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# Assessment of archaeometallurgical residues from Cefn Graianog, G1598 (2014)

Revised Version; replaces Report 2015/12

Dr Tim Young

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# Assessment of archaeometallurgical residues from Cefn Graianog, G1598 (2014)

# (revised version)

**Dr T.P. Young**

## Abstract

*This was a small assemblage (23.3kg of residues, from 36 distinct contexts) mainly from three distinct complexes of features, together with lesser quantities of residues from several isolated features. Only seven contexts yielded more than 1kg of residues.*

*The dominant macro-residues were varieties of flow slags from bloomery iron smelting. Although much of this material was in the form of individual prills and slag droplets, the collection included some flows where the prills were aggregated into elongate composite flows, morphologically resembling tapped slag. A few examples of these flows showed a degree of reddening, supporting the possibility of the flows having been tapped from the furnace. A further additional flow showed deformation, with half of the width of the flow inverted onto the other – suggesting manipulation of the semi-solidified flow. The material closely resembles that recovered during the 2012/13 seasons, subsequently dated to a period within the 7$^{th}$ – 9$^{th}$ centuries AD.*

*Some fragments of macro-residue were almost certainly from smithing and the sieved residues showed significant quantities of hammerscale (both flake and spheroidal) within many of the contexts (17 out of 36 contexts).*

*Several contexts (17 in total) contained particles of bog iron ore, with three contexts containing significant quantities (one containing almost 2kg).*

*In addition to a few isolated contexts, the residues occur in four separate complexes of features, potentially buildings, with the material from the 2013 indicating a fifth such focus. Of the four describe here, the western Complex 1 produced approximately 3.6kg of residues, with moderately abundant hammerscale in some contexts, the central Complex 2 yielded 12.5kg of residues, with three contexts yielding good assemblages of smelting slags and most productive contexts producing evidence for both smelting and smithing and the eastern Complex 3 produced evidence for smelting alone, including a large collection of bog iron ore. Complex 4 produced only very limited metallurgical evidence. The precise nature of the potential metallurgical features within each complex requires further investigation.*

*The presence of tapslag-like residues in Complexes 1 and 2 as well as a folded slag flow in the more Complex 1, suggests (but does not prove conclusively) that these areas may have been associated with the use a slag-tapping technology (potentially younger than the non-tapping). The eastern complex yielded no such materials and might therefore (but again not certainly) have been using a non-tapping technology, as appeared to be the case with the material from 2013.*

*The location of the site on a gravel ridge above a low-lying boggy area, suggests that it may have formed a location for the smelting of locally-derived ores.*

*Further analytical investigation of the assemblage is strongly recommended.*

# Contents

Abstract ..... 1

Methods ..... 2

Results
Description of Residues
Bloomery iron smelting residues ..... 2
Smithing slags ..... 2
Indeterminate residues ..... 2
Iron Ore ..... 3
Other ..... 3
Distribution of residues ..... 3

Interpretation ..... 3

Discussion ..... 4

Further work ..... 5

Figure Captions ..... 5

References ..... 6

Table 1: ..... 7
Table 2: ..... 20
Figure 1 ..... 21
Figure 2 ..... 22

# 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.

This report replaces Young (2015c) which describe only a subset of the material; this report addresses the entire collection.

The examined materials are listed in Table 1.

This project was commissioned by Dave McNicol, of the Gwynedd Archaeological Trust.

# Results

### *Description of residues*

The submitted materials amounted to an overall total of approximately 26kg. The macroscopic material collection totalled approximately 20.8kg, of which 3.9kg was fine debris and dust, 2.4kg was iron ore and 280g of concretions. Of the 14.2kg of archaeometallurgical residues, 9.5kg comprised flow slags, 3.6kg were indeterminate iron slags, with the remainder including various other classes. Most of the sampled contexts also had samples of sieved and magnetically-separated microresidues. The summary catalogue of the material is presented in Table 1.

#### *Bloomery iron smelting residues*

Most of the collection comprised flow slags. Of these, 8.7kg were grey-coloured flow slags. Some of these were elongate and fragile, but most of the pieces were either from conventional flows or were from masses of coalesced flows, commonly superficially resembling tapped slag. The coalesced specimens were themselves typically rather elongate and narrow. There were no pieces of substantial accumulations. These materials did not show any reddening of their surfaces. One fragment (from context (173)) showed half of a coalesced flow mass folded and inverted on top of the other half, indicating deformation when semi-molten. Most of the individual flow lobes and tubes within the flow slag were small, mostly less than 15mm diameter and the majority of only half that value, but some contexts contained a significant proportion of much broader, inflated lobes, probably indicating continued slag supply with little lateral flow.

A further 830g of flow slag accumulations showed a slightly reddened, maroon, surface, suggesting surficial oxidation of the slag when hot – such as may occur when slag is tapped from the furnace.

Probably related to the flow slags are a small quantity of fragments of narrow slag rods and runners (total 290g).

Most of the flow slags showed bases dimpled through contact with fuel, although some were entirely rough-surfaced, suggestive of flow through the basal ashy sediment. Some of the otherwise smooth-surfaced flows showed slight wrinkling of the upper surface from contraction or deflation, and some showed an unusual minutely dimpled texture cause by a very high vesicularity just below the top of the flow lobes.

#### *Smithing slags*

There were no complete, certain examples of smithing hearth cakes (SHCs), but several fragments that may derive from SHCs were recovered. None was a certain example.

There were also two fragments from the burr region of slag cakes (the burr is the zone where the hot zone impinges on the wall, just below the blowhole, resulting in erosion by melting of the wall into a smoothly arcuate embayment with a highly indurated surface). Burrs may develop in both smelting furnaces and smithing hearths; the present examples are small (resembling those formed in smithing hearths) but are thin (a feature sometimes more commonly found in smelting furnace slags).

#### *Indeterminate residues*

There was a variety of dense slags totalling 3.6kg with a charcoal-rich or more massive fabric, or fragmented to a degree to which they no longer exhibited diagnostic features that might allow them to be assigned to either smithing or smelting.

In addition, there was a total of 283g of vitrified hearth or furnace ceramic and 112g of slag derived mainly from the melting of the wall, with little input of iron.

Neither group could be attributed to a process with any certainty and most of this material occurred in very small fragments.

*Iron ore*
Small particles of iron ore occurred widely in the sieved samples, both as raw and haematised (roasted) pieces, typically with a particle size of less than 2mm. The macroscopic collections also included ore material, with contexts (67), (227) and (230) yielding collections of 178g, 213g and 1982g respectively.

Most of the ore is a bog iron ore with thin veinlets and mottles of a pinkish-brown hydrated iron oxide. A lesser proportion of the material appears to be very manganese-rich, with small fragments of soft wad-like concretions, together with tubular concretions in a similar material (context (230).

*Other*
The macroscopic collections included, in addition to the material described above, rare fragments of fired clay that were not demonstrable hearth/furnace lining, occasional fragments of vitrified or glazed pebbles, and concretions formed around iron or slag (sometimes containing charcoal and hammerscale).

The microscopic residues were rich in clasts of stone (some magnetic, especially where heated), occasional burnt bone fragments and finely granular magnetic material (some of which may be ore, but some perhaps secondary minerals derived from alteration of slag or iron).

The assemblage also included three examples of thin slag films with a right angled re-entrant. Such slag films are usually caused by slag adhering to the tip of the smith's poker or tongs. Although typically an indicator of smithing, such artefacts might also be formed during smelting.

***Distribution of residues***
The distribution of the residues is illustrated in Table 2 and in Figure 1. This table divides the productive contexts by geographical area and indicates the total weight of various macroscopic residue classes and a general indication of the abundance of microresidues.

The residues occurred, mostly in very small quantities, in a variety of isolated contexts in the north and west of the 2014 area (contexts (69), (73), (99) and (122)). The very low concentrations suggest that these may not have bene metallurgical features, although the hammerscale and slag associated with the in-situ burning in context (122) (a fill of pit [120]) hints at the possibility of use of this pit as a smithing hearth.

The majority of the residues were contained within the fills and spreads of four complexes of cut features (Complexes 1-4 of Table 2 and Figure 1; the complexes are employed here simply as a means of differentiating the various productive feature clusters). A similar cluster of features from the 2013 season is identified as Cluster 5. Although the complexes differ in detail, they typically include both spreads (probably the remains of working floors) and distinct cut features, typically beneath the spreads.

Complex 1 comprised fills from eight adjacent cut features ([131], [141], [149], [155], [159], 172] and [178]) together with spread (133). A series of sparse assemblages from cut features immediately to the south ([187], [199}, [202] and [204]) are also included here, although it is possible they are associated with a separate structure. Four of the adjacent features contain rich assemblages of hammerscale, suggesting smithing had taken place within the immediate area. Smelting slags were also present, including examples of possible tapped slag (in pit [172]). The amounts of flow slags were however fairly low, with pit [124] containing the greatest, but with a total of just 726g of residues. The gullies to the south of Complex 1 may form a separate complex; they yielded only small quantities of slag and hammerscale, and so were probably distant from the actual metalworking.

Complex 2 yielded a larger quantity of residues (12.5kg of submitted material over half of the total). The residues included both smithing and smelting residues. The greatest quantities of smelting residues were from gully [211] (3855g), gully or pit [217] (5607g) and pit [240] (1601g). Gullies [211] and [217], together with pit [126] yielded rich assemblages of hammerscale, and five other contexts also yielded scale. Sub-circular cut [124] yielded not only scale, but also the only large fragment of a SHC from the site. The productive cut features included two equant pits (cuts [124] and [222]), several slightly elongate pits (cuts [126], [215], [217], [240] and [244]), and two similarly-sized elongate cuts (cuts [206] and [211]). Complex 2 contained a symmetrically-located stone hearth, but this contained only a concretion on a small iron artefact and no archaeometallurgical residues.

Complex 3 included a spread rich in smelting debris (total 3.4kg), together with a small pit [229] (0.45 x 0.28 x 0.2m) that contained approximately 2kg of bog iron ore and a shallow slightly elongate pit ([263]; of similar dimensions to the main group of pits in Complex 2).

## Interpretation

The amount of archaeometallurgical waste recovered from the site is relatively low. This may reflect the deposition of the waste into slag mounds or other areas of deposition not preserved into the archaeological record. There are no large, deep features close to the likely foci of activity to have accumulated waste. Much of what is preserved is either in shallow features or in spreads that are probably the working floors.

A close parallel for the style of feature (and complex) found on this site is to be found in the site at South Hook, Pembrokeshire (Crane & Murphy 2010), a site with metallurgical activity of the 9$^{th}$-10$^{th}$ centuries AD. South Hook provided excellent structural evidence for two early slag tapping bloomery furnaces, but only 53kg of residues.

The majority of the residues at Cefn Graianog are indicative of bloomery iron-smelting. The details of the technology are unclear: although the majority of material suggests an origin in a non-slag tapping furnace. Such furnaces may have had a simple basal pit or chamber, into which the slag descended during the smelt, or they may have had a lower section of the shaft with a frontal arch (to permit clearance of the slag and probably the bloom) which functioned in the same manner. Some of the material, however, showed evidence for slag tapping (the common occurrence of elongate composite flow slag pieces, reddening of the slag surface and presence of deformed flow slags).

The residues and the contexts yielding them from the 2014 season, are very similar to those recovered in the 2013 campaign (Young 2015b; here referred to as Complex 5).

Identification of the individual cut features within the complexes is not straightforward. The nature of the associated working floors (archaeological spreads) means that deposits of mixed origin fill many of the features, thus internal fills may not necessarily be indicative of the use of the features.

The nature of the cuts requires further investigation (through further interrogation of the excavation records), but some possibilities may be investigated through consideration of the dimensions of the features.

The basal pits of early medieval non-slag tapping slagpit furnaces in southern Britain are typically in the range of 400mm to 1000mm diameter (e.g. Haslam 1980; Rainbird & Young in press; Reed *et al.* 2006; Young 2014, 2015a). Such pits might be one interpretation of the small equant pits ([229], [159], [222], [255]).

Simple floor-level smithing hearths are more variable in form, varying from circular to slightly elongate (ratio of long to short axes 1:1 to 1.6:1). Their long and short axes in plan are plotted in Figure 2 as pen squares. Examples from the early medieval of Ireland are shown as open squares in Figure 2 (sites at Killeany, Coolamurry, Garryleagh, Cornamucklagh and Aghavea; Young 2008b, 2008a, 2009, 2014a, 2014c). Examples of early medieval smithing hearths from South Wales are entirely different, with a dumbbell shape (one end the true hearth, the other a probable anvil setting; Young ); their overall dimensions appear on Figure 2 by purple *). The hearth end of the S Welsh structures (1.25x1.1m at Pontardulais and 0.66x0.62m at Gelligaer) is also rather equant (ratio of long to short axes approximately 1.1). The Irish hearths have similar dimensions to the larger equant pits (pits [124], [172] and [141], as well as some of the elongate pits (e.g. pits [075] and [215]). Of these pits, it should be noted that pit [124] contained an SHC fragment and [172] tool casts and abundant microresidues.

There are few examples of early medieval slag-tapping furnaces known; these are illustrated by orange dots in Figure 2. They have ratios of long to short axes 2:1 to 3.75:1. These include examples from Ramsbury (Haslam 1980), Tisbury (author's unpublished data) and South Hook (Crane & Murphy 2010). This, admittedly small, dataset shows a degree of coincidence with the group of elongate pits (pits [075], [126], [149], [217], [219], [240], [244] and [263]).

Thus the pit morphology suggests various possible contenders for identification as slagpit furnaces, slag tapping furnaces and smithing hearths. Further work is required to clarify the identification of the archaeological features.

The interpretation of the smithing activity is hampered by the paucity of evidence. There are very few pieces of slag interpretable as the macroscopic residues of smithing. Hammerscale is, in contrast, locally abundant and generally widespread. The dominance of flake hammerscale would suggest the working of at last partly-consolidated iron (Young 2011) rather than the welding of blooms. This may suggest that the raw blooms produced by smelting were being smithed down to bar (or at least billet) on the site.

# Discussion

The material from the 2014 season is broadly similar to that found on the site previously. The evidence for the smelting technology is slightly ambiguous: it may represent a mixture of slag tapping and non-tapping technologies, or perhaps an early form of slag tapping with a rather low volume of tapped slag. Several of the Cefn Graianog pits are of similar size to known early slag tapping furnaces and are worthy of further investigation.

The evidence for the nature of the smithing being undertaken is largely from the microresidues, which suggest that working down to bar (or even perhaps to artefacts) was being undertaken on site. This is similar to the situation at South Hook (Crane & Murphy 2010), but differs from that commonly encountered in England where most smithing may have been undertaken at estate/manorial centres, rather than at the site of smelting. It is possible that an abundance of ore in the adjacent wetlands allowed the Cefn Graianog smelting settlement to be rather more permanent than typical.

Dating evidence from the 2013 season includes radiocarbon dates from Complex 5 suggest a date within the period of late 7$^{th}$ century to late 9$^{th}$ century AD. Sites in southern England and South Wales have been interpreted (e.g. Young 2010; 2015) as suggesting the replacement of slag pit furnaces by slag tapping in the late 9$^{th}$ to early 10$^{th}$ centuries.

The situation in North Wales is even more poorly evidenced than further south. The non-tapping furnaces of the later Iron Age have been well documented by Crew (Crew 1987, 1989, 1991, 1998, 2009), and similar furnaces appear to have been employed locally during the Roman period. These furnaces had an arch to facilitate hearth clearance/repair (and possibly bloom removal). The furnaces are not recorded as possessing external working hollows (unlike other similar contemporary furnaces (e.g. Derrrinsallagh, Co. Laois, Ireland; Young 2008c; Knockbrack, Co. Kerry, Ireland, Hull & Taylor 2006). Thus it is possible that North Wales maintained a native tradition of non-tapping furnaces through the Roman period, in contrast to areas further south and east in which the Iron Age style of furnace may have been entirely replaced by slag-tapping variants in the Roman period. The only early medieval smelting site described in any detail to date, is that at Borras Quarry (work ongoing), which has yielded slags suggestive of probable non-tapping furnaces.

The occurrence of flow slags with both dull and shiny surfaces, slag spheroids, charcoal-rich ferruginous sediments, fine lining debris and spiky 'sinter' (probably of fine slag and ore particles) can be most closely paralleled with finds inside abandoned furnaces on some Irish sites (e.g. Celbridge, Young 2003a; Morrett Site 'D', Young 2005b), but somewhat similar fines assemblages have been found on some British Iron Age sites (e.g. the northern furnaces at Twinyeo, Devon, Young 2013). The significance of the fine scale residues from the basal pits at these sites may be that smelting at these sites produced modest volumes of slag compared with the pit volume, and that the pit was sufficiently deep that its base lay well below the bloom and immediately associated slag.

At many sites, the non-tapped flow slag preserves moulds of the original pit/chamber packing. Such a packing is usually of split wood (e.g. Carlin 2008; Rainbird & Young in press; Young 2003b, 2014) but is occasionally of cereal straws or grass (e.g. Mikkelsen

1997; Young 2015a). The Cefn Graianog assemblage contains no material for which a pit-packing was identifiable. This may reflect the tendency of the assemblage to include only smaller slag particles, but might also be circumstantial evidence for the use of slag-tapping process.

The characteristics of the site, with evidence for multiple workshops mostly undertaking both iron smelting and smithing, suggest a settlement that is arguably in the tradition of the earlier iron-making settlements of Crawcwellt West (Crew 1989, 1998, 2009) and Bryn-y-castell (Crew 1987, 2009). Dating the ironworking activity of the various complexes (presumably structures) will be important in determining their degree of contemporaneity.

## Further work

The development of working floors in the complexes (both complexes 1-4 describe here and Complex 5, for which the residues were described in young 2014) has obscured the nature of the associated cut features; further work (through the interrogation of the field records) is required to increase understanding of the features.

The nature of the macroscopic residues as potential very early (for the early medieval) tapped slags gives their investigation a more than local significance. Indeed this stage of the development of the iron smelting process is under intense investigation elsewhere (e.g. Hemyock, Churchills Farm). The presence of collections of bog iron ore also give the assemblage significance, for the smelting residues should be able to be linked to the raw material.

The value of the collection is further raised by the presence of limited macro- and abundant micro-residues from smithing.

The artefactual material from the site should be checked to see if it includes any metallic iron produced at the site.

With all these components to the residue assemblage and important style of working, it is recommended that a programme of further laboratory analysis is conducted to characterise the process and to permit modelling of the efficiency and yield of the smelting process (details of the proposed methodology to be submitted separately).

Whether or not further detailed investigation is commissioned, the assemblage is one of regional and potentially national significance. It should there be deposited in its entirety with the site archive in an appropriate institution.

## Figure Captions

Figure 1. Plan of features yielding archaeometallurgical residues (shown on red), based on provisional versions of the 203 and 2014 PX reports, showing the ‘complexes’ as employed in this report.

Figure 2. Plot of width against length for cut features yielding archaeometallurgical residues in Complex 1 (red), Complex 2 (blue), Complex 3 (green) and Complex 4 (grey). Comparative data are provided for smithing hearths from Ireland (open squares) and South Wales (*), as well as early medieval slag tapping smelting furnaces (orange). For sources of the comparative, data see text.

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*Table 1: summary catalogue. Assm = assemblage, FHS = flake hammerscale, SHS = spheroidal hammerscale*

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 67 | 3 | slag | 94 | 94 | 1 | complex mass of flow slag; top distinctly maroon- so very likely to be tapslag |
| 67 | 3 | iron rich concretions (coarse) | 178 | 178 | 21 | fragments of coarse sand in silt with veins of iron oxide; a low grade ore |
| 67 | 3 | magnetic material | <1 | <1 | assm | mainly stone, trace of FHS |
| 67 | 3 | iron rich concretions? | 4 | 4 | assm | small concretionary fragments, including veined bog ore |
| 67 | 3 | possible metalworking debris | <1 | <1 | assm | mainly concretion, but some roast(?) ore and one piece FHS |
| 69 | 21 | metalworking debris coarse | 40 | 40 | asm | four pieces of flow slag and 1 small probable ore piece |
| 69 | 21 | magnetic material | <1 | <1 | assm | stone, granules, slag fragments |
| 69 | 21 | metalworking debris | 4 | 4 | assm | flow slag, lining slag, vitrified stone |
| 69 | 21 | ceramic | 2 | 2 | assm | probably fired clay, buff, with coarse sand |
| 69 | 21 | coal/cinder | <1 | <1 | 2 | 1 piece coal?, 1 piece burnt residue, possibly burnt bone |
| 69 | | | | 21 | 1 | flow-lobed slag fragment, with fuel-dimpled base |
| | | | | 16 | 1 | slag lump with dimpled base. |
| 73 | 20 | metalworking debris | 2 | 2 | assm | 10 fragments of flow slag, 3 stones |
| 73 | 20 | magnetic material | <2 | <2 | assm | stone, roast ore |
| 76 | 16 | possible metalworking debris | 6 | 6 | 7 | ore |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 99 | | | | 100 | 3 | highly Mn-encrusted fragments of massive and/or charcoal-bearing slag, details obscured |
| | | | | 38 | 1 | dense flow slag fragment, one side dimpled, the other sandy attachment |
| 122 | 9 | metalworking debris | <1 | | | |
| | | | | <1 | 1 | single coffee bean spheroid |
| 122 | 9 | metalworking debris | 68 | 68 | 2 | large fragment dense rusty slag resting on indurated grey ceramic, also tiny fragment of rusty indeterminate slag |
| 122 | 9 | magnetic material | 2 | 2 | assm | mainly stone ,some fine slag debris and some FHS |
| 125 | 41 | metalworking debris | 358 | | | |
| | | | | 224 | 1 | possible fragment of SHC, maximum of 50%, micro-dimpled, body of slag porous with rounded void and some charcoal impressions |
| | | | | 50 | 6 | fragments of dark shiny flow slag |
| | | | | 4 | 2 | small blebs with explosion from corroding iron |
| | | | | 80 | 20 | indeterminate slag fragments |
| 125 | 41 | md magnet | 6 | 6 | assm | mainly stone and slag debris, some FHS and rare SHS |
| 125 | 41 | metalworking debris | 28 | | | |
| | | | | 28 | assm | flow slag fragments, lining slag fragments, concretions, roasted ore, slag spheroids |
| 125 | | | | 14 | 1 | flow slag fragment |
| | | | | 10 | 1 | heavily accreted and altered slag fragment |
| | | | | 10 | 1 | burr-like fragment of dense slag with quartz grains and rough attachment surface |
| 127 | 19 | metalworking debris coarse | 326 | | | |
| | | | | 94 | 18 | small fragments of grey flow slag |
| | | | | 80 | 1 | large very dense inflated single flow lobe |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| | | | | 12 | 1 | dull flow slag in irregular lobes |
| | | | | 56 | 2 | base of dense slag- unclear if very large flow slag lobes or crust-like cake |
| | | | | 72 | 38 | small fragments of indeterminate slag |
| 127 | 19 | metalworking debris | 90 | | | |
| | | | | 90 | assm | slag debris, mostly flow type slags, some haematised, some look very abraded |
| 127 | 19 | metalworking debris magnetic | 4 | | | |
| | | | | 4 | assm | slag, ore, moderate FHS |
| 127 | | | | 74 | 1 | tap slag like block, but no reddening. Dense flow lobes rest on highly vesicular basal fracture |
| | | | | 30 | 1 | fragments of tap-slag like material |
| | | | | 11 | 1 | rounded slag fragment |
| 132 | 22 | magnetic material | <1 | <1 | assm | ferruginous granules, FHS, single slag fragment |
| 132 | 22 | metalworking debris coarse & fine | 36 | 36 | assm | variety of slag types, some stone and a concretion |
| 133 | | | | 36 | 2 | flow slag fragments |
| 142 | 34 | metalworking debris magnetic | <2 | <2 | assm | mainly stone , some ore (some roast), some slag debris, some FHS and rare SHS |
| 142 | 34 | metalworking debris coarse | 132 | | | |
| | | | | 30 | 3 | low density lining slag in flow slag prilly flows |
| | | | | 6 | 3 | small dense slag fragments |
| | | | | 22 | 1 | very rusty low-density flow slag flow (probably) but sheet-like form does not exclude other possibilities |
| | | | | 76 | 14 | dense flow slag fragments |
| 142 | 34 | metalworking debris | 16 | 16 | assm | ore, concretion, lining, slag, flow slag, slag spheroid |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 148 | | | | 86 | 1 | fragment of composite flow slag flow, rather like tapslag, but no reddening, fuel impressions on base, smooth grey, plastic lustre |
| 150 | 35 | metalworking debris coarse | 310 | | | |
| | | | | 78 | 9 | pale grey flow slag, mostly in fairly small pieces |
| | | | | 22 | 1 | dull flow slag in somewhat conical form |
| | | | | 4 | 1 | vitrified lining |
| | | | | 122 | 1 | strange rounded charcoal-bearing slag nub with some lining-influenced material. Dense and showing some signs of exploding suggesting it contains iron. Is this evidence of 'raking'? |
| | | | | 76 | 30 | small fragments of indeterminate iron slag |
| 150 | 35 | metalworking debris | 22 | | | |
| | | | | 22 | assm | flow slags, lining, other slag fragments, concretions |
| 150 | 35 | metalworking debris magnetic | 10 | 10 | assm | mostly slag and ore, moderate level of FHS, some stone |
| 150 | | | | 70 | 1 | fragment of charcoal-rich slag with small-scale prilly base |
| 155 | | | | 16 | 1 | anastomosing prills of flow slag, wrinkled, with dimpled base |
| | | | | 9 | 1 | vesicular slag adhering to fired clay |
| | | | | 3 | 1 | vesicular slag fragment |
| 156 | 17 | metalworking debris coarse | 220 | | | |
| | | | | 32 | 10 | flow slag fragments |
| | | | | 52 | 6 | other dense slag fragments |
| | | | | 6 | 4 | vitrified lining fragments |
| | | | | 6 | 3 | concretions |
| | | | | 2 | 1 | very thin slag sheet - possible slag flat but probably simply a non-wetted surface |
| | | | | 128 | assm | indeterminate fragments, debris and dust |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 156 | 17 | possible furnace lining | 200 | | | |
| | | | | 200 | 3 | sandy/gravelly concretions with charcoal, slag fragments and abundant FHS |
| 156 | 17 | metalworking debris | 92 | | | |
| | | | | 92 | assm | slag fragments, concretions, lining, plenty of FHS, large spheroids |
| 156 | 17 | metalworking debris magnetic | 4 | 4 | assm | stone, granules, some slag, but rich in FHS, trace of SHS |
| 160 | | | | 15 | 1 | flow slag prill |
| 173 | 32 | metalworking debris coarse | 434 | | | |
| | | | | 116 | 16 | fragments of flow slags, some with maroon surface |
| | | | | 72 | 1 | large flow slag fragment, folded in half, dimpled base and flow lobed top inverted on one side |
| | | | | 2 | 1 | slag film with 90 degree re-entrant, probably flaked-off from tool |
| | | | | 36 | 2 | large pale flow-lobed slags, like flow slags but very low density |
| | | | | 156 | 8 | rough fragments of fine charcoal-bearing slag, some have rounded lining slag-like surfaces |
| | | | | 54 | 29 | small indeterminate slag fragments |
| 173 | 32 | metalworking debris | 80 | | | |
| | | | | 80 | assm | mainly rather irregular worn slag fragments, some flow slag and some large spheroids, rare ore fragments |
| 173 | 32 | metalworking debris magnetic | 16 | 16 | assm | mainly finely granular material, some clear stone, some probable slag fragments and moderate amount of FHS |
| 173 | | | | 151 | 4 | smooth masses of flow slag prills, |
| | | | | 142 | 3 | rough surfaced flow slags in broader flows |
| | | | | 97 | 6 | fragments of prilly charcoal rich slags |
| 179 | 18 | metalworking debris | 2 | 2 | assm | slag, roast ore, FHS, lining |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 179 | 18 | magnetic material | 2 | 2 | assm | slag, granules of ore, moderately abundant FHS |
| 188 | 25 | rock crystal chip | <1 | <1 | 1 | quartz fragment |
| 188 | 25 | magnetic material | 1 | 1 | assm | stone, granules, slag fragments, FHS |
| 188 | 25 | metalworking debris | 2 | 2 | assm | flow slag, rust, ore, vitrified lining, |
| 199 | | | | 70 | 6 | slag prills, one rough, the others smooth. One of the smooth pieces is very pale and glassy |
| 203 | 23 | magnetic material | 1 | 1 | assm | stone, granules, sparse FHS |
| 203 | 23 | metalworking debris fine & coarse | 10 | 10 | assm | flow slags, lining slag, concretion |
| 205 | 24 | magnetic material | 1 | 1 | assm | stone, slag fragments, single SHS |
| 205 | 24 | iron rich concretions | 2 | 2 | assm | natural iron panning in sand/gravel |
| 205 | 24 | metalworking debris coarse | <1 | <1 | 1 | flow slag fragment with slightly maroon surface |
| 207 | 26 | metalworking debris | 4 | 4 | assm | mainly small pieces of flow slag, one concretion bearing FHS |
| 207 | 26 | metalworking debris coarse | 44 | | | |
| | | | | 8 | 1 | charcoal-rich concretion |
| | | | | 22 | 2 | fragments from large dense lobes |
| | | | | 14 | 4 | dense slag pieces |
| 207 | 26 | metalworking debris magnetic | <2 | | | |
| | | | | <2 | assm | stone, ore, lining, trace FHS |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 211 | 30 | metalworking debris coarse | 2780 | | | |
| | | | | 1045 | assm | indeterminate rusty (mainly) slag fragments debris and rust. At least some apparent FHS |
| | | | | 1010 | 166 | flow slag, mainly in fragments of individual prills but a few tap slag-like blocks |
| | | | | 135 | 3 | large lobes - inflated flow slag |
| | | | | 140 | 1 | large block of piled lobes, probably from the margin of a furnace bottom cake. Low density |
| | | | | 50 | 4 | dull flow slag |
| | | | | 275 | 6 | irregular blocks of massive slag, rusty, one is a slice of an SHC-like mass |
| | | | | 30 | 4 | vitrified lining |
| | | | | 10 | 2 | soft earth dark brown concretions |
| | | | | 55 | 1 | piece of thin burr, with flow slag intruding lining below burr proper; altered lining only has a thin skin of slag overlying it - so presumably a smelting burr |
| | | | | 5 | 1 | small fragment of similar burr |
| 211 | 30 | metalworking debris (remainder bagged) | 78 | | | |
| | | | | 78 | assm | mainly flow slag debris, rich in spheres, one large slag flat or tool coating, some glazed stones |
| 211 | 30 | magnetic material | 22 | 22 | assm | lining slags, abundant FHS and SHS, indeterminate granular material (corroded iron/slag/concretion?) |
| 212 | 27 | metalworking debris coarse | 950 | | | |
| | | | | 522 | 98 | dense flow slags |
| | | | | 102 | 6 | slag in dense sheet-like form, probably basal crusts, but at least two pieces could be SHC fragments |
| | | | | 20 | 2 | lining slags |
| | | | | 6 | 1 | stone |
| | | | | 300 | assm | small indeterminate slag fragments and dust |
| 212 | 27 | furnace lining coarse | 72 | 70 | assm | |
| | | | | 48 | 8 | vitrified furnace lining |
| | | | | 10 | 2 | stone fragments |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| | | | | 6 | 1 | flow slag fragment attached to ferruginous concretion |
| 212 | 27 | metalworking debris coarse | 96 | | | |
| | | | | 96 | assm | small fragments of flow slags including many coffee-bean spheroids |
| 212 | 27 | metalworking debris/concretion? | 32 | | | |
| | | | | 32 | assm | poor slag debris and (ashy?) concretions |
| 212 | 27 | magnetic material | 16 | | | |
| | | | | 16 | assm | mainly rusty debris and a few slag fragments. Rare FHS and SHS |
| 212 | | | | 111 | 7 | flow slag fragments, mostly with dimpled bases and one with cavernous top caused by upper vesicular layer |
| 216 | 28 | iron object coarse | 4 | 4 | 1 | flat iron concretion on uncertain oval slightly dished core |
| 216 | 28 | metalworking debris (remainder bagged) | 2 | 2 | assm | stone, flow slag fragments, burnt bone |
| 216 | 28 | magnetic material | <2 | <2 | assm | stone |
| 218 | 29 | 1 of 3 coarse | 1690 | | | |
| | | | | 520 | 89 | grey flow slag, mainly in small pieces but a few tap slag-like amalgamations |
| | | | | 282 | 1 | large block of granular rusty slag, internal structure not visible |
| | | | | 172 | 4 | irregular slag fragments of larger size than main debris collection |
| | | | | 168 | 1 | sheet of internally-lobed material on non-wetted chilled base. Slag contains pre-existing droplets and stone clasts. Maybe slowly-accumulated hearth floor? Main part of slag is delicate coralline olivine |
| | | | | 550 | assm | indeterminate slag fragments, debris and dust |
| 218 | 29 | 2 of 3 coarse | 2500 | | | |
| | | | | 512 | 8 | tap slag-like material with very broad (but few) bulbous flow lobes |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| | | | | 892 | 127 | grey flow slag, mostly in small fragments |
| | | | | 40 | 10 | vitrified lining material and lining slags |
| | | | | 54 | 8 | stones |
| | | | | 38 | 1 | blebby tongue-like lining slag mass |
| | | | | 172 | 2 | incomplete sheets of amalgamated prills - could be from furnace floor/side or might be incipient SHCs |
| | | | | 40 | 2 | thin sheet fragments with tubular vesicles |
| | | | | 730 | assm | indeterminate fragments, debris and dust |
| | | | | 2 | 2 | rust spalls |
| | | | | | | plus several charcoal fragments |
| 218 | 29 | 3 of 3 | 2255 | | | |
| | | | | 996 | 128 | small fragments of grey flow slag |
| | | | | 620 | assm | indeterminate slag fragments, debris and dust |
| | | | | 26 | 1 | 45mm length of slag rod, c15mm diameter |
| | | | | 12 | 1 | possible half section of rod |
| | | | | 64 | 5 | FB-like material of small amalgamated blebs |
| | | | | 54 | 1 | beard-like mass of spiky, blebby, slag attached to curved sheet, granular on other side; could be slag penetrating into ash floor perhaps. Perhaps peeled from floor or wall |
| | | | | 14 | 1 | elongate fragment of similar sheet with spiky slag |
| | | | | 62 | 7 | blebby/granular slags in small amalgamations - including one with possible cylindrical tool hole |
| | | | | 24 | 5 | lining/fuel ash slag |
| | | | | 4 | 2 | vitrified lining |
| | | | | 6 | 2 | possible manganese oxide concretion |
| | | | | 52 | 1 | ferruginous concretion |
| | | | | 104 | 3 | dense slags with dimpled bases and large rounded voids |
| | | | | 38 | 6 | fragments of thin slag sheets of uncertain origin |
| | | | | 14 | 3 | slag blebs attached to stone chips |
| | | | | 50 | 1 | irregular dimpled/blebby slag flow sheet |
| | | | | 20 | 1 | coalesced rounded blebs forming thin sheet |
| | | | | 74 | 1 | irregular mass of flowed slag of rather low density in elongate mass |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| | | | | 4 | 1 | stone |
| 218 | 29 | possible furnace lining | 112 | | | |
| | | | | 106 | 21 | fragments of deeply vitrified and slagged lining. Some clearly from near blowhole, no pieces with blowhole itself |
| 218 | 29 | metalworking debris (remainder bagged) | 56 | | | |
| | | | | 56 | assm | slag debris, flow slags, spheres, flats, FAS etc plus some rust/concretion. |
| 218 | 29 | magnetic material | 14 | 14 | assm | stone, granules, some slag, plenty of FHS |
| 218 | | | | 52 | 1 | charcoal rich slag attached to oxidised-fired wall - probable sub-blowhole attachment. |
| | | | | 37 | 4 | flow slag fragments, one very long and delicate |
| 220 | 39 | possible furnace lining | 14 | 14 | 1 | thickly slagged oxidised furnace/hearth lining |
| 221 | | | | 64 | 1 | prills - probably part of a small birds foot of divergent flows |
| | | | | 3 | 1 | prill fragment |
| | | | | 93 | 1 | irregular block of vesicular, possibly charcoal-bearing, slag; encrusted in secondary oxides. |
| 223 | 21 | metalworking debris fine & coarse | 20 | 20 | assm | most of weight is large lining slag lobed nub, smaller fragments include small flow slag, ore, stone, and concretion fragments on corroded iron with imprints of ?straw |
| 223 | 31 | magnetic material | 2 | 2 | assm | stone, granules, FHS, SHS |
| 227 | 35 | metalworking debris | 210 | 210 | assm | mainly fragmented bog ore with a few small slag fragments; many fragments slightly reddened |
| 227 | 33 | metalworking debris coarse | 66 | | | |
| | | | | 20 | 4 | flow slags |
| | | | | 2 | 3 | roasted ore |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | ore |
| | | | | 28 | 1 | rusty charcoal-bearing slag |
| | | | | 2 | 4 | indeterminate slag fragments |
| 230 | 36 | metalworking debris coarse | 2180 | | | |
| | | | | 198 | 14 | flow slag, dense |
| | | | | 1982 | assm | bog ore, variable density |
| 230 | 36 | metalworking debris (remainder bagged) | 30 | 30 | assm | ore (including ?wad tubes) flow slag, unclear if ore/wad are detrital or authigenic |
| 241 | 42 | metalworking debris coarse | 1540 | | | |
| | | | | 994 | 94 | well-formed flow slag in mainly narrow lobate horizontal flows |
| | | | | 76 | 5 | dull-surfaced flow slag in very elongate conical lobes |
| | | | | 116 | 1 | rather scrappy runner, 40mm wide base, dimpled base, shallow, passes towards mounded rusted slag at one end |
| | | | | 351 | assm | lots of small indeterminate slag fragments |
| | | | | 1 | 1 | thin possible slag cast from tool tip with rounded end |
| | | | | 2 | 1 | small fragment of oxidised-fired vitrified lining |
| 241 | 42 | metalworking debris | 122 | 122 | assm | mainly flow slag assemblage, prills, blebs, lobes and other fragments; also some lining slag, lots of coffee beans |
| 241 | 42 | metalworking debris magnetic | 16 | 16 | assm | mainly FHS, some slag debris, rare SHS, some concretionary material |
| 241 | | | | 62 | 3 | coalesced flow slag prills |
| 246 | | | | 117 | 1 | anastomosed flow slag prills, individual prills only rather loosely bonded |
| | | | | 12 | 1 | flow slag prill |
| 248 | 38 | magnetic material | <1 | <1 | assm | stone, FHS, rare SHS |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 248 | 38 | metalworking debris | <1 | <1 | assm | 1 ore, 1 roasted ore and 1 slag particle |
| 260 | 39 | md sample bagged | 56 | 56 | assm | mostly flow slag fragments, but also fragments of charcoal-bearing slag, concretion with spheroids |
| 260 | 39 | metalworking debris | 3190 | | | |
| | | | | 1615 | 162 | pale to mid grey flow slag, mostly very tapslag like. One piece has sandy base to part as well as usual fuel contact base. Mostly elongate flows with few lobes |
| | | | | 746 | 21 | variant of flow slag with little flow but ballooning lobes up to 50mm wide and 30mm deep. One runner-like piece is even larger and has flat base and raised top |
| | | | | 92 | 1 | possibly large lobe as above, but might be broken margin from a plano-convex cake |
| | | | | 136 | 2 | two flow slag pieces with elongate runner/rod like form, up to 30mm wide and deep |
| | | | | 102 | 3 | rather featureless slag blocks showing signs of cracking fom iron explosion. |
| | | | | 42 | 2 | iron slag with possible furnace floor/wall ceramic attached |
| | | | | 42 | 1 | slag fragment from possible SHC, tubular vesicles at base. Porous above, may just been from one of the big flow types |
| | | | | 546 | assm | fine slag debris, indeterminate slag fragments and dust |
| 260 | 39 | magnetic material | 14 | 14 | assm | slag debris with ore and concretions, but no hammerscale |
| 260 | | | | 61 | 5 | elongate prill fragments, two largely clear of adhering materials and smooth, the other three rough. |
| 264 | 40 | metalworking debris | 306 | 306 | assm | small ore fragments, rusty debris, slag fragments, slag spheres, lining fragment |
| 264 | 40 | metalworking debris coarse | 266 | | | |
| | | | | 188 | 20 | flow slags - mainly in long thin flows across floor |
| | | | | 1 | 1 | probably vein-like mineralisation in coarse sandy sediment |
| | | | | 1 | 1 | coarse sandy material with parallel bloating foliation; probably lining |
| | | | | 76 | 55 | slag debris without clear surviving signs of flow |

| C | S | other | Swt | wt | no | notes |
|---|---|---|---|---|---|---|
| 264 | | pot | 8 | 8 | 2 | fragments of vitrified reduced-fired lining |

*Table 2: summary of residues from Cefn Graianog 2014, by complex and context.*

| Area | C | cut | context description | debris etc | tap slag | flow slag | indet dense | rods & runner | burr | SHC | lining | fired clay | lining slag | Vitr. stone | ore | concr -etion | spheroid | tool cast | FHS | SHS | *total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 69 | 68 | fill of pit [068]; sub-circular 2.1x1.4x0.82m | | | 21 | 16 | | | | | y | y | y | | | | | | | *37* |
| N | 73 | 72 | main fill of sub-rectangular pit [72], 2.1x1.4x0.42m | | | y | | | | | | | | | y | | | | | | *0* |
| N | 99 | 99 | spread, 1.5x1.3x0.05m | | | 38 | 100 | | | | | | | | | | | | | | *138* |
| W | 122 | 120 | in-situ burning within pit [120], 2.2x1.2x0.23m | | | | 68 | | | | | | | | | | y | | y | | *68* |
| Cpx 1 | 132 | 131 | fill of [131], possible sub-rectangular pit, 1.5x1.35x0.11m | | | | | | | | | | | | | | | | | | *0* |
| Cpx 1 | 133 | 133 | spread: brownish grey sandy silt deposit | | | 36 | | | | | | | | | | | | | | | *36* |
| Cpx 1 | 142 | 141 | fill of [141], sub-rectangular pit, 1.2x1.1x0.32m | | | 98 | 6 | | | | | | 30 | | y | | y | | | | *134* |
| Cpx 1 | 148 | 149 | fill of [149], sub-rectangular pit, 1.75x0.95x0.28m | | | 86 | | | | | | | | | | | | | | | *86* |
| Cpx 1 | 150 | 149 | in-situ burning within pit [149], 1.75x0.95x0.28m | | | 100 | 268 | | | | 4 | | | | y | y | | | Y | | *372* |
| Cpx 1 | 156 | 155 | fill of [155], sub-rectangular pit, 0.6x0.45x0.14m | 128 | | 48 | 66 | | | | 6 | | | | | 200 | y | | Y | tr | *448* |
| Cpx 1 | 160 | 159 | fill of [159], possible sub-oval pit, 0.65x0.35x0.1m | | | 15 | | | | | | | | | | | | | | | *15* |
| Cpx 1 | 173 | 172 | upper fill of [172], sub-square pit, 1.1x0.93x0.32m | | 224 | 193 | 307 | | | | | | | | y | | y | 2 | Y | | *726* |
| Cpx 1 | 179 | 178 | fill of [178], circular posthole, 0.21x0.18x0.35m | | | | y | | | | | | | | y | | | | Y | | *0* |
| Cpx 1 | 188 | 187 | fill of [187], small curvilinear gully, 5x1x0.34m | | | y | y | | | | y | | | | y | | | | y | | *0* |
| Cpx 1 | 199 | 199 | spread: light-mid greyish brown clayey silt deposit | | | 70 | | | | | | | | | | | | | | | *70* |
| Cpx 1 | 203 | 202 | fill of [202], linear gully, 4.6x0.55x0.16m | | | y | | | | | | | y | | | y | | | y | | *0* |
| Cpx 1 | 205 | 204 | fill of [204], Slightly curvilinear gully, 7.3x0.45x0.16m | | | 1 | y | | | | | | | | | y | | | | tr | *1* |
| Cpx 2 | 125 | 124 | fill of pit [124], Sub-circular pit, 0.9x0.85x0.32m | | | 64 | 94 | | 10 | 224 | | | y | | y | y | y | | y | y | *392* |
| Cpx 2 | 127 | 126 | fill of [126], sub-rectangular pit, 1.35x0.6x0.19m | | | 290 | 139 | | | | | | | | y | | | | Y | | *429* |
| Cpx 2 | 207 | 206 | fill of [206], linear gully, 3.4x0.55x0.16m | | | 22 | 14 | | | | y | | | | y | 8 | | | y | | *44* |
| Cpx 2 | 212 | 211 | fill of [211], linear gully, 3.5x0.5x0.2m | 1345 | | 1825 | 517 | | 60 | | 78 | | 20 | | | y | Y | | y | y | *3855* |
| Cpx 2 | 216 | 215 | in-situ burning within stone hearth [215], 1.15x0.7x0.2m | | | y | | | | | | | | | | 4 | | | | | *4* |
| Cpx 2 | 218 | 217 | fill of [217], curvilinear gully/ pit, 1.8x0.45x0.25m | 1900 | 512 | 1629 | 1256 | 38 | | | 150 | | 62 | | 6 | 54 | y | | Y | | *5607* |
| Cpx 2 | 220 | 219 | upper fill of [219], Sub-oval pit, 1.75x1.1x0.2m | | | | | | | | 14 | | | | | | | | | | *14* |
| Cpx 2 | 221 | 219 | main fill of [219], sub-oval pit, 1.75x1.1x0.2m | | | 67 | 93 | | | | | | | | | | | | | | *160* |
| Cpx 2 | 223 | 222 | fill of [222], Circular posthole/ pit, 0.55x0.47x0.55m | | | | | | | | 20 | | | | | | | | y | y | *20* |
| Cpx 2 | 227 | 226 | fill of [226], circular posthole, 0.21m diameter, 0.3m deep | | | 20 | 30 | | | | | | | | 213 | | | | | | *263* |
| Cpx 2 | 241 | 240 | fill of pit [240], 1.15x0.45x0.27m | | | 1132 | 351 | 116 | | | 2 | | | | | | Y | | Y | y | *1601* |
| Cpx 2 | 246 | 244 | fill of pit [244], 1.5x0.35x0.5m | | | 129 | | | | | | | | | | | | | | | *129* |
| Cpx 2 | 248 | 247 | fill of posthole [247], 0.25m diameter, 0.24m deep | | | | y | | | | | | | | y | | | | y | tr | *0* |
| Cpx 3 | 230 | 229 | fill of [229], sub-rectangular pit, 0.45x0.28x0.2m | | | 198 | | | | | | | | | 1982 | | | | | | *2180* |
| Cpx 3 | 260 | 260 | spread: black clayey silt deposit | 546 | | 2422 | 236 | 136 | | 42 | | | | | y | y | | | | | *3382* |
| Cpx 3 | 264 | 263 | fill of [263], irregular pit, 1x0.5x0.05m | | | 180 | 76 | | | | 9 | | | | 1 | | y | | | | *266* |
| Cpx 4 | 67 | 66 | fill of gully [066] | | 94 | | | | | | | | | | 178 | | | | y | | *272* |
| Cpx 4 | 76 | 75 | fill of possible sub-circular pit [075], 1.36x0.87x0.38m | | | | | | | | | | | | 6 | | | | | | *6* |
| | | | *total* | 3919 | 830 | 8684 | 3637 | 290 | 70 | 266 | 283 | | 112 | | 2386 | 276 | | 2 | | | |

Figure 1

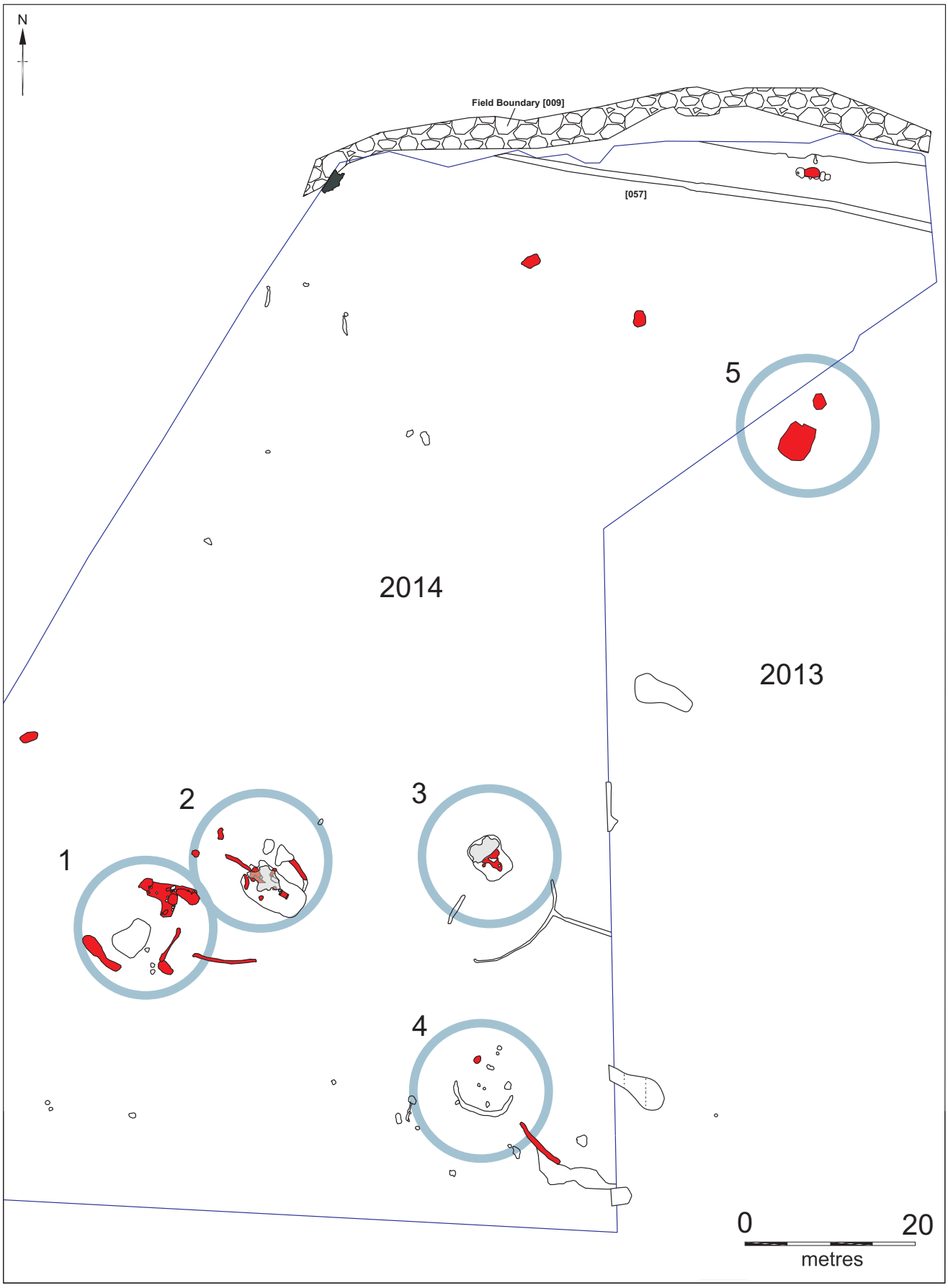
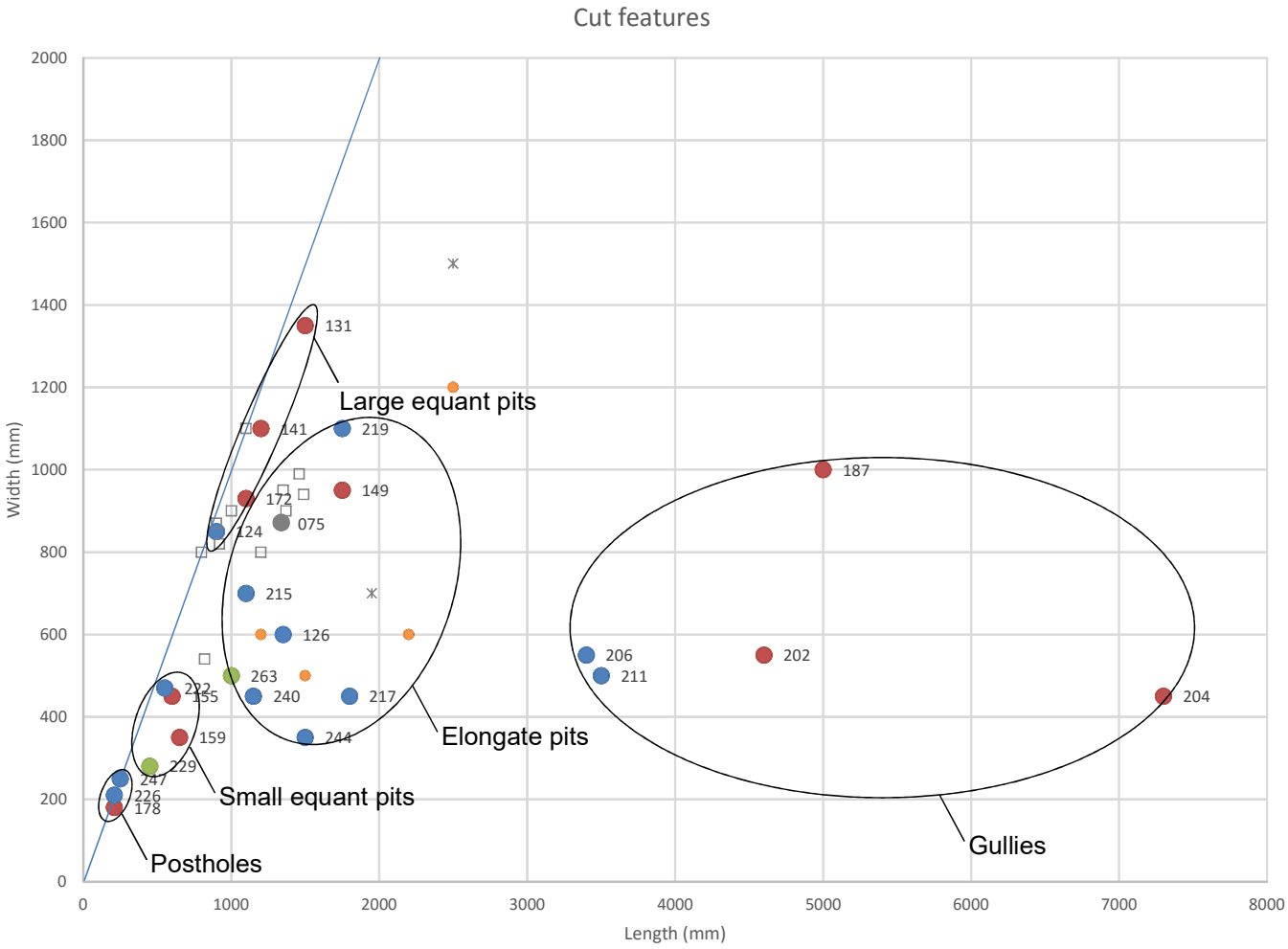


Figure 2


Cut features
Width (mm)
Length (mm)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
6000
7000
8000
131
141
219
149
172
075
124
215
126
263
222
155
240
217
244
159
229
247
226
178
187
206
211
202
204
Large equant pits
Elongate pits
Small equant pits
Postholes
Gullies

# GeoArch

*geoarchaeological, archaeometallurgical & geophysical investigations*


Unit 6,
Western Industrial Estate,
Caerphilly,
CF83 1BQ

| | |
|---|---|
| *Office:* | 029 20881431 |
| *Mobile:* | 07802 413704 |
| *Fax:* | 08700 547366 |
| *E-Mail:* | Tim.Young@GeoArch.co.uk |
| *Web:* | www.GeoArch.co.uk |