pale grey tone indicates materials that not archaeometallurgical.

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
7	6	bag 1 of 1 (bag #56)	24			
				24	1	angular fragment of dense, rather granular, iron slag with a few vesicles
8		bag 1 of 1 (bag #11)	544			
				32	1	fragment of margin of tuyère, with radius of approximately 40mm, ceramic has coarse angular quartz, with front face of tuyère now almost entirely covered in quartz with interstitial black glass
				48	1	vitrified oxidised lining; ceramic rich in quartz including ?sandstone fragments. Slight lifting of slag off ceramic at one end might just be tuyère margin, but not certain
				198	8	dense slags in blebby sheets with much adhering charcoal
				20	2	vesicular slag chips
				42	1	blebby slag lump
				176	1	fragment of thick crust with tubular vesicles, attached to sandstone clast in wall/floor, which appears to be steep; top has smooth but irregular dimpled surface, base away from clast is finely fuel dimpled
				22	1	natural conglomerate
9	354	bag 1 of 1 (bag #20)	1254			
				178	1	large piece of SHC crust - unclear if this is the whole crust or just deformed fragment
				110	1	dense slag sheet, with tubular vesicles, from the base of a well-formed SHC ; the top is absent with crystal terminations covered in delicate organics including leaves
				220	1	very irregular lump of slag, including the base of the SHC with tool marks; charcoal rich, unclear if contorted
				460	1	large part of open SHC bowl/crust, crystal terminations on top, dense bowl with prills on base and remains of angled previous crust
				10	1	slagged ceramic fragment
				34	4	dense flow slags
				222	9	dense blebby slags, less distinct flow lobes than group above
				20	1	conglomerate
11	10	bag 1 of 1 (bag #2)	132			
				30	1	rounded mass of rusty charcoal-rich slag
				14	1	strange blebby slag, reddened; an agglomeration of sub-spheroidal blebs, some hollow
C	**F**	**bag**	**Sample wt.**	**Item wt.**	**Item no.**	**Notes**

				64	5	grey thin slag sheet, with smooth, only slightly dimpled base, irregular top with ashy? coating, possibly from an SHC margin
				20	1	igneous rock - basalt?
13	12	bag 1 of 2 (bag #12)	208			
				106	5	dense blebby slags, two small fragments are individual blebs, larger pieces are amalgamated prills into 15-20mm thick crude sheets, probably SHC fragments
				47	2	sheets of material, possibly SHC fragments but may alternatively be concretionary sheets of slag blebs, charcoal, and corroded iron
				32	5	vitrified lining, sandy and gravelly
				<1	2	pale grey clay with tubes suggestive of moulds after hair temper
				<1	4	tiny concretionary fragments
				16	2	rock fragments
13	12	bag 2 of 2 (bag #6)	100			
				34	1	vitrified reduced-fired ceramic, embayed section shows reddening of surface of slag - probable the blowhole margin
				<1	1	fragment of vitrified ceramic
				14	1	dimpled very thin dense slag sheet, triangular in shape
				12	1	gravelly ceramic fragment, mainly oxidised, rounded convex external section - possible tuyère margin
				4	2	slag droplets in ashy matrix
				10	3	dense slag droplets
				20	7	blebby slag in ferruginous accretionary matrix with charcoal debris
14	278	bag 1 of 2	4045			
				24	3	vitrified reduced lining
				18	1	vitrified face of ceramic with margin of blowhole to one side
				18	3	blebby lining slags
				128	4	massive vitrified gravelly ceramics
				4	1	small rusty sheet-like concretion
				1290	140	small slag fragments
				80	9	dense flow slag prills
				568	9	SHC fragments - from small SHCs with dense lower crust
				150	1	dense piece of charcoal-rich slag bearing dense elongate prills
C	**F**	**bag**	**Sample wt.**	**Item wt.**	**Item no.**	**Notes**

				298	1	large part (or even all) of a finely charcoal-rich dense SHC, 100x(55)x45mm
				260	1	central part of small biconvex SHC, all edges missing; basal crust has extremely marked and abundant tubular vesicles
				220	1	part of SHC 95mm wide, 45mm thick, dimpled top, microdimpled base, one half minimum
				154	1	dense rounded slag mass, with fine charcoal
				160	1	irregular mass, dimpled or prilly surfaces, one stone inclusion, slightly lobate on one side may be part of steep side
				100	1	irregular lump of slag with fine charcoal in rounded mass
				164	1	65x65x30mm, discoidal lump, probably a small plano-convex SHC
				80	1	probable small SHC- dense crescentic piece 55x40x30mm, but may be fragment of something larger
				42	1	microprilly slag lump
				16	1	dense slag fragment with charcoal inclusions
				8	1	dense slag lobe with one very flat side
				2	1	slagged oxidised ceramic
				76	1	conglomerate
				188	10	rocks (some at least burnt pebble fragments)
						plus 415g fines in base of bag
14	278	bag 2 of 2	7855			
				626	10	lobate flow slags, rather like tap slags, probably contorted, base shows some charcoal contact moulds
				1335	1	large slightly biconvex SHC, 140x170x70(50)mm, covered in concretion rich in charcoal and possibly other organics
				864	1	120x100x65mm, SHC with dense base and well formed upper slab, rather quadrilateral in outline, but with one side folded over possibly; basal part of SHC is a 100x100mm disc.
				398	1	120x(60)x40mm, slightly dished SHC, crust up to 20mm with tubular concretions, base irregularly dimpled, top finely charcoal dimpled
				390	1	75x90x50mm, end of very dense SHC, plano-convex, surfaces masked by accretion
				322	1	irregular lump of internally prilly slag with moderately large charcoal fragments
				228	1	80x90x45(35)mm small neat SHC, top is highly vesicular and apparently extremely quartz rich, base neat, microprilly.
				208	1	85x85x35mm thin concavo-convex SHC, dished smooth top, base rounded, slightly prilly. Raised lip on one side has tiny area of contact with oxidised ceramic
				256	1	strange angular SHC; gently curved side has non-wetted surface, then probably angular bend of dense slag, top of mass is blebby. Adhering accretion has flake hammerscale
				186	1	extremely dense prilly slag mass, 75x55x40mm, main dense part elliptical 45x55mm
				250	1	irregular rounded slag lump with fine charcoal, possibly twisted, could be SHC, but probably just a fragment
C	**F**	**bag**	**Sample wt.**	**Item wt.**	**Item no.**	**Notes**

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
				254	1	70x100x50mm mass - probably rather irregular SHC, possibly slightly concavo-convex, thin basal sheet, has vertical open hole trough from top to bottom at thick end
				216	1	irregular charcoal rich slag lump - possibly a plano-convex block with one end folded over. Low density.
				180	1	mass of microprilly slag with abundant charcoal inclusions
				184	1	dense slag with patches of vesicular (fuel ash) slag, fused on coarse red sandstone
				776	23	smaller slag fragments, most unidentifiable but probably SHC fragments
				42	1	concretionary slag lump - possibly detritus on iron core
				34	1	glassy black mass with white quartzose gravel
				136	1	most of small SHC, rough base and prilly, charcoal-rich body, 75x55x35mm
				354	4	fragments of SHC crust
				36	1	gravelly lining slag
				286	5	probable SHC fragments
				292	3	slag fragments with very large charcoal fragments, one of the pieces is a thin dimpled basal sheet with coarse charcoal on top, others more massive
						plus 390g bag of fines from sieving/cleaning
17		bag 1 of 1 (bag #50)	204			
				70	1	dimpled slag sheet, basal crust fragment from SHC
				134	1	central fragment from SHC; dimpled maroon base, coarse vesicular dense slag, trace of glaze on top,
18		bag 1 of 1 (bag #14)	234			
				124	1	2 conjoining pieces from the dimpled base of an SHC, rich internally in charcoal, top not preserved
				106	1	heavily accreted fragment from dimpled base of a small SHC
20	19	bag 1 of 1 (bag #25)	20			
				18	4	small slag fragments
				2	1	sandstone or concretion
21	19	bag 1 of 1 (bag #59)	8			
				8	1	small fragment of vesicular iron slag
22		bag 1 of 3 (bag #5)	470			
				470	1	spalled edge of basalt (?) boulder

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
22		bag 2 of 3 (bag #37)	36			
				16	4	weathered slag blebs
				10	1	siltstone
				8	1	concretion
22		bag 3 of 3 (bag #48)	120			
				120	1	distal end of dense but pale SHC, (60)x70x30mm; slightly dished top with broad dimples; base has very slightly raised iron-rich protrusions. Fracture surface slightly rounded so possibly more or less original end
25	24	bag 1 of 1 (bag #55)	80			
				80	1	fragment broken into 3 of vitrified ceramic with angle of around 140 degrees - just possibly basal angle of flat-based tuyère, but very far from certain
27	26	bag 1 of 3 (bag #49)	58			
				2	1	white fired? clay with some iron mottles
				56	6	blebby slags overgrown by concretion
27	26	bag 2 of 3 (bag #33)	102			
				92	1	chaotic vitrified grey ceramic or quartz-rich rock
				10	1	blebby iron slag scrap
27	26	bag 3 of 3 (bag #57)	38			
				4	2	weathered slag blebs
				<1	1	small fine concretion
				28	1	basalt
29	28	bag 1 of 1 (bag #22)	<2			
				<2	1	mottled concretion with coarse quartz
31	30	bag 1 of 1 (bag #60)	<2			
				<2	8	fragments of broken concretion, brown rim and particulate pale, ashy? core
33		bag 1 of 8	50			

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
				50	1	dense slag, probably SHC crust, containing enclaves of grey gravelly ceramic, large spherical vesicles; enclaves have elongate fringing olivine on etched surfaces
75		bag 1 of 2 (bag #54)	82			
				82	2	abraded lumps of SHC, one showing thick crust with tubular vesicles, the other simpler, both dense
75		bag 2 of 2 (bag #52)	10			
				10	1	fragment of smithing floor concretion with FHS
77		(bag #47)	46			
				46	2	gravelly lining slag in sheets attached to very bleached clay in one piece and oxidised fired lining in the other
77		bag 1 of 7 (bag #31)	50			
				50	1	charcoal-bearing vesicular slag, probably from SHC
77		bag 2 of 7 (bag #41)	156			
				82	1	fragment of dense slag- the lower crust from a probable open-bowl concavo-convex SHC; has slight tubular vesicles up to 15mm thick
				67	1	gravelly vitrified ceramic - strongly convex contact between ceramic and overlying gravelly slag
				5	1	maroon-surfaced dense flow slag
77		bag 3 of 7 (bag #45)	64			
				64	1	conglomerate
77		bag 4 of 7 (bag #34)	48			
				38	7	blebby slags
				<1	1	tabular rusty fragment of concretion or spall
				4	3	gravel and sandstone
				<2	2	small fine concretions
77		bag 5 of 7 (bag #44)	16			
				8	1	fragment of charcoal-bearing slag
				4	7	mottled concretions

				<2	1	tabular iron concretion or spall
77		bag 6 of 7 (bag #28)	<2			
				<2	1	small concretion with iron oxide mottles
77		bag 7 of 7 (bag #35)	68			
				56	1	tip of small SHC, very dense, rusted, base smoothly dimpled, top with fine charcoal debris,
				8	1	burnt stone
91	90	bag 1 of 2 (bag #9)	628			
				48	1	fragment of dense SHC, gravelly, possibly burr, but surface of slag has smooth, maroon slightly lobate surface. Almost completely non-vesicular.
				116	1	fragment of slag sheet with irregular smooth, slicked top with some holes, base of sheet has very large charcoal fragments
				212	8	charcoal-rich slag fragments, most with a smooth surface similar to piece above
				88	2	fragments of slag sheet, one certainly one possibly pieces from SHC basal crust
				98	10	blebby slags coated in pale concretion
				48	1	dense rounded slag nub, partially with a surface resembling the surface of the SHC fragments above
				40	3	blebby and microprilly iron slags
				<1	2	fine grained concretions
91	90	bag 2 of 2 (bag #4)	34			
				4	2	lining slag fragments
				16	3	charcoal rich slag fragments
				6	1	irregular crinkled vesicular slag sheet with maroon surface
				>2	2	muddy concretions
95	94	bag 1 of 2 (bag #19)	1175			
				114	1	fragment of coarse grained SHC, abundant charcoal on base,
				84	1	irregular twisted SHC fragment
				432	10	fragments of dense SHCs, three have gravelly contacts, probably burr fragments
				146	5	slag nubs and blebs, not parts of SHCs, hearth slags
C	**F**	**bag**	**Sample wt.**	**Item wt.**	**Item no.**	**Notes**

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
				132	1	thin broad dense SHC fragment, c10mm thick, concavo convex slightly prilly base, hints of downwards prills just around margin
				192	1	fragment of dense SHC, 20mm thick in centre of bowl of concavo-convex SHC, base dimpled and with charcoal clasts
				76	4	rock fragments
95	94	bag2 of 2 (bag #40)	134			
				46	1	dense SHC fragment with large central vesicle, vesicle filled with pale charcoal-rich clay
				6	1	dense slag bleb
				34	2	sheet like slag with smooth but irregular maroon surface on one side
				12	1	fired reduced clay, attached to charcoal-rich concretion
				34	1	dense irregular charcoal-bearing slag fragment
104	103	bag 1 of 1 (bag #3 or #13)	326			
				142	3	dense flow slags, at least 2 or 3 show large contacts suggestive of smelting slags, very dense
				68	12	small scraps of charcoal-rich slags, some with clear prilly textures
				28	1	fragment of probable SHC crust with adhering concretion including large FHS with unusual strong crystal domain structure
				88	1	fragment from lip of cake with steeply dipping crust, coarsely crystalline, coarse crystals protrude into upper cavities, side has base which is fuel-dimpled and locally reddened (as is top), top of side curves over into overhanging layer of lobate, reddened slag.
107	252	bag 1 of 1 (bag #58)	96			
				66	10	slag blebs and larger dimpled nubs
				12	5	porous iron concretions - like fine bog ore
				6	4	exploded tiny concretion on iron
				6	3	concretions or fired grey clay
109	108	bag 1 of 1 (bag #27)	54			
				14	1	dense flow slag prill
				40	1	dense slag in rounded nub attached to oxidised fired wall. The ceramic contains coarse quartz grains
130		bag 1 of 1 (bag #61)	18			
				10	1	weathered iron slag

				8	1	dolerite-like rock
136	135	bag 1 of 1 (bag #24)	10			
				8	2	iron slag prills
				<1	1	concretion onion skin
145		bag 1 of 4 (bag #15)	808			
				334	1	central section (possibly 50%) of charcoal rich SHC, 110mm wide, 55mm deep, possibly rather deformed
				436	1	fragment of very dense SHC, one end shows half of a deep burr region of interaction with grey ceramic
				40	1	maroon well-flowed slag in lobes - possibly discrete flow slag but just possibly from SHC margin. Single lobe in thickness, convex base
145		bag 2 of 4 (bag #8)	320			
				320	1	irregularly shaped block of charcoal rich microprilly slag; has a small area of ceramic contact, around which the slag is reddened and smooth; possibly a sub-blowhole mass of some sort but no clear indications of orientation
145		bag 3 of 4 (bag #29)	4			
				4	1	bone fragment
145			3840			
				1115	2	similar pieces from very large slag cake, margin of cake is upfolded angularly with planar interior surface and rounded margin; the planar upper surface and other parts of the inner bowl are lightly covered with oxidised ceramic, extending down 50mm from lobate lip then 40mm across top of bowl. The slag is rich in gravel clasts and is very dense; away from the margin the bowl appears concavo-convex with maroon lobes topping fill, c40mm thickness, and a lower 20mm dense bowl. This be a large slag cake folded around embedded failed tuyère tip, but is very hard to interpret. The base has thin oxide-rich skim with fuel imprints towards margin, with fuel more deeply impressed towards centre
				1185	1	strange open irregular bowl of slag, probably large SHC, 170x160x45mm, all edges appear missing, base smoothly rounded, top with lots of fine fuel impressions
				210	1	fragment from near the margin of the lip of large slag cake with open or hollow bowl and flat topped margin
				1325	1	large SHC 170x150x50mm with elongate oval SHC, plano-convex, attached to slag along and below face of gravelly tuyère - the margin of which just shows in this piece. Lower half of tuyère is elliptical and 150mm wide (estimated) by perhaps 60mm to vertical margins

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
211	210	bag 1 of 1(bag #53)	20			

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
				8	1	concretion on slag
				12	1	vitrified oxidised gravelly lining
253	252	bag 1 of 1 (bag #32)	238			
				226	1	most of small dense almost semi-circular SHC. 70x90x35mm. Top slightly concentrically ridged, base irregularly lobate with micro-dimples
				6	1	coarse sandstone
258		bag 1 of 2 (bag #46)	54			
				34	9	weathered slag blebs
				10	1	slagged and vitrified lining
				<1	1	corroded iron or slag
				2	1	orange ceramic
				<1	1	bone
				<1	1	small pottery sherd
258		bag 2 of 2 (bag #21)	718			
				131	1	60x60x45mm, central part of SHC or possibly entire SHC, roughly square slab like top, 10-25mm thick, with conical protrusion on base
				125	1	60x60x35mm, small concavo-convex SHC, formed of amalgamated prills; hollowed top contains charcoal debris
				127	1	irregular shaped, charcoal-rich slag, some charcoal rather coarse
				175	1	triangular dense slag, with additional thin sheet fragment attached to base, probably central part of SHC with edges missing, 70x75x45mm
				106	1	rounded rusted lump of charcoal bearing slag, one curved face might be suggestive of SHC base
				53	6	slag fragments, irregular in form, probably broken from material equivalent to SHCs above
				5	1	dense flow slag prill
259	12	bag 1 of 1 (bag #10)	298			
				186	34	blebby slag scraps in ferruginous coatings. One piece has flat surface with lip - possibly suggesting it was picked up with tongs?
				8	4	as above but identifiable as small scale prills
				24	2	blebs of lining slag
				76	11	vitrified lining - largest piece probably shows lag flap on blowhole margin at one end

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
260	12	bag 1 of 1 (bag #39)	212			
				74	6	concretions (plus bits) with fine matrix, unclear if on iron but possibly
				62	12	small concretions rich in fine charcoal, at least one including hammerscale
				44	3	dense prilly flow slags
				16	4	concretions formed on weathered slag blebs
				4	2	vitrified oxidised fired ceramic
				8	1	sandstone
267		bag 1 of 1 (bag #30)	118			
				118	1	slab of garnet-mica schist
267		bag 1 of 3 (bag #38)	400			
				400	1	80x100x50(15), curious biconvex SHC, or alternatively simply the burr region from a larger SHC. Dense slag, including raised upper section,
267		bag 2 of 3 (bag #51)	400			
				204	1	substantial part of small SHC, base rich in charcoal inclusions of up to 20mm, top5mm denser, but upper surface obscured by concretion
				146	1	part of small SHC, base rich in large charcoal, top obscured, slightly dished
				50	30	debris of small pieces, some definitely from above SHCs or similar, others appear to be charcoal-rich concretions rather than slag
267		bag 3 of 3	418			
				246	1	rounded lump of charcoal rich slag, fairly regular so probably all or part of small SHC, 90x80x40(25).
				152	1	rounded slag lump, probably worn part of a small SHC
				24	2	two small fragments of charcoal-rich slag
268		slag 1 of 2 (bag #16)	908			
				546	5	charcoal-rich slag with some internal prills, charcoal pieces up to 40mm
				360	5	irregular pieces of dense vesicular iron slag, some suggestive of SHC crusts, but not certain
				2	3	sandstone fragment and other sediment pieces
268		bag 2 of 2 (bag #26)	122			

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
				122	1	rounded mass of rusty charcoal rich slag
276		bag 1 of 1 (bag #17)	1265			
				128	1	fragment of dished SHC with smooth puddle top, gravelly clasts, dimpled and charcoal marked base
				908	1	dense triangular SHC, 120x110x60mm, top slightly dished, oval dished top occupies one end of triangle
				230	1	40mm thick vesicular slag, raised lobes on top of SHC fragment, charcoal inclusions near top
277	278	bag 1 of 1 (bag #36)	100			
				90	1	large piece of margin of tuyère, approximately 50mm radius, some slagging on face, but also almost contiguous gravel clasts on glazed front
				8	2	blebby slags coated in pale clay with charcoal
				2	1	small fine grained concretion
279	near furnace	bag 1 of 1 (bag #42)	38			
				26	1	blebby dimpled vesicular slag
				6	1	vitrified oxidised lining
280	254	bag 1 of 1 (bag #1)	34			
				34	1	worn and accreted piece of iron slag, dense, possibly a crust fragment
281		bag 1 of 1 (bag #7)	30			
				24	1	slag sheet coated in pale clay with possible manganese blebs
				6	1	slag bleb encrusted in white clay with some charcoal
289		bag 1 of 1 (bag #18)	518			
				136	1	lobate cake lip, resembles smelting pit cakes, has narrow but long wood charcoal lying parallel to wall, base slightly dimpled, margin of smooth lobe
				252	10	dense slags in irregular pieces, smaller pieces slightly prilly, larger are more blocky
				6	1	small fragment of slagged and vitrified oxidised fired wall
				32	1	fragment of thin but very dense slag sheet
				86	2	dense slag fragments with unusual planar surfaces - apparently granular slag with smooth coating - possibly of secondary oxides.

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
290		bag 1 of 1 (bag #13)	166			
				166	1	90x75x35mm, glassy tongue, lower surface rusted, gravelly particles (white, glazing green) and dark glass
304	303	bag 1 of 1 (bag #43)	150			
				150	1	rounded rusted lump of charcoal bearing slag. Amount of rust suggests the slag contained metallic iron
316	315	(bag #23)	<2			
				<2	6	small concretions, one on bone, one on charcoal, others show granules/mottles of iron of slightly angular shape
		Surface finds				
			8435			tray of small pieces
			8065			tray of larger pieces and lining
				8259	565	smaller slag pieces
				802	24	lining slag lumps - mainly gravelly
				50	6	vitrified lining fragments
				1891	9	substantial SHC fragments
				212	1	small SHC; 80x60x35mm, slightly concavo-convex
				222	1	small SHC; 85x60x35mm, plano-convex
				222	1	small SHC; 65x90x45, concavo-convex with possible tool-mark on base
				232	1	small SHC; 90x65x40mm (25mm bowl) - fluid slag piece, well-flowed and not certainly SHC
				186	1	small SHC; 85x75x35mm, concavo-convex with tool-mark on base
				172	1	small SHC; 75x80x35(30) flat topped with prill on upper surface
				150	1	small SHC; 65x60x30, plano-convex
				154	1	small SHC; 65x95x35mm, asymmetrical plano-convex SHC
				200	1	small SHC; 95x75x30 probably slightly deformed SHC - slab-like but curved
				384	1	small SHC; 85x90x45(30)mm, well-formed SHC with lobate base, slab inclined on slightly biconvex top
				162	1	small SHC; 80x70x30mm, slightly dished top with probable fuel dimples
				516	1	double layer SHC; 75x120x75mm overall, top SHC c30mm thick, on top of inclined earlier SHC 35mm thick
				222	1	70x70x50mm rather irregular pyramidal SHC
				420	1	rounded mass
				304	1	SHC - 80% of original, plano-convex 40mm thick

C	F	bag	Sample wt.	Item wt.	Item no.	Notes
				592	1	40-50% very deep SHC, lower dense puddle with tubular vesicles 30mm, upper slab also dense but homogeneous 20mm, top possibly missing top of large vesicles?, base micro-dimpled, sides steep very dense, c. 120mm diameter
				232	1	slab attached to grey ceramic - probably SHC but may just be slag coating off wall/floor
				380	1	dense rounded mass - possibly deformed?
				146	1	low density classic tongue, transverse, attached to oxidised fired ceramic, 55x85x40mm
				202	11	rocks
				190	2	basalt/dolerite
		bag 2 of 8	54			
				4	1	small fragment of lining slag
				50	1	medium sandstone with adhering pale clay
		bag 3 of 8	74			
				42	1	vitrified lining, probably from close to blowhole
				32	1	complex mix of lining slag (sandy/gravelly) and vesicular more iron-rich slag patches
		bag 4 of 8	444			
				444	3	three very dense but weathered SHC fragments. They show a thick dense crust of up to 30mm with tubular vesicles. The pieces show weathering to a buff coloured surface in places, with adhering concretion (particularly around the lower openings of the tubular vesicles)
		bag 5 of 7	1385			
				186	2	rounded nub of slag with slightly lobate and microprilly surface, probably the base of an SHC and possibly the entire thickness, very charcoal rich. Second piece is small fragment probably broken from main piece
				276	1	iron rich slag attached to highly vitrified gravelly ceramic. The most likely interpretation is that this is attached to the bottom of the face of a tuyère - so that the ceramic surface is the tuyère base
				954	1	165x90x55mm, rounded SHC, probably somewhat worn base; has slightly double-lobed form with a possible basal tool-mark, top shows a high charcoal content
		bag 6 of 8	26			
				26	1	dense grey slag sheet, 5mm thick
		bag 8 of 8	80			
				70	1	very irregular slag fragment - perhaps a twisted fragment of SHC

10	3	iron slag droplets/blebs

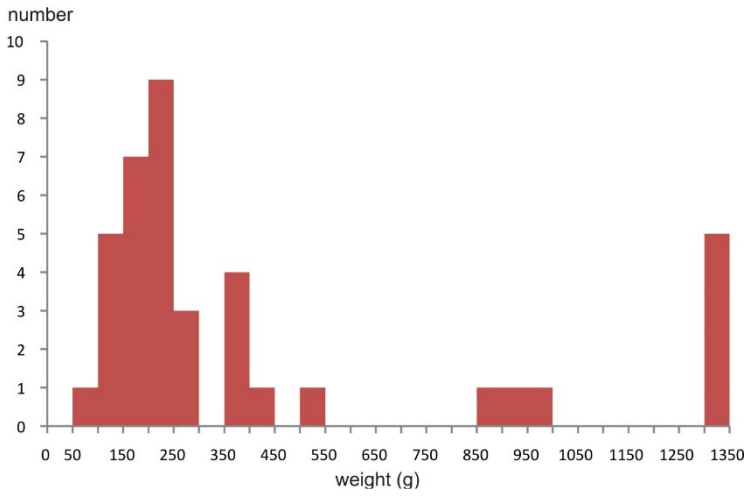
Table 2: summary catalogue of archaeometallurgical residues and associated materials by material type and feature. Weights in grams.

C		Indeterminate slags	SHC	flow slag	tuyère and other vitrified ceramic	lining slag	other fired clay	slag droplets	smithing floor concretion	*Total*
7	fill of linear [6] = 81/83	24								*24*
17	fill of linear cut [6]		204							*204*
11	fill of pit [10]	44	64							*108*
13	fill of possible pit [12]	34	153		79			14		*280*
259	fill of pit [12]	186		8	76	24				*294*
260	fill of pit [12]	90		44	4				62	*200*
25	fill of linear cut [24]				80					*80*
27	fill of linear cut [26]	70				92				*162*
75	fill of linear [73], =74		82					10		*92*
91	fill of gully [90], similar to 342	536	136			4				*676*
95	fill of metalled surface 94	206	868				12			*1086*
104	fill of ditch [103] = 304	156	28	142						*326*
109	fill of pit [108]	40		14						*54*
130	deposit	10								*10*
136	fill of pit [135]			8						*8*
211	fill of linear cut [210]	8			12					*20*
20	fill of outer enclosure ditch [252]	18								*18*
21	fill of outer enclosure ditch [252]	8								*8*
253	fill of outer enclosure ditch [252] = 329		226							*226*
107	upper fill of ditch [252] = 329	66								*66*
280	lower fill of palisade slot [254]	34								*34*
14	fill of hearth [278] = 279	3902	6765	706	44	216				*11633*
277	lining of hearth [278]	8			90					*98*
279	fill of hearth [278] = 14	26			6					*32*
281	deposit	30								*30*
289	redeposited natural	506			6					*512*
290	deposit		166							*166*
304	upper fill of early ditch [303] = 104, 130	150								*150*
258	fill of ditch [309]	162	590	5	10		2			*769*
8	upper fill of gully [354] = 8,18 & 350	260	176		80					*516*
9	upper fill of gully [354] = 8,18 & 350	222	968	34	10					*1234*
18	upper fill of gully [354] =8,9,350		230							*230*
77	fill of linear [361]	46	188	5	113					*352*
145	fill of linear cut [361] = 263		4925	40						*4965*
268	fill of linear cut [361]	668	360							*1028*
276	fill of linear cut [361]		1266							*1266*
22	fill of linear cut [368]	4	120							*124*
33	33 is cut of modern drain		50							*50*
	surface finds	9137	8929		46	32		10		*18154*
	Total	*16651*	*26494*	*1006*	*656*	*368*	*14*	*34*	*62*	*45285*

Table 3: Comparison of the SHC weight-frequency distribution with that of other medieval/post-medieval sites engaged in iron working.

Site:	Garryleagh	Clonmacnoise	Mucklagh	Coolamurry	**Aghavea**	Ardreigh	Navan
County:	Cork	Offaly	Offaly	Wexford	**Fermanagh**	Kildare	Meath
Reference:	Young 2009	Author's unpub. data	Young 2008b	Young 2008a	**This study**	Young 2012b	Young 2007
Age:	13th-14th	medieval	17th-18th	12th-13th		Medieval	E. Med.
SHC count	25	33	66	41	**38**	32	17
SHC min. wt	84	68	62	62	**80**	92	60
SHC max. wt	802	1457	1206	2588	**1335**	2665	2990
SHC mean wt	316	341	373	386	**403**	495	507
% <500g	76%	79%	77%	80%	**79%**	69%	82%
% <1000g	100%	94%	95%	93%	**89%**	88%	88%
% >1000g	0%	6%	5%	5%	**11%**	12%	12%
% >3000g	0%	0%	0%	0%	**0%**	0%	0%

Figure 1. Weight-frequency diagram for SHCs from Aghavea.



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