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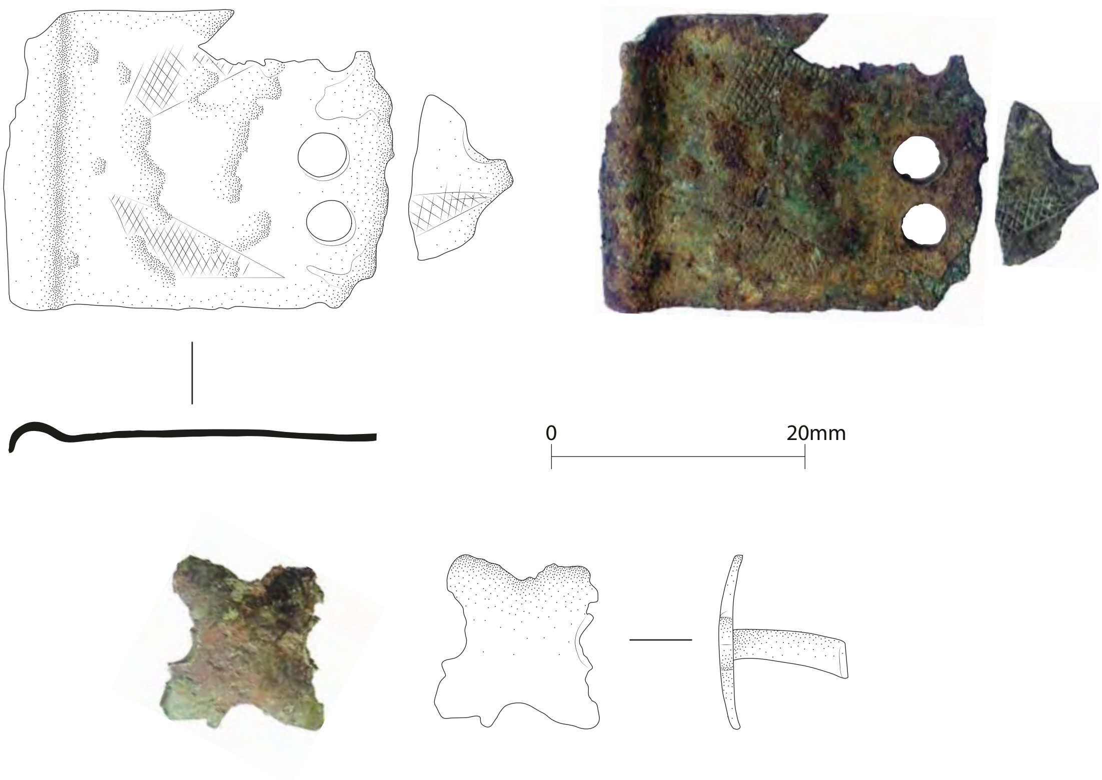
Evaluation of Scheduling Proposals 2016-2017

Hen Gastell, Llanwnda

Final Excavation Report



Cadw

Llywodraeth Cymru
Welsh Government

Ymddiriedolaeth Archaeolegol Gwynedd
Gwynedd Archaeological Trust

Evaluation of Scheduling Proposals 2016-2017

Hen Gastell, Llanwnda

Final Excavation Report

Project No. G2246

Report No. 1369

Prepared for: Cadw

March 2017

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Cover photograph: medieval copper alloy decorative dress accessories from Hen Gastell

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Published by Gwynedd Archaeological Trust
Gwynedd Archaeological Trust
Craig Beuno, Garth Road,
Bangor, Gwynedd, LL57 2RT

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G2246 EVALUATION OF SCHEDULING PROPOSALS 2016-17

HEN GASTELL, LLANWNDA (PRN 584, SH 47135737)

GAT report 1369

1. SUMMARY

Hen Gastell, Llanwnda is a small defended enclosure (PRN 584), with a ditch and bank around the northern side of the site. It has an interior platform with a low inner bank visible around three sides. Following on from a geophysical survey and evaluation trench in 2013 a more extensive excavation was carried out in 2014 within the interior of the site. This revealed a structure defined by large postholes. This may have either been circular with one flattened side or the rounded end of a longer structure. Remains of a smithing hearth, with associated pits full of metal-working debris, was found inside this structure. The inner bank was shown to continue around the south-western corner of the site and extensive burnt stone deposits were found overlying the inner edge of the bank. The burnt stone deposits are suggested as being waste from cooking and other activities taking place inside the building. Sections through the inner bank showed it to be composed of rounded cobbles with a buried soil beneath. Finds, including copper alloy decorative mounts, indicate occupants of some status. Radiocarbon dates demonstrate a fairly short duration of use of the inner platform lasting no more than three or four generations sometime in the 11th and 12th centuries cal AD.

This site therefore appears to be a medieval defended site of fairly high status, but below the level of a llys, with possibly a timber tower or a hall. The site was abandoned and dismantled after a fairly short period of importance and was not reused except as the location of a possible small farmhouse in the post-medieval period.

Lloc amddiffynnol bychan yw Hen Gastell, Llanwnda, Gwynedd (PRN 584), gyda ffos a chlawdd o amgylch ochr ogleddol y safle. Mae ganddo lwyfan mewnol gyda chlawdd mewnol isel yn weladwy o amgylch y tair ochr. Yn dilyn arolwg geoffisegol a ffos werthuso yn 2013, gwnaethpwyd cloddiad mwy helaeth yn 2014 tu mewn i'r safle. Cafodd y cloddiad hwn gan wirfoddolwr ei redeg gan Ymddiriedolaeth Archaeolegol Gwynedd gyda chymorth grant gan Cadw. Datgelodd y cloddiad strwythur wedi'i ddiffinio gan dyllau pyst mawr, a allai fod wedi bod yn naill ai crwn gydag un ochr wastad neu yn ben crwn o strwythur hirach. Cafodd olion aelwyd ofannu, gyda phyllau cysylltiedig yn llawn malurion gwaith metal, ei chanfod y tu mewn i'r strwythur hwn. Canfuwyd bod y clawdd mewnol yn parhau o amgylch cornel dde-orllewinol y safle a chafodd dyddodion cerrig llosg helaeth eu darganfod yn gorchuddio ymyl mewnol y clawdd. Awgrymir mai gwastraff o goginio a gweithgareddau eraill oedd yn digwydd y tu mewn i'r adeilad yw'r dyddodion cerrig llosg. Dangosodd toriadau trwy'r clawdd mewnol iddo gael ei greu o gerrig crynion gyda phridd claddedig oddi tano. Mae darganfyddiadau, gan gynnwys mowntiau addurniadol o aloi copr, yn dynodi preswylwyr o statws. Mae dyddiadau radiocarbon yn dangos mai am gyfnod gweddol fyr y defnyddiwyd y llwyfan mewnol, yn para dim mwy na thair neu bedair cenhedlaeth rhywbryd yn yr 11eg a'r 12fed ganrif OC.

Ymddengys felly mai safle amddiffynnol canoloesol o statws eithaf uchel yw hwn, ond yn is na lefel llys, gyda thŵr pren neu neuadd o bosib. Cafodd y safle ei adael a'i ddatgymalu ar ôl cyfnod cymharol fyr o bwys ac ni chafodd ei ailddefnyddio ac eithrio fel lleoliad ffermdy bychan posibl yn y cyfnod ôl-ganoloesol.

2. INTRODUCTION

The Prehistoric Defended Enclosures Project (G1770) was a Cadw grant-aided project carried out by Gwynedd Archaeological Trust (GAT) to provide information for management and schedule enhancement of this class of site in Gwynedd and Anglesey (Smith 2003). This project highlighted the site of Hen Gastell (PRN 584), amongst others, as a site of potentially national importance that was not scheduled. This atypical defended enclosure, located at Llanwnda, Gwynedd, required further evaluation before a decision on scheduling could be made. A geophysical survey was therefore carried out on 1st October 2013, and the information from this survey was used to locate a trial trench. This was excavated between 21st and 25th October 2013. A topographic survey was also carried out to allow an improved interpretation of the site. The results of this work have been reported in GAT report 1167 (Kenney and Hopewell 2014).

More information was required to establish the nature and date of the site so a second phase of work was undertaken. Samples taken during the trial excavation were processed and material was submitted for radiocarbon dating in order to obtain a rough date for the site. The material was submitted on 22nd May 2014 and the results were received on 6th August 2014. An excavation was carried out between 3rd and 28th July 2014 to investigate the interior of the site and establish its use. The first two weeks of this was run as a community excavation. In the last week a smaller team of experience volunteers helped to complete the excavation and recording.

A preliminary report was produced on the work in March 2015 (Kenney 2015, GAT Report No 1228). This described the features investigated and proposed analysis and other work to be carried out. An assessment of potential report (Kenney 2016, GAT Report No 1306) was then produced giving a full site narrative and detailed drawings of the archaeological features and presenting the assessment by specialists of artefacts and samples. Some specialists recommended further work and the present report includes the results of that further work, and incorporates the new findings into the interpretation of the site. This is the full and final report on the excavations. It largely replaces GAT Report No 1306 and includes all the specialist evidence from both the assessment and further work.

Plate 1. View of 3D model: Hen Gastell from the west

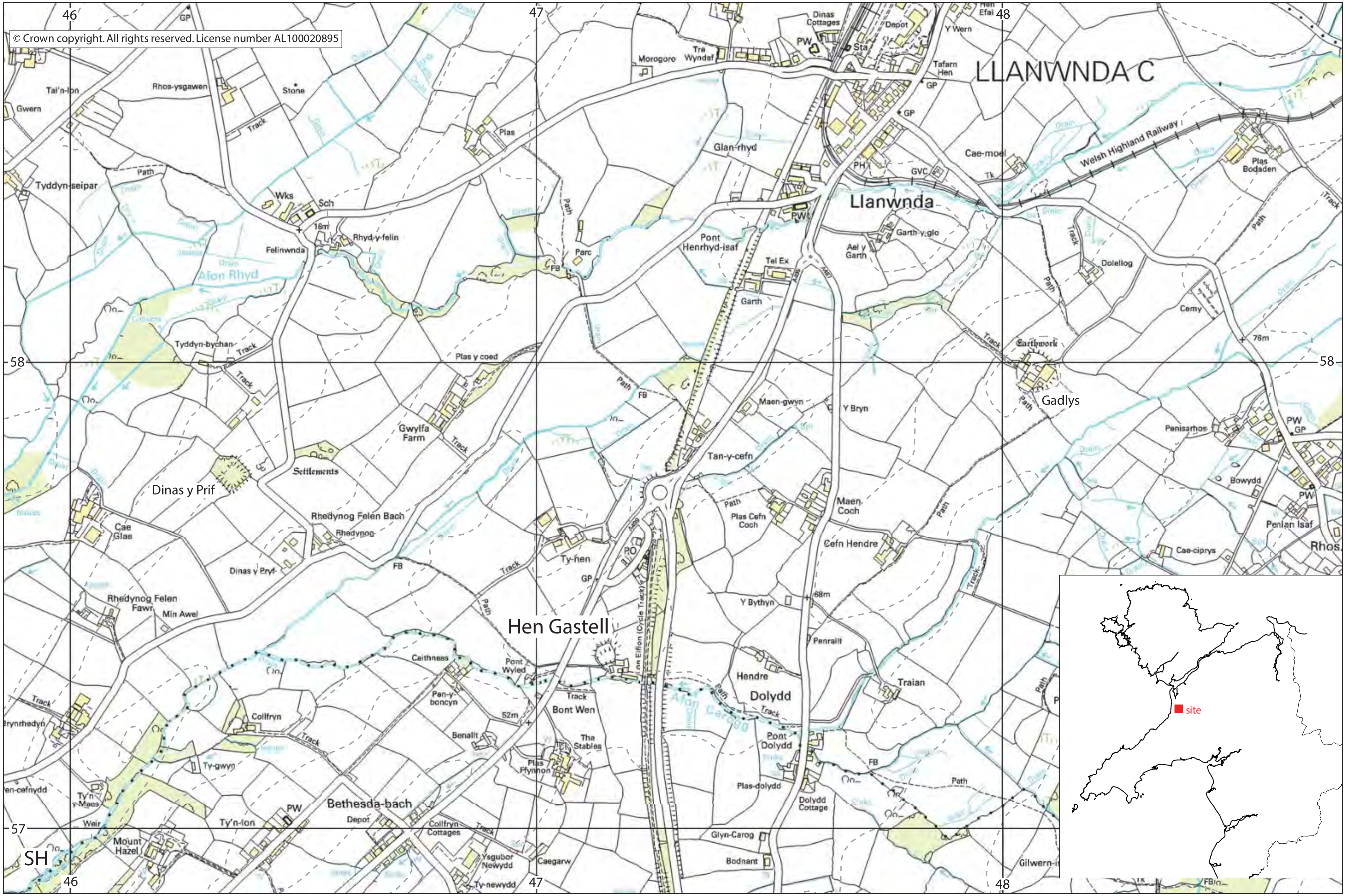


Figure 1. Location of Hen Gastell and nearby sites

Figure 2. Hen Gastell showing topography and location of trenches

3. BACKGROUND

Hen Gastell is located at SH 4713 5737 on the southern edge of Llanwnda community area, on the northern bank of the Afon Carrog (Figure 1). It lies on a narrow band of sedimentary bedrock composed of Lower Cambrian sandstones and conglomerates. This bedrock is overlain by moraines of glacial till with outwash sand and gravel deposits (Geology of Britain Viewer). Ridges of moraine probably account for the gently undulating nature of the landscape.

Hen Gastell is situated on the end of a low ridge and its southern side is defined by a steep bluff (plate 1, figure 2). It is under improved pasture and currently well-grazed by sheep, keeping the grass short and making earthwork features easily visible. The site has been modified by stone revetment walls built to support the steeper slopes. Cloddiau (earth banks faced with stone) and drystone walls run across the site, enclosing most of the monument within a small field.

The site is defined on the northern side by a deep and wide ditch, which encloses a small sub-rectangular interior platform. Outside the ditch is a bank. The RCAHMW considered the site to be a "small promontory fort" (RCAHMW 1960, 225), and it was include in the Prehistoric Defended Enclosures Project on the assumption that it was prehistoric and a defended site. Smith, however, considered it to be unconvincing as a defensive site. He speculated that it was an Iron Age settlement reusing an earlier feature, such as a henge, or that the ditch was a natural feature, perhaps a relict river meander (Smith 2005, 10). The interpretation of the site in defensive terms is problematic as the bank is outside the ditch and higher than the interior of the site.

A farm-house, named Hen Gastell after the earthworks, has been built against the south-eastern corner of the site. There has been an assumption that part of the site was cut away to level ground for the farm, so creating the steep bluff, but there is no convincing evidence for this (see below).

A quern of unknown type is reported to have come from the site (RCAHMW 1960, 225) and a single waste flint

Plate 2. Site under excavation from the air (copyright Alan K Hole)

flake was collected from a molehill during a site visit associated with an assessment for the Penygroes/Llanllyfni Bypass (GAT 1993, 7).

The 2013 evaluation work (Kenney and Hopewell 2014) clarified many details of the site. It showed that the ditch was massive and steep-sided. Comparisons of ground levels showed the full height of the outer bank and proved that it was a substantial feature. The outer bank at its full height before erosion and with the ditch open to its full depth would have been very impressive, but would not have been a conventionally effective defensive feature due to the apparent lack of an outer ditch to prevent access to the bank.

It appeared that the inner bank had probably run around the southern side of the interior suggesting that very little of the interior had been lost. There was no reason for the farm to cut into the monument as the main farm buildings are to the side of it and the quantity of gravel that would have to be moved to level the area if the ridge had continued would seem to have been excessive for the return. It is likely that the bluff was originally created by the river cutting through the gravel ridge and that the natural scarp has been straightened and modified but not significantly cut back.

The evaluation showed that there had been activity on the interior platform and that further remains were likely to survive, but the nature of this activity could not be established in the small area excavated. The evaluation also demonstrated later activity in the ditch, possibly a cut for a semi-subterranean building, most likely to be post-medieval in date. A trackway cut through the outer bank and the field walls forming a small paddock may have been associated with this proposed building.
More work was required to clarify the nature and date of the site. Although further investigation of the semi-subterranean building would be of considerable interest this would not have clarified the original use of the site. Further work was therefore concentrated on the interior platform where occupation and other activity was likely to have been focused.

4. METHODOLOGY

4.1. 3D digital model

A 3D digital model of the site was created in order to retain an accurate, measurable record of the site prior to excavation. The whole site was photographed with a GPS enabled Canon DX3100 digital camera set to maximum resolution (RAW) mounted on a camera pole. This produced a series of overlapping frames from an elevated viewpoint. A number of control points on the ground were digitally surveyed using a Trimble TSC2 controlled GPS receiver (Trimble R6 Unit), with the results tied into the National Grid. The photographs were converted to JPEGs (2mb maximum size) with the use of the ViewNX 2 program. The resulting 1675 JPEGs were used to produce a 3D model of the site using photogrammetry software program Agisoft PhotoScan. A 3D modelling software program, Blender, was used to produce a video from the model. This was shown on the site open day and linked to the GAT website to allow the public to view it:
(http://www.heneb.co.uk/hengastell/info.html).

The GPS co-ordinates of the ground control points were integrated so as to convert the model to the proper scale and location to an accuracy of less than 10mm. It is therefore possible to interrogate the model to determine the height and length of specific features. The final model will be archived with the rest of the digital archive from the project so that it can be used in future research. See plate 1 for an orthographic elevation of the site from the 3D model. A 3D pdf of the site accompanies this report.

4.2. Excavation

A trench measuring c.14m by 13m was dug inside the western half of the interior platform of the site, with an extension running through the inner bank (plate 2, figure 2). The topsoil and ploughsoil were stripped from the trench using a mini-digger with a toothless bucket under constant archaeological supervision. Machining reached the natural substratum in the interior but care was taken stripping over the inner bank where only the turf was removed by machine. The topsoil and ploughsoil were stored by the trench side in separate heaps to allow for backfilling and the spoil was kept at least 1m from the edge of the trench to prevent collapse into the trench. The machining was carried out on 3rd and 4th July 2014.

Plates 3 to 5. Volunteers cleaning, excavating and recording on site

The main trench is referred to as trench 2 (trench 1 being the evaluation trench dug in 2013). Another trench (trench 3) measuring c.8m by 5m was opened on the northern side of the outer bank (figure 2). This trench was intended to investigate the nature of the bank and any buried soil below it. However the number and complexity of features within trench 2 fully occupied volunteer and staff time on the project, so it was not possible to investigate trench 3. This trench was deturfed by hand and then used for school children to experience trowelling. Once the school visits had finished the topsoil was removed by hand over the trench, but as time prohibited other work being carried out the trench was backfilled at the end of the field work without further investigation or recording.

The excavation was carried out between 7th and 28th July 2014 by a team of volunteers with supervision from GAT staff. The trench was cleaned by hand and any remaining overburden removed. Cut features in the interior were half sectioned, their sections drawn and then the features were fully excavated. Deposits of burnt stone within the trench were removed by hand after planning and bank deposits in the south-western corner of the site were fully excavated by hand. In the north-western side of the trench a slot was hand dug through the inner bank so that it could be recorded in section down to natural deposits.

All features were recorded by hand drawn plans and sections, context sheets and photographs. Volunteers were involved in recording under the close supervision of professional field staff. The trench plan was located by a Trimble Global Positioning System (GPS), and the height of the Temporary Bench Mark used to calculate levels was also located by GPS. The full size of postholes [2118] and [2122] was only determined on the last day after rain had revealed the packing fills. Speed and confidence in finding the edges of the postholes meant that all the packing fill was removed with the aim of drawing a profile rather than a section. However in the rush of getting everything finished the present author, who was to draw the profiles, forgot to do so. The sections produced in figure 7 for these two features are created from the sections of the post-pipes plus the profile of the posthole as obtained from a 3D model of the completed site. The profiles are therefore not as accurate as if drawn by hand.

All artefacts found were retained. Soil samples were taken from contexts with visible charcoal.

4.3. **Public engagement**

The excavation was set up as a community training dig to allow as many people as possible to experience working on an archaeological excavation. From 7th to 18th July 2014 the focus was on training and most people working on the site had little or no previous archaeological experience. This included young people on work experience from schools in the region. They were given a full health and safety induction and detailed training and supervision to allow them to excavate, plan, take photographs and make written records (plates 3 to 5).

In the last week (21st to 28th July 2014) a smaller team of experienced volunteers assisted GAT staff to complete the excavation and recording.

During the excavation Anita Daimond, GAT Outreach officer, arranged for children from local schools to visit the site. Under her guidance they carried out a small excavation of their own on the outside of the outer bank and were able to see the archaeologists at work (plate 6).

Plate 6. School children excavating in trench 3

Plate 7. Inside the marquee at the Open Day

Plate 8. Site tours were given in Welsh and English on a wet Open Day

Table of pre-visits to schools

School	Date	no of pupils	no of teachers
Ysgol Felinwnda	08/07/2014	11	1
Ysgol Bontnewydd	11/07/2014	18	1
Ysgol Llandwrog	11/07/2014	16	2
Canolfan Llwybrau Ni (Pupil Referral Unit)	14/07/2014	5	3
Ysgol Bronyfoel	14/07/2014	14	2
Ysgol Carmel	14/07/2014	19	1

Table of site visits by schools

School	Date	no of pupils	no of teachers
Ysgol Felinwnda	10/07/2014	11	2
Ysgol Rhostryfan	10/07/2014	20	1
Ysgol Rhosgadfan	11/07/2014	18	1
Ysgol Llandwrog	14/07/2014	16	2
Canolfan Llwybrau Ni (Pupil Referral Unit)	15/07/2014	3	3
Ysgol Bronyfoel	15/07/2014	14	2
Ysgol Bontnewydd	16/07/2014	18	2
Ysgol Carmel	16/07/2014	19	2

An Open Day was held on the 19th July 2014, allowing the public to visit the site (plates 7 and 8). Despite rain for much of the morning this was a great success. About 100 people came to see the site and tours of the site ran in Welsh and English throughout the day. There were displays in a marquee and a canteen where tea and coffee were served. A projected and animated 3D image of the site was also displayed in the canteen. There were children's activities including colouring in historical pictures and a chance to examine a collection of reproduction medieval artefacts on loan from Cadw that intrigued children and adults alike. Plaid Cymru Councillor John Wynn Jones was invited to visit the site and was given a tour by Anita Diamond, the Trust's Outreach Officer. Emily La Trobe-Bateman, Head of Heritage Management at GAT, discussed the work of the Trust with him, especially the value of projects like Hen Gastell where volunteers can get involved in archaeological excavations.

A blog was maintained on the GAT website (http://www.heneb.co.uk/hengastell/blog.html) during the excavation so that people could follow the progress of the dig. The information and photographs were also released on Facebook and Twitter.

4.4. **Post-excavation analysis and reporting**

A preliminary report was produced on the work in March 2015 (Kenney 2015, GAT Report No 1228). This described the features investigated and proposed analysis and other work to be carried out. An assessment of potential report (Kenney 2016, GAT Report No 1306) was then produced giving a full site narrative and detailed drawings of the archaeological features and presenting the assessment by specialists of artefacts and samples. Some specialists recommended further work and the present report includes the results of that further work, and incorporates the new findings into the interpretation of the site. This is the full and final report on the excavations. It largely replaces GAT Report No 1306 and includes all the specialist evidence from both the assessment and further work.

During the post-excavation phase site records were checked and cross referenced, then scanned to provide back-up copies of the paper records. Site drawings were combined into a plan of the site and selected sections were drawn up. A database of photographs was created to provide metadata for archiving. All finds were cleaned as appropriate and boxed for long term archiving. Those recommended for conservation were conserved. Soil samples were processed (see appendix III.2) so that the flots and finds recovered could be studied.

Plate 9. Arc of postholes marked by white arrows

Plate 10. Posthole [2122] fully excavated

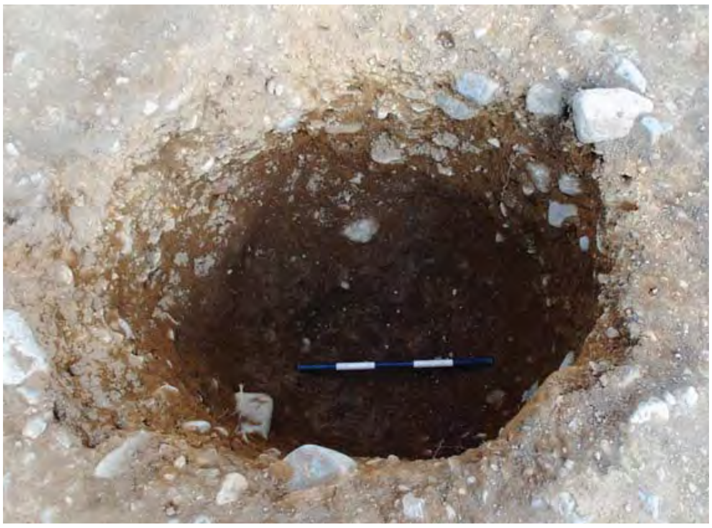


Plate 11. Posthole [2068] half sectioned showing burnt stone in post-pipe

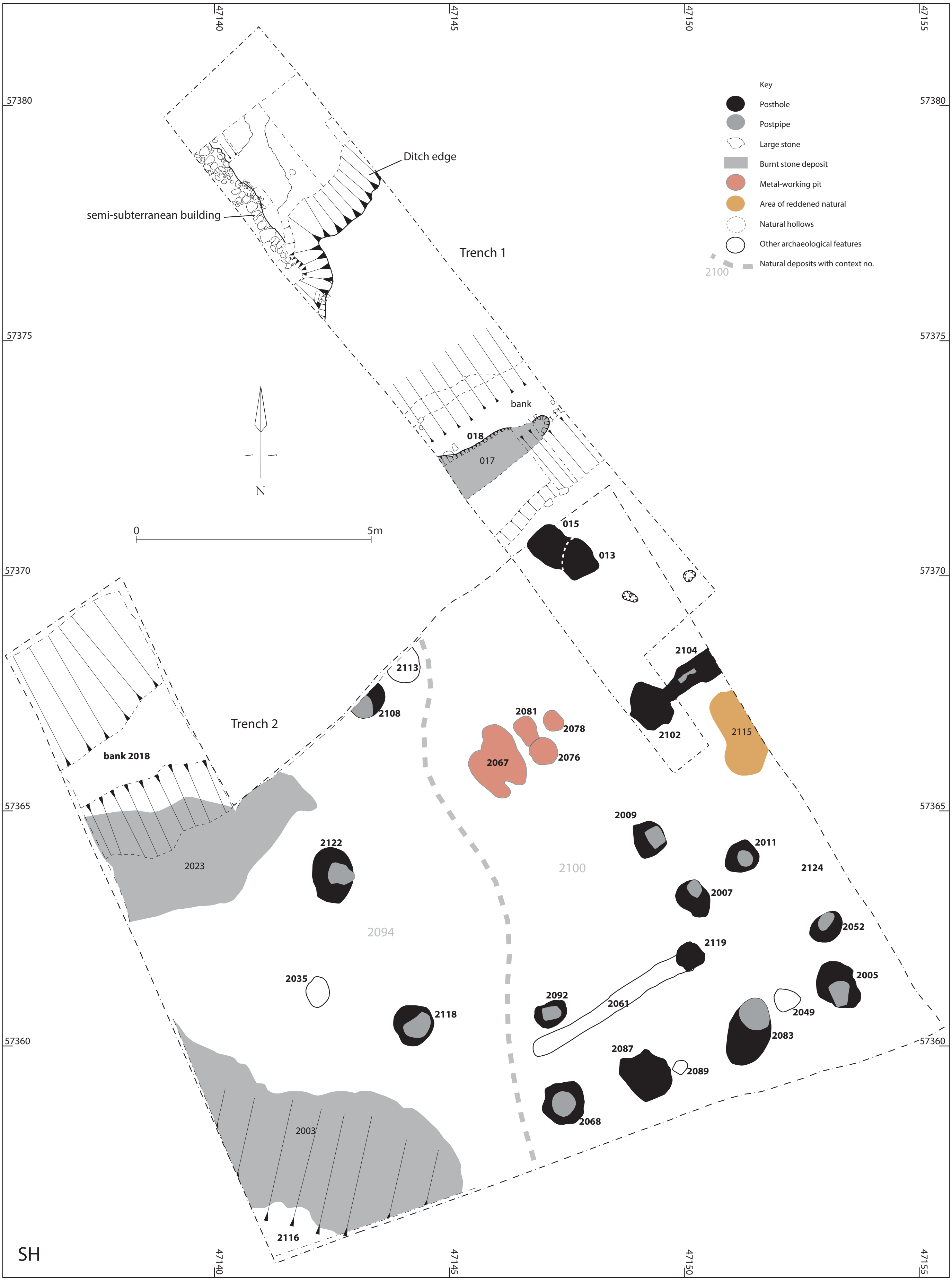


Figure 3. Outline plan of features within trench 2, also showing trench 1

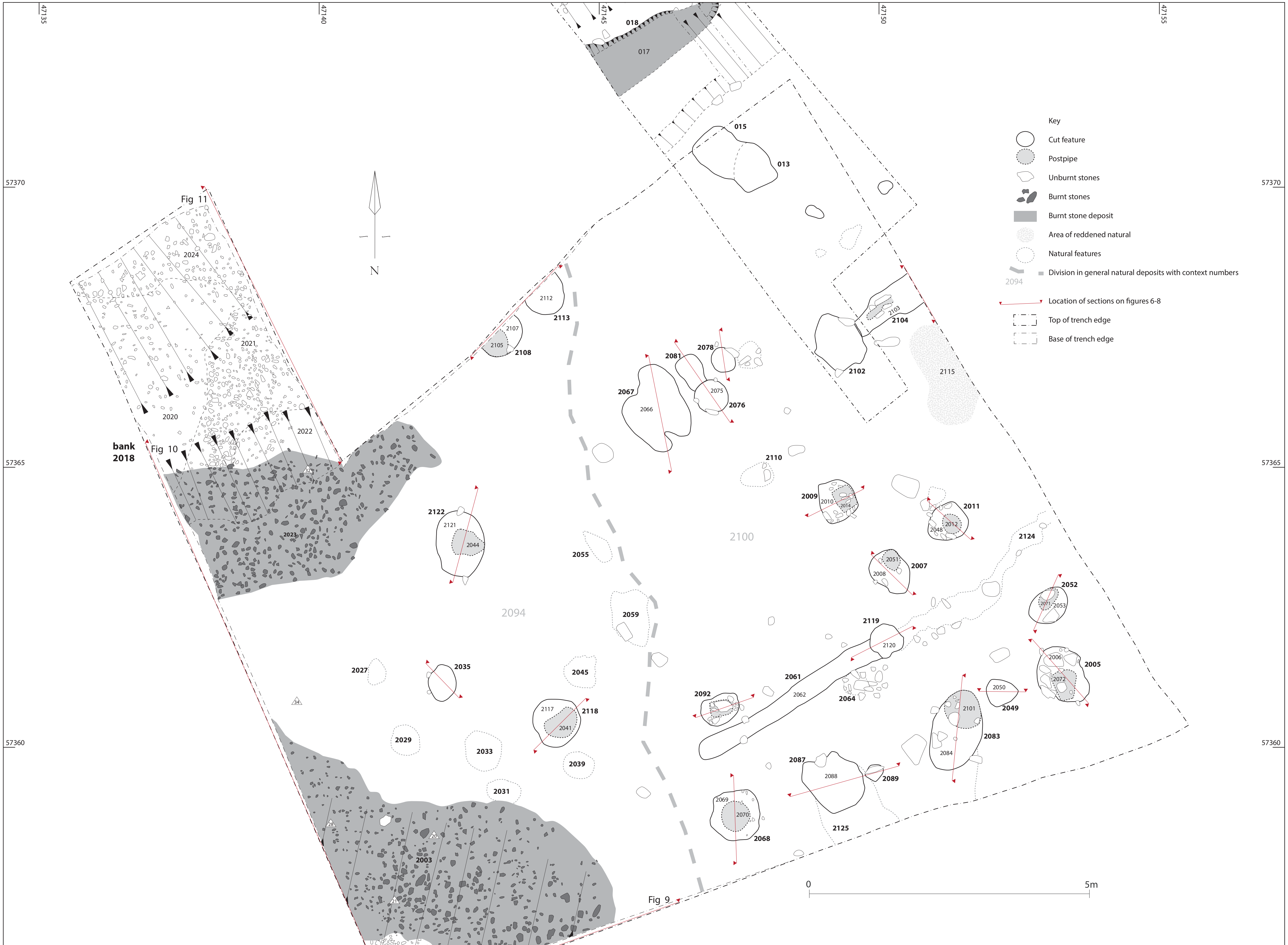


Figure 4. Plan of trench 2 showing burnt stone deposits and detail of post-pipes and packing stones

Figure 5. Plan of trench 2 showing banks exposed and other features fully excavated

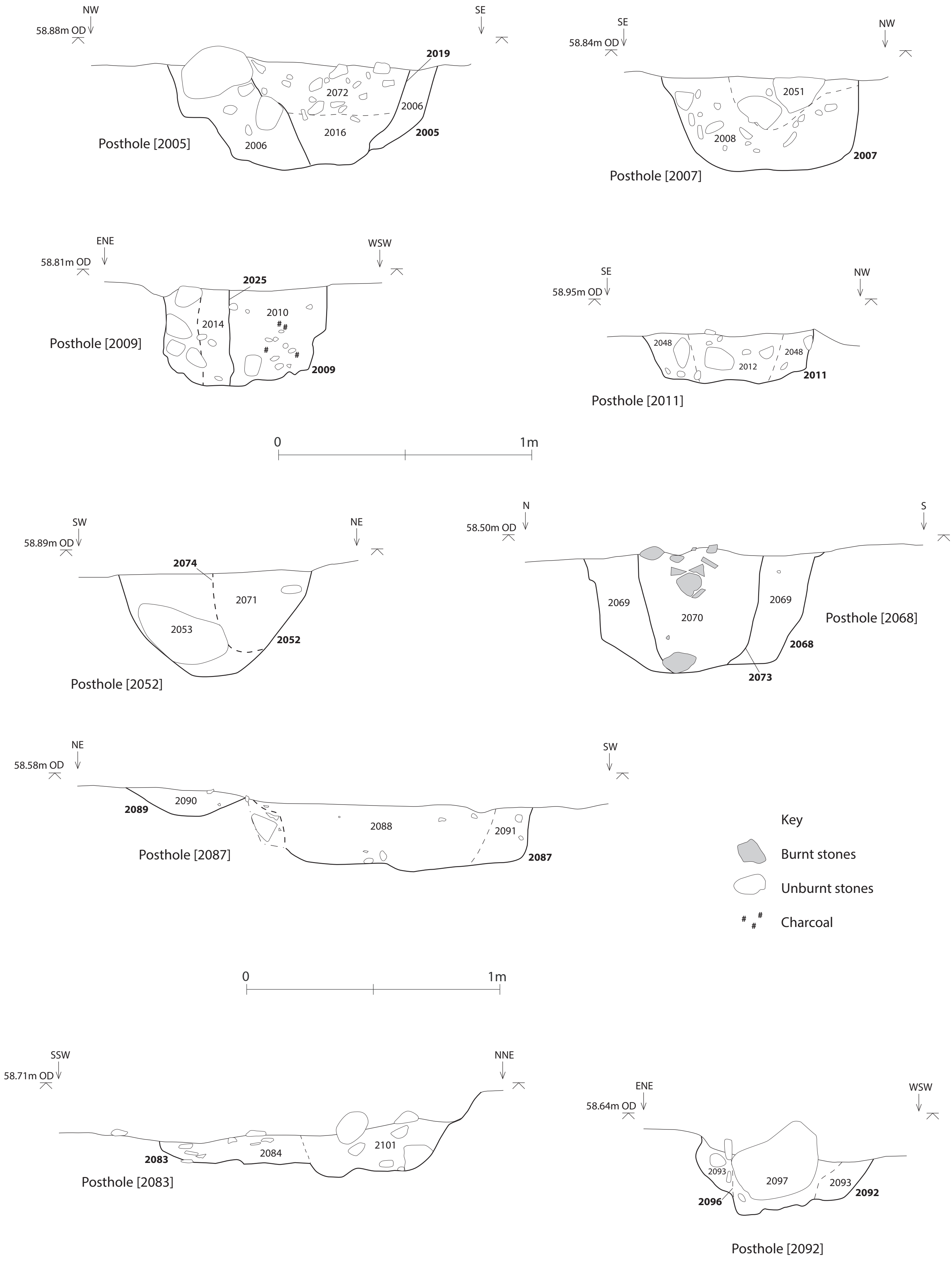


Figure 6. Sections of postholes

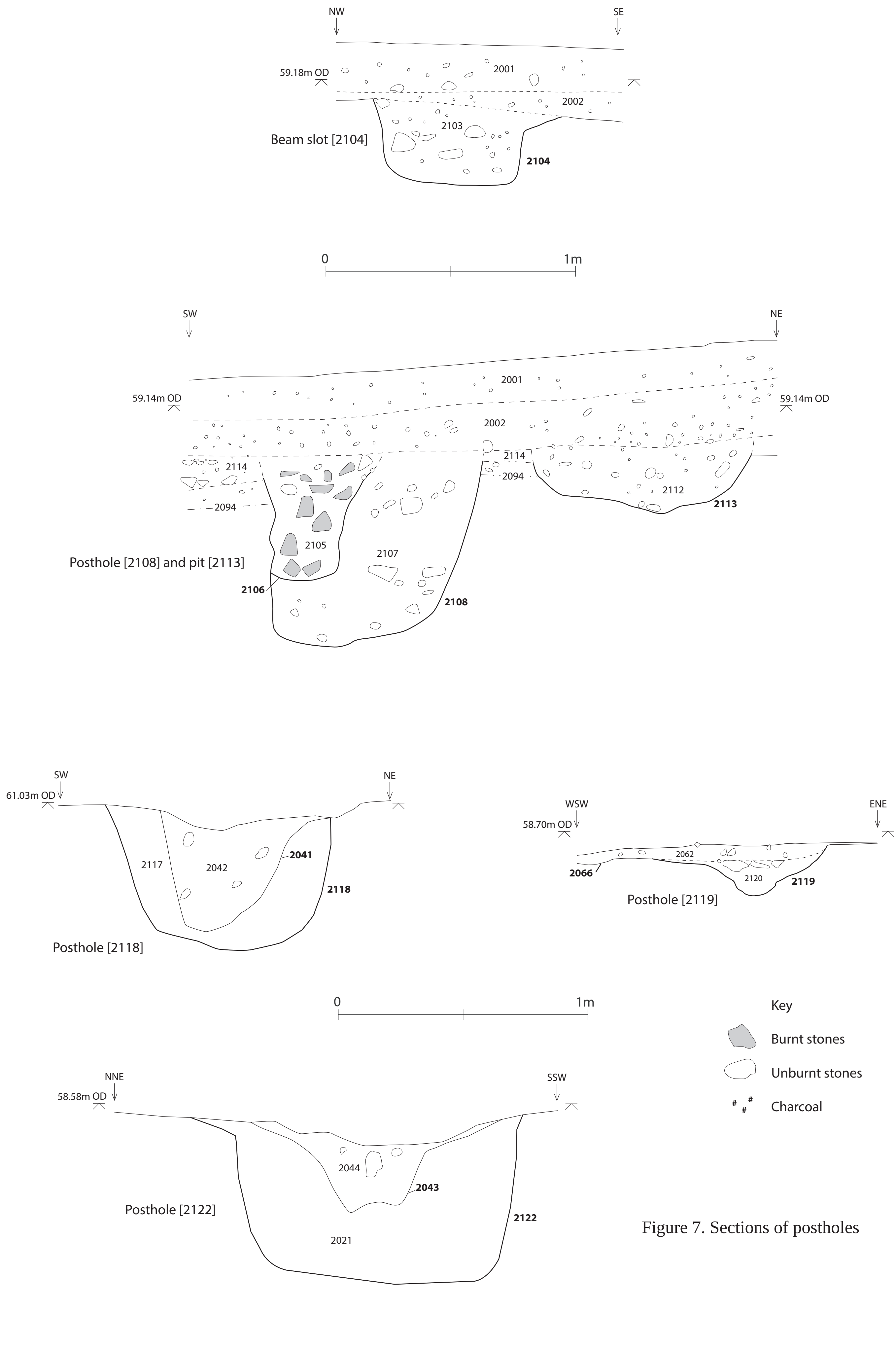


Figure 7. Sections of postholes

4.5. **Copyright**

5. RESULTS

Detailed descriptions of all contexts are listed in appendix IV. See figure 2 for the location of the trench and figures 3, 4 and 5 for the features within the trench.

5.1. Topsoil, ploughsoil and natural

The topsoil and ploughsoil became thicker towards the south-western side of the trench. Against the south-western section the topsoil (2001) was up to 0.26m deep and the ploughsoil (2002) was up to 0.54m deep. In contrast, against the north-eastern baulk the natural deposits were little more than 0.2m below the ground surface, with the ploughsoil in places being less than 0.05m deep. The ploughsoil (2002) was a grey-brown silt with occasional stones, while the topsoil, the active organic horizon, was similar but darker grey. The differences in depth suggest that the ploughing had moved soil downslope from north-east to south-west, where it had built up against the remains of the inner bank on the edge of the platform. The very level appearance of the platform today is therefore due to the movement of soil after the site was abandoned and used as a small field. The platform must have been more sloping when the monument was in use.

The natural deposits also changed from north-east to south-west across the trench. In the north-eastern half of the trench the glacial gravels were close to the surface. This deposit (2100) was a very compact, friable orange-brown gravelly, slightly clayey, sand containing numerous stones, some up to 0.40m long. It was concreted and very hard in places, although elsewhere was loose and friable. The largest stones protruded from the deposit. In the south-western half of the trench the gravel was covered by a yellowish brown silt (2094) with abundant stones. The two natural deposits merged where they met.

5.2. Postholes

For sections see figures 6 and 7

Most of the features found during the excavation were postholes. These could generally be confidently identified as such because they contained packing stones and/or a post-pipe, where the post had decayed away. Four large postholes ([2068], [2108], [2118] and [2122]) formed an arc across the trench (plate 9). These were sub-circular, between about 0.9m and 1.0m in diameter and between 0.5 and 0.77m deep (plate 10). They become shallower from north-west to south-east, probably indicating some truncation of the ground towards the south-east, probably due to ploughing. All the postholes in this feature had visible post-pipes, which were up to about 0.5m in diameter, indicating that the original posts were of similar dimensions. The post-pipes in [2068] and [2108] were filled with dark deposits containing a high proportion of burnt stone (plates 11 and 12) and fragments of burnt bone. Extensive deposits of burnt stone had built-up against the inner bank (see below), and as this also contained burnt bone fragments and had a similar appearance it is likely that this was the source of the stone in the post-pipes. It seems probable that these post-pipes were created not by the post rotting away but by the post being removed and the burnt stone deposit being deliberately used to fill the resulting hole.

The post-pipes in postholes [2118] and [2122] were filled with dark brown sandy silt with occasional flecks of charcoal and small stones. In all four postholes the post had been held in place by a packing deposit that seemed to be the natural gravel dug out of the hole that was then placed back in again. In the case of [2118] and [2122] this packing fill was not initially recognised and only after rain had shown up the differences in the deposits could it be seen that the postholes had not been completely excavated.

Plate 12. Posthole [2108] half sectioned showing burnt stone in post-pipe

Plate 13. Post-pipe and packing stones in posthole [2005]

Plate 14. Stone blocking top of post-pipe [2096] in posthole [2092]

As well as forming the end of the arc posthole [2068] also formed the start of a straight line of postholes running west-south-west to east-north-east close to the south-eastern edge of the trench. The other three postholes on this line ([2005], [2083] and [2087]) were also very substantial, measuring up to 1.2m long and up to 0.92m wide. However they were shallower; between 0.3m and 0.45m deep, and either oval or rather irregular in plan. The deepest was [2005] and at 0.45m it was not much different to [2068] at 0.50m deep. It may be that these two at the end of the line were deeper and the two in the middle were never very deep. However, as mentioned above, all the features along this side of the trench may have been subject to some truncation by ploughing. No post-pipe was recognised in [2087], which seemed to have been disturbed, but [2005] contained a nearly rectangular post-pipe measuring 0.65m by 0.22m. It also had large packing stones up to 0.34m long (plate 13). Posthole [2083] also had an area of darker fill at one end measuring 0.66m in diameter, but only 0.15m deep, so although this was not a well-preserved post-pipe, it probably still indicated the position and rough size of the post.

Roughly parallel and to the north-east of this line of large postholes was a line of three smaller postholes ([2052], [2119], and [2092]). These were still substantial but no larger than 0.80 by 0.50m, and up to 0.43m deep. Posthole [2052] also had the remains of a possibly disturbed post-pipe measuring 0.38m by 0.24m and posthole [2092] had a fairly clear post-pipe measuring 0.4m by 0.34m. This had a large cobble in the top measuring 0.4m long and blocking the post-pipe (plate 14). It is probable that the post had been pulled out in this case and the stone had fallen or been placed into the top of the void. There was also a stone in the top of the post-pipe in [2052], so the same had probably happened here. Posthole [2119] was obscured by a shallow linear feature [2061], which had probably disturbed and truncated it. At 0.26m deep this was the shallowest of these postholes and it had no surviving packing stones or post-pipe.

To the north-east of this line was another group of three postholes ([2007], [2009], and [2011]). Postholes [2007] and [2009] were very similar, both sub-rectangular, measuring up to 0.85m by 0.60m and 0.40m deep. They contained post-pipes measuring about 0.5 by 0.4m. These were rectangular and positioned in the south-eastern corner of [2009] and the north-eastern corner of [2007], so that they were mirror images of each other. Posthole [2011], which measured 0.74m by 0.68m, and 0.29m deep, had a darker deposit in the middle of its fill. Although this seemed to have been disturbed and was not a well-preserved post-pipe it appears to have been where a post was removed. These substantial postholes seemed to form a group. Certainly [2007] and [2009] must have been a pair functioning together.

A feature, recorded as pit [026] in the evaluation trench, was reopened and the area to the north-east of it also explored. In the context of the other postholes on the site this appears likely to also have been a posthole. It was re-recorded as [2102], and was rather polygonal in plan; measuring 1.10 by 0.90m, and 0.20m deep. There was a large stone in the side of the cut but this was not a packing stone as it was embedded in the natural. The interpretation of this feature as a posthole was supported by a straight slot running north-east from it. This slot [2104] ran south-west to north-east, and was hidden under the baulk at its north-eastern end. It had a narrower rounded south-western end, which just reached feature [2102] (plate 15). The base of the slot was shallower at this end. Its sides were near vertical and the base was flat, and it measured more than 1.26m long by 0.35-0.66m wide, and was at most 0.30m deep. Its fill was a friable brown silty sand with some stones. A few of the larger stones, up to 25cm long, were set on edge and appeared to be *in situ* packing stones. This suggests that the slot was a beam slot to hold a horizontal timber. This would have run from the post in [2102], which could have helped to support a superstructure based on the horizontal beam.

The arc of large postholes and the line on the south-eastern side seem to have formed the wall of a timber structure. If the arc is projected it can be seen that the feature [015] found in the evaluation trench was on the same arc and was almost certainly another posthole and part of the same structure. This feature was no more than 0.2m deep but was dug into the very hard natural and so great depth may not have been necessary. It had probably also been truncated by ploughing as it was not far below the present soil surface. This is the only posthole that seems to have been replaced, as feature [013] seemed to cut through it. This feature is slightly off the arc of postholes and may have been an additional support as the timbers rotted rather than a complete replacement.

The arc could have formed part of a circle 12m in diameter. If an entire circle is extrapolated from the arc it would suggest that there was another posthole just obscured under the north-western baulk between postholes [2108] and [015], and that the circle continued under the north-eastern baulk. The south-eastern arc of the structure was flattened off as shown by the line of postholes. The three smaller postholes behind this line seem to have been directly related to this structure. It is possible that postholes [2011] and [2102] were a pair despite

Plate 15. Posthole [2102] and beam slot [2104]

Plate 16. Pits [2076], [2078] and [2081] fully excavated

Plate 17. Hollow [2067] half sectioned

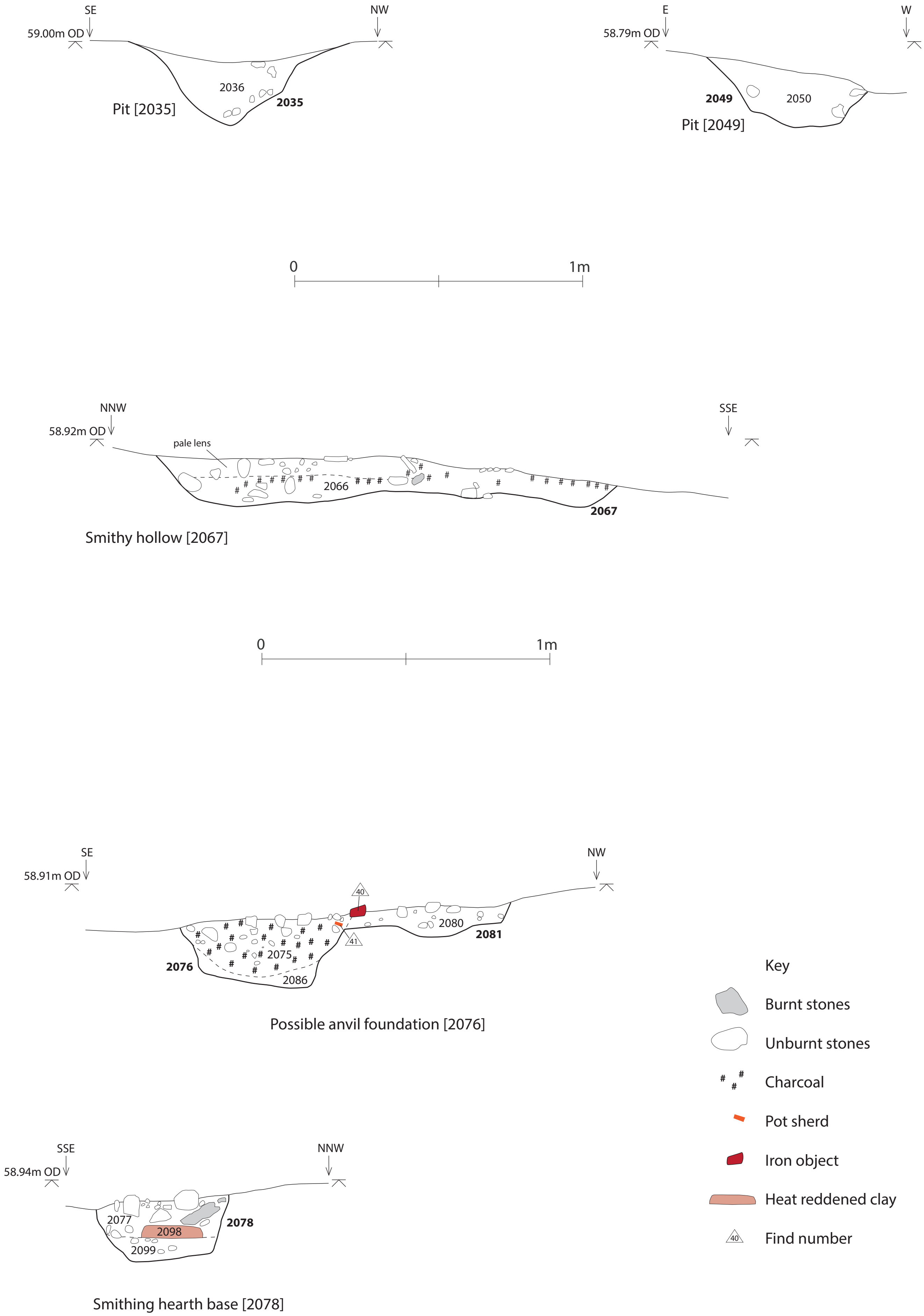


Figure 8. Sections of pits

their difference in size, but there was no visible trace of a beam slot related to [2011], despite close inspection of this area. The similarities between postholes [2007] and [2009] show that they must have been a pair but it is not obvious how they function with the rest of the structure.

Post-packing deposits from the postholes contained few finds but some fragments of burnt bone were recovered from soil samples and small quantities of metal-working debris. This material probably became incorporated into the packing deposits during the use of the building. There was also an iron timber nail (SF43) from the packing in posthole [2068]. This was presumably from the building itself, lost either during construction or repairs. Posthole [2087] contained a flint flake.

The fills of the post-pipes were slightly richer in finds, including a flint blade (SF36), presumably residual, two fiddle-key horseshoe nails of 11-12th century date (SF38 and 39) and a small, iron stem or rivet (SF103). Very small amounts of burnt bone were found in many of the post-pipe fills but the fill of the post-pipe in posthole [2068] contained 14g of burnt bone (SF42 and 84). There were also small quantities of metal-working debris from many of the post-pipe fills, but the soil sample from the post-pipe in posthole [2108] produced 18.8g of mixed slag and hammerscale (SF140 and 141). This sample also produced 6.3g of burnt bone (SF153). Most of the finds in the post-pipes probably relate to the use of the building, having eroded into the hole after the post was removed or had rotted. However in the post-pipes containing burnt stones, in postholes [2068] and [2108], the finds were probably introduced with the burnt stones from the dump around the inside of the bank. The fairly high level of burnt bone and metal-working debris in these fills reflects the levels of these materials in the burnt stone layers.

5.3. Metal-working pits

For sections see figure 8

Three small pits and a shallow hollow were excavated just north-west of the centre of the structure described above. The three pits ([2076], [2078], [2081]) were roughly circular ([2076] being more oval), up to 0.6m in

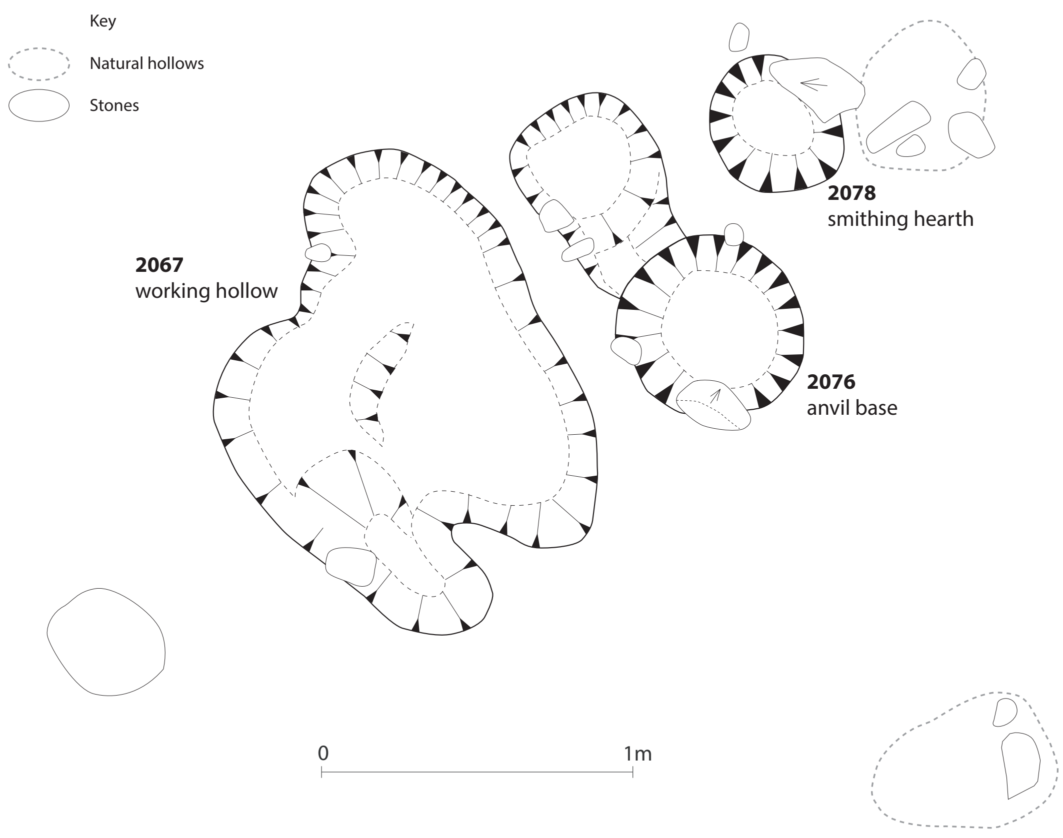


Figure 9. Detail of smithing site

Plate 18. Iron-rich concretion object SF40 from pit [2081]

Plate 19. Smithing hearth pit [2078] half sectioned, showing clay in the base of the pit

Plate 20. Pit [2113] in baulk section

diameter and a maximum of 0.2m deep (plate 16). The adjacent hollow [2067] was irregular in plan and measured 1.60m by 1.10m, but was only 0.15m deep (plate 17). The hollow was filled by a dark greyish-brown sandy silt with lenses of charcoal present throughout. Slag and other metal-working debris was collected by hand and from soil samples from this feature (SF46, 104, 105, 106). This comprised 2.8kg of macro-residues with in addition over 1kg of 'smithing floor' and 0.9kg of fine-grained metallurgical residues. There were also fragments of furnace lining (SF 62), and two small pieces of rectangular iron strip (SF155.1 and SF155.2), probably pieces of bar iron.

Feature [2081] was little more than a hollow in the natural, with a clean silty fill lacking charcoal but it did contain a tiny fragment of a copper alloy rivet shank (SF64) and an object formed from iron concretions (SF40). The rivet shank was part of a high status decorative item as analysis showed that it had been gilded (Parkes, appendix VIII). Object SF40 (plate 18) was initially taken for a piece of farming machinery but once cleaned up it appeared more intriguing. It is a dense, cuboidal block of concretionary material containing hammerscale, measuring 90mm by 55m and up to 52mm deep. The sides taper slightly inwards towards the base, with a void showing traces of wood impressions in the base. Young (appendix IX.2) interprets this as a concretion generated in a void, into which an object, probably the basal spike of an anvil, was wedged by narrow wooden wedges.

Pit [2076] was almost precisely circular and appeared to cut feature [2081]. It had steep sides and a flat base and was the deepest of these features, at 0.3m deep. It had a thin sandy deposit in the base, probably from erosion of the sides, but the main fill was dark grey-brown sandy silt with a high proportion of charcoal. A total of 430g of slag was recovered from this feature (SF57, 107, 108), including a broad spectrum of residues with a rich hammerscale assemblage. A sherd of post-medieval pottery (SF41) found near the top of the fill (figure 8) was probably intrusive considering the radiocarbon date obtained from this activity (see below), but a tiny sherd of medieval pottery was also recovered from a soil sample from this feature. This sherd (SF151, figure 13) was the only medieval pottery found on the site and is similar to earthenwares produced in the 13th and early 14th centuries in Cheshire and Rhuddlan. However the sherd is not particularly diagnostic and there is nothing that would rule out an earlier date, although this would be unusual as very little pottery was used in North Wales before the 13th century (Edwards, appendix XII).

Pit [2078] was the smallest feature in the group, measuring 0.47m by 0.40m and 0.2m deep. It was sub-circular with steep sides and a flat base and a stone projecting from the natural deposits in one side. A thin charcoal-rich silt lined the base of the pit on which lay a lump of heat-reddened clay (plate 19). This did not fill the whole of the base of the pit and it was unclear whether it was part of a floor or collapse from a roof or superstructure. The main fill was a dark brown sandy silt with c.30% stones, many of which were heat-fractured. A total of about 330g of metal-working debris (SF1209, 110, 111, 123, 137, 144) was recovered from all the fills of this pit as well as a fragmented large piece of smithing hearth cake (SF65). A timber nail was found in the lowest layer of the pit and a small iron knife (SF55, figure 14) was also recovered from the pit, with traces of mineralised organic remains, probably a handle, on its tang (Parkes, appendix VIII).

These features are interpreted as a smithing site with pit [2078] being a small, floor level smithing hearth (figure 9). Pit [2076], with its hammerscale-rich assemblage, seems to have been the focus of hammering objects and was probably the foundation cut for a wooden anvil block on which a small metal anvil could be placed. Hollow [2081] may have been worn by the smith standing there while using the hearth and anvil. Waste from the smithing was dumped or accumulated in feature [2067] (Young appendix IX). The knife from pit [2078] and fragments of bar iron in [2067] may represent the types of objects being produced. The size of the smithing hearth cake fragments recovered from the site suggest that mainly small items were produced, although one large cake does show that some larger work was also undertaken.

5.4. Other features

For sections see figure 8

Many of the features investigated appeared to be of a natural origin ([2027], [2029], [2031], [2033], [2037], [2039], [2045], [2055], [2059], [2064], and [2110]). Some of these may have been caused by tree roots, others were the result of animal burrowing in the softer soil in the western half of the trench. Others were little more than an unevenness in the surface of the natural or where a stone had been pulled out by the plough. Feature [2035] was slightly deeper at 0.2m and may have been the truncated remains of a small pit. Features [2049] and [2089] on the line of postholes on the south-eastern side of the main structure could also be genuine archaeological features, possibly related to this wall line, but apart from flecks of charcoal in the fill of [2089] there was little to prove this.

Plate 21. Area of burnt natural [2115]

Plate 22. Ice wedge [2124], continuing under baulk

Plate 23. NE facing section through bank 2116

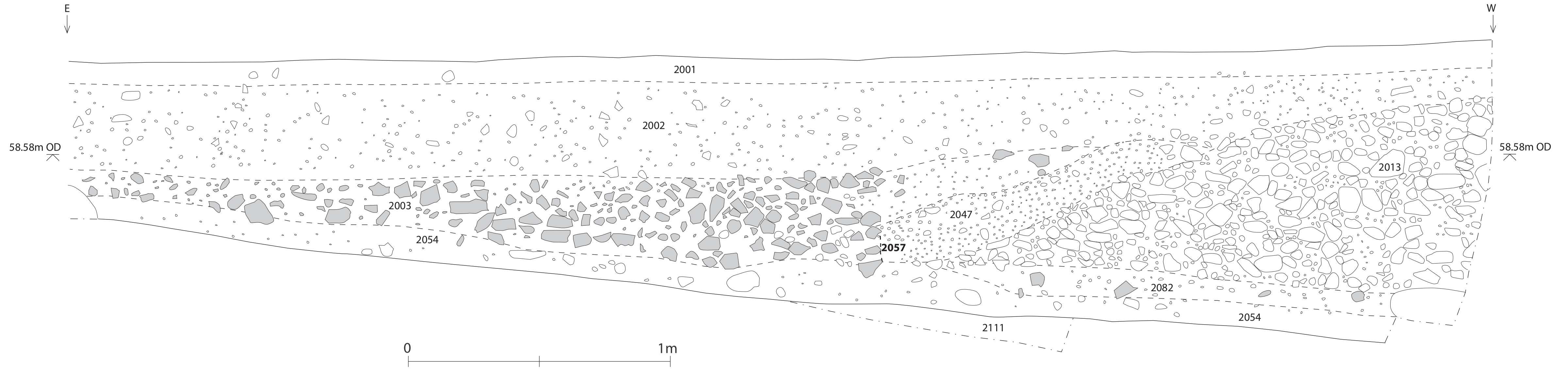
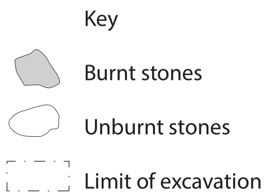


Figure 10. North facing section through bank (2116) and burnt stone layer (2003)

Figure 11. East facing section through banks (2116) and (2018) and burnt stone layers (2003) and (2023)



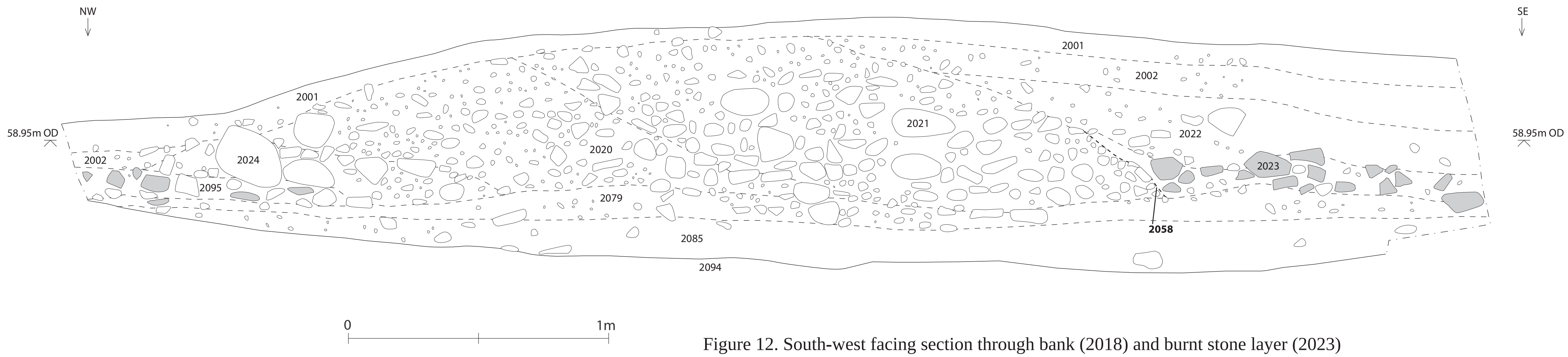


Figure 12. South-west facing section through bank (2018) and burnt stone layer (2023)

Figures 10 to 12

Feature [2113], partly hidden under the north-western baulk of the trench appeared to be a pit with steep sides and a flat base (plate 20). It measured c.0.8m in diameter and was 0.25m deep. Its fill was a brown sandy silt with no charcoal present. Its position next to posthole [2108] could suggest that it had a structural function. It would certainly have been very close to the wall supported by these postholes.

Extending from the north-eastern baulk was an irregular area of reddened natural sub-stratum (2115) (plate 21). It is assumed that the reddening was caused by heat but as there was no charcoal present it is possible that the heat was from a bonfire on the present surface as the natural was only 0.25m below the surface at this point. However, no charcoal could be seen in the ploughsoil as might be expected from a fairly recent bonfire.

A straight, narrow feature [2061] ran south-west to north-east across the trench within the area of the posthole structure. This was about 4.1m long and up to 0.6m wide. It was originally thought to be longer but the north-eastern end was much more irregular than the rest and wandering rather than straight. This end [2124], on investigation, had steep sides and a narrow base not reached after digging 0.35m down into the feature. The stony fill was very clean and this is almost certainly a natural ice wedge (plate 19). The remaining, straight part of the feature [2061] was no more than 0.06m deep and was filled with dark brown silt. It was considered possibly to be the trace of a beam slot, especially as it appeared to have a posthole [2119] at the north-eastern end. However if that were the case, it should have run to posthole [2092], which it avoided to the south. It therefore seems probable that [2061] was unrelated to the sub-circular structure and was either a hollow in the top of the ice wedge that held ploughsoil or a plough scar in the surface of the natural.

5.5. Inner bank

See figures 10 to 12.

The inner bank was investigated in two places. The first was the south-western corner of the trench where the bank could be seen turning the corner around the edge of the inner platform, and the second the north-western side of the trench where an extension to the trench was dug specifically to investigate the bank.

In the south-western corner of the trench the bank (2116) was a substantial feature, 0.7m high, built mainly of rounded cobbles (2013) with a deposit of gravel (2047) against the inner face (plate 23, figures 10 and 11). The bank rested on a dark silty layer (2082) containing occasional charcoal and burnt bone along with quantities of heat-shattered stone. This only survived under the bank but it was unclear whether it was a deliberate levelling layer for the bank or remains of a more general occupation layer that had been eroded away elsewhere and was only preserved under the bank. Underlying this deposit was a buried soil composed of an organic A horizon (2054) and an inorganic sandy silt B horizon (2111).

The gravel over the bank was cut at its foot by a near vertical edge 0.12m high [2057]. This straight cut truncated the base of the gravel deposits and could be seen in both plan and section.

In the north-western corner of the trench, the bank (2018) was up to 0.6m high. This comprised a dump of orange gravel (2020) with rounded stones (2021) dumped against the south-eastern side. These deposits formed the main part of the bank (plate 24, figure 12). Under the toe of deposit (2020) on the north-western side was a darker, more soily layer with larger stones (2024). This does not seem to have been a deliberate revetment but probably the result of some turf being deposited in this area and larger stones rolling to the base of the bank. There was no continuous layer of burnt stones under this part of the bank but there was a patch of burnt stones (2095) under its northern side. Under this was a buried soil (2079/2085).

The inner, south-eastern side of the bank was also cut by a vertical edge [2058]. This was 0.2m high and quite well-defined in plan, but less easy to see in section. The cause of this truncation of the bank base is uncertain.

After the base of the bank had been truncated, an extensive deposit of burnt stone was dumped up against its inside face (plate 25). This was recorded as (2003) in the south-west corner of the trench and (2023) in the north-western part. Traces of the deposit along the base of the western baulk of the trench suggested that this was a continuous deposit and that more of it survived, beyond the excavation, built up against the western part of the bank. This deposit contained about 75% angular heat-shattered stones in a very dark brown, sandy silt matrix with flecks of charcoal. Samples of the stones were studied and were seen to be stones naturally occurring in the glacial gravels

Plate 24. Section of bank (2018)

Plate 25. Section of bank (2116) with burnt stone deposit (2003) built up against inner side

Plate 26. Copper alloy decorative mount (SF32), before conservation (cm scale)

but rounded by glacial or fluvial action. Their angular shape was due to the cracking of the rounded pebbles by heat in a fire. They could have been collected from the river where they were washed out of the glacial deposits (Jenkins appendix XIII).

Soil samples were recovered from these deposits: 40 litres was taken from context (2003) and 20 litres from (2023). Forty litres of soil had previously been recovered from the similar deposit (017) in trench 1. These soil samples produced charcoal and charred plant remains as well as burnt bone and metal-working debris. A total of 137g of burnt bone was recovered by hand collection and from soil samples from deposits (2003) and (2023). Much of this is in small fragments but some is identifiable, including an unburnt pig's tooth from (2003) (SF30). The burnt stone deposit found in trench 1 (017) also produced some burnt bone including a pig's tooth. A total of 119.5g of metal-working debris was recovered from deposits (2003) and (2023) as well as occasional pieces of furnace lining (SF21 and 61). The slag includes hammerscale and possible smithing hearth cake fragments and one piece of furnace lining (SF21) which has part of a blowhole or tuyère with an unusually large bore. This could indicate that the clay was packed around a metal tuyère (Young, appendix IX). It seems likely that this material came from the smithing hearth but the quantities were not large, so the burnt stone deposits are not primarily waste from the hearth.

All the soil samples produced fragments of burnt hazelnut shells, with a large number in context (2003), but hazel charcoal was found only in one of the 10 litre samples from (2003). All samples had a fairly high proportion of charcoal with most identifiable pieces being of oak, except in context 17 where alder, willow/poplar and ash were as common or more common than oak. Contexts (2003) and (017) produced charred cereal grains, although the samples from (2023) did not contain any. Most of the cereal grains were unidentifiable but context (017) contained 6 oat grains. A small number of seeds of dock, the cabbage family and grasses were also present.

The scarcity of hazel charcoal suggests the hazelnut shells were introduced as food waste not on fuel branches. The cereal grains are also suggestive of food waste, as is the amount of bone, mostly burnt, found in these deposits. The burnt stone deposits contained a larger weight of bone than all the other sampled deposits on the site put together and this material appears to be from food waste. Although the burnt stone deposits include some smithing waste, including part of a tuyère, which presumably came from the smithing hearth, this is not predominantly a deposit of waste from the hearth, as it contains little more than was generally distributed over the site.
A timber nail (SF35), two fiddle-key horseshoe nails dating to the 11^{th} to 12^{th} centuries (SF28.1 and SF156) and the blade of a small knife (SF28.2) (figure 14) were recovered from the burnt stone deposits, as well as a flint flake (SF53). There were also copper alloy finds; a decorated strap end (SF20) and two very similar decorative studs (SF32) and (SF34). The latter was recorded as coming from the buried soil (2054) but most likely was from the very base of (2003). These studs have four leaves or petals to provide a decorative effect and were probably used to decorate a leather belt or other personal accessory (plate 26, figure 13).

The burnt stone deposits clearly post-date the inner bank construction but their relationship with the building was not demonstrated stratigraphically. Radiocarbon dates discussed below suggest that they are probably contemporary with the use of the building. The presence of very similar deposits within the post-pipes of some of the larger postholes suggests that the posts were removed and the resulting voids filled with the same material, but it is likely that this came from the pre-existing dumps around the bank.

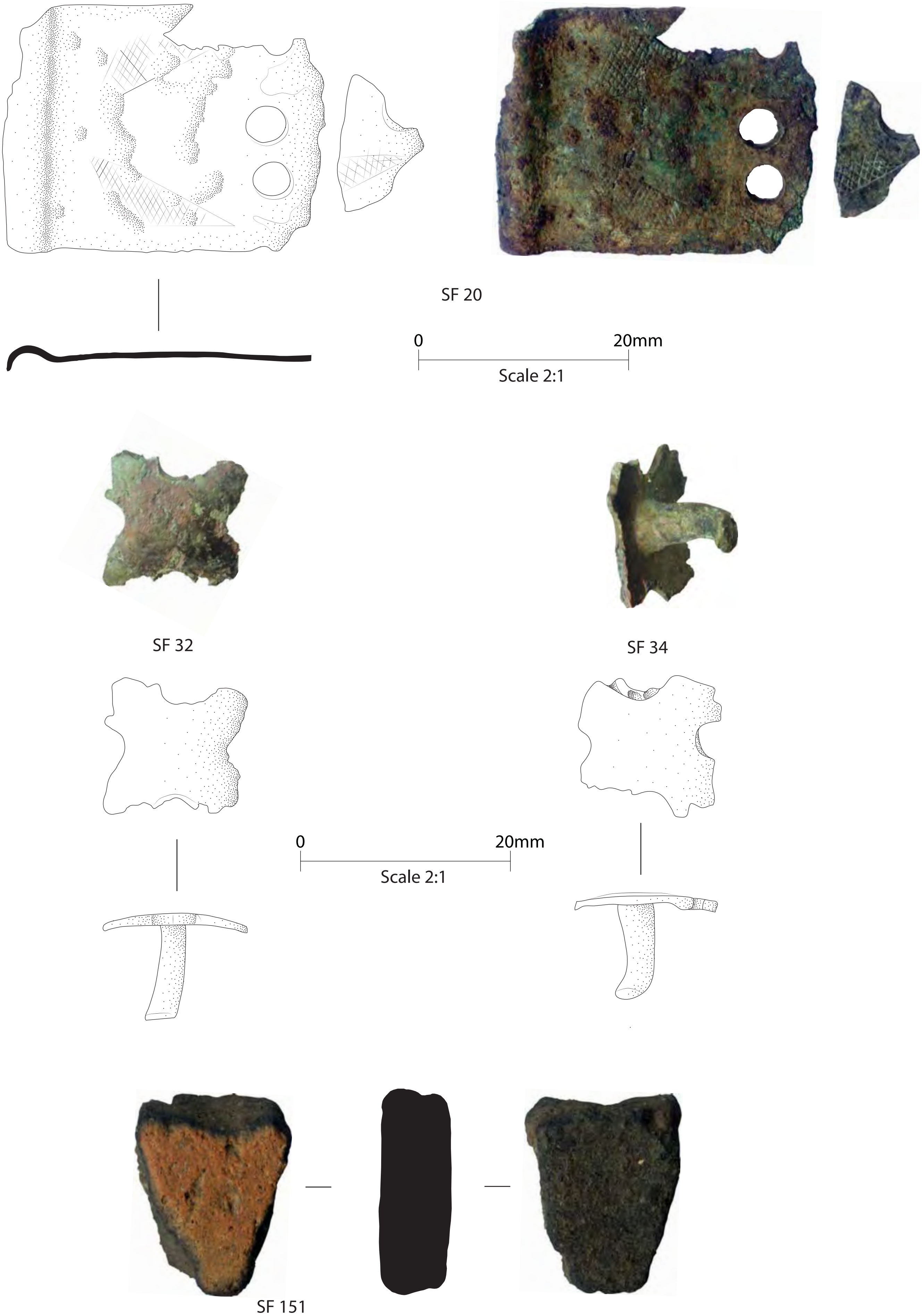
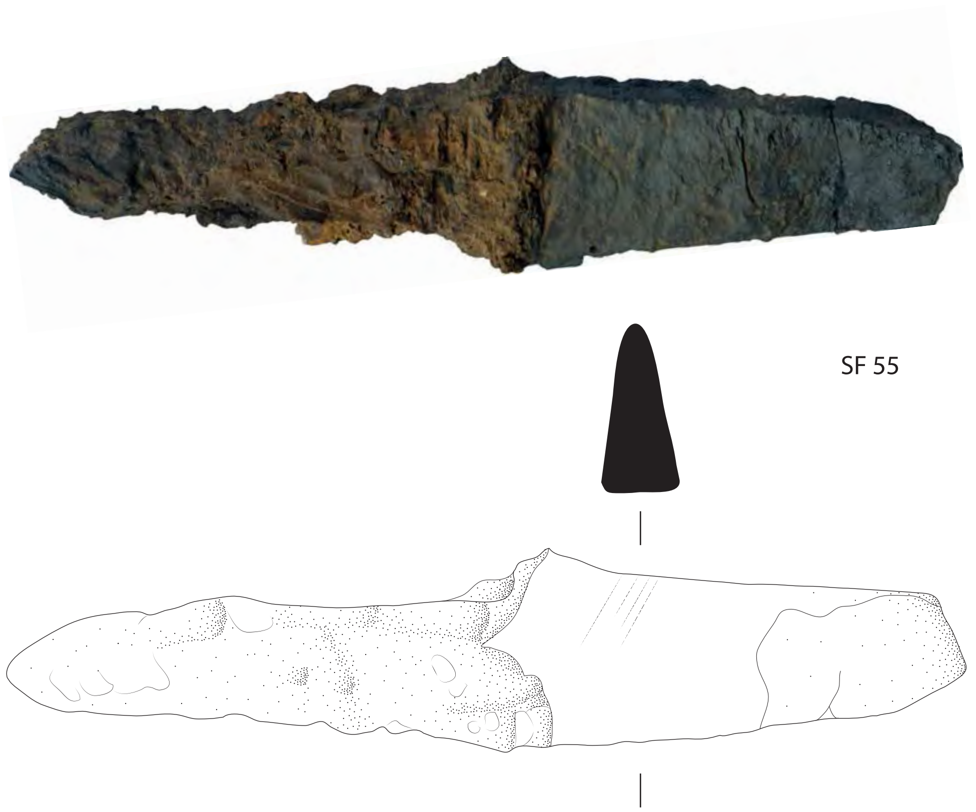


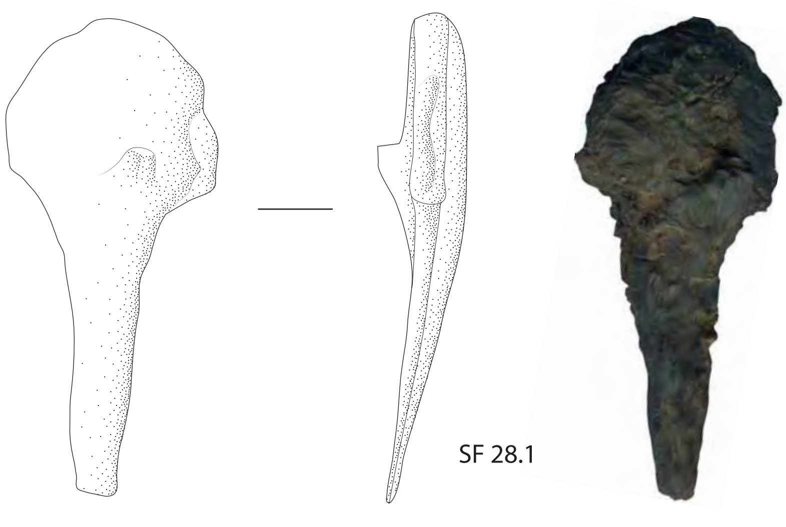
Figure 13. Photographs and drawing of copper alloy finds: SF20 - strap end, SF32 and 34 - decorative mounts. Photograph of medieval pot sherd SF151 (all at scale of 2:1, drawings by Tanya Williams)



SF 55

0 20mm

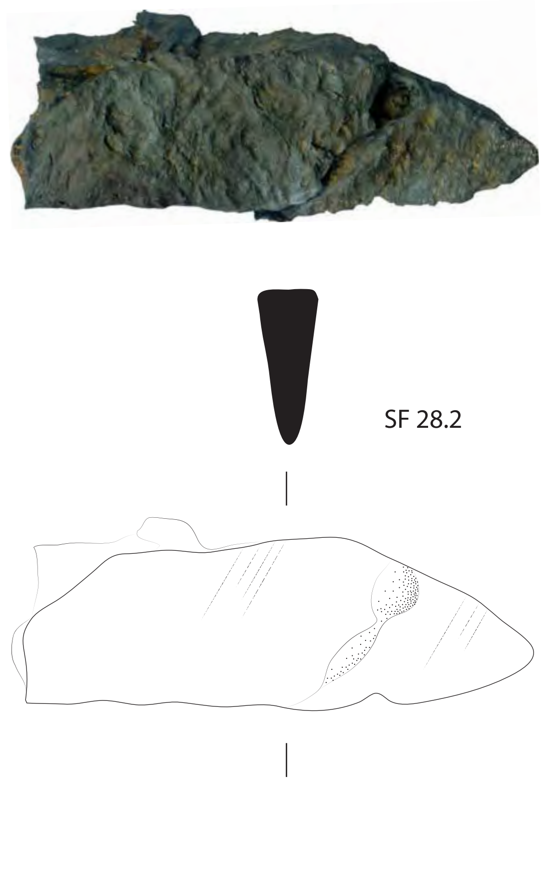
Scale 2:1



SF 28.1

0 20mm

Scale 2:1



SF 28.2

SF 154

Figure 14. Photographs and drawing of iron objects: SF55 - knife, SF154 - possible arrowhead socket, SF28.1 - fiddle-key horseshoe nail, SF28.2 - knife blade (all at scale of 2:1, drawings by Tanya Williams)

5.6. Finds

See appendix I for a detailed list of finds and appendices VII to XIII for full specialist reports.

Metal objects
Following best practice all iron objects were x-rayed, even those from the topsoil, to ensure that no significant artefacts were missed. This was worthwhile as one of the iron finds recovered by metal-detecting was found to be the socket possibly of an arrowhead (SF154). All copper alloy objects and selected iron objects were conserved. This was done by Phil Parkes of Cardiff Conservation Services.

Seventy six objects were assessed by Quita Mould. They are quantified by material below.

Material	Count
Iron	37
Copper alloy	31
Lead	6
White metal	1
Silver	1
Total	**76**

The majority of the objects were recovered during the metal-detector survey in 2013 or while metal-detecting the exposed ploughsoil in 2014. These were clearly 19th or 20th century items principally occurring as a result of casual loss. A small number of metal-detected items were datable to the 11-12th century, late medieval or early post medieval periods. Nineteen objects came from stratified contexts of potentially direct relevance to the interpretation of the site.

Several copper alloy items interpreted as dress accessories were found, including two copper alloy mounts (SF32, 34) and a decorated strap end (SF20) suggested as being of late medieval date (14th-early 16th centuries) (Mould, appendix VIII) (figure 13). There was also a small broken tip from a gilded copper alloy rivet/pin (SF64), a piece broken from a rivet cut from copper alloy sheet (SF18) and two iron stem/rivet fragments (SF103) from a metal mount or possibly a pin.

A small knife (SF 55) was found in the upper fill of pit [2078] associated with metalworking activity, and the tip of another knife (SF28.2) was found the burnt stone deposit (2003) (figure 14). Four fiddlekey horseshoe nails (SF 28.1, 38, 39 and 156) datable to the 11th-12th centuries were found in stratified deposits, along with two unstratified nails of a similar type. Two timber nails and a broken shank from a third were recovered from stratified deposits (SF43, SF145 and SF35). Two small pieces of rectangular strip (SF155.1 and SF155.2) were found in the slag-rich fill (2066) of an irregular, shallow hollow [2067] adjacent to the smithing forge. It is likely that the strip fragments are pieces of bar iron produced by the smithy.

The unstratified material comprised principally of coins and small personal items (buckles, buttons, badge, thimble, silver ferrule, modern key, heel irons) of chiefly 19th and 20th century date and apparently the result of casual loss. A smaller quantity of household items (furniture knob, window catch, window lead, copper alloy miscellaneous fittings) may suggest that some of the material derives from later occupation in the vicinity or brought in from elsewhere. Other unstratified finds included a mason's pick, tool handle tang, a modern spanner, broken horseshoes and a musket ball.

A small number of the unstratified objects could be dated to the medieval or early post medieval period, including a cuboid-headed horseshoe nail (14th-15th century), a socket possibly broken from a small medieval arrowhead (SF154) (figure 14), and a small rotary key and timber nail with faceted head (medieval/early post medieval).

Copper Alloy Objects
Quita Mould
Figure 13
Two small cast copper alloy mounts (SF32 and 34) were found, one (SF32) in the burnt stone deposit (2023), the other (SF34) in the top of the relict soil (2054), but probably actually from the burnt stone deposit (2003). The

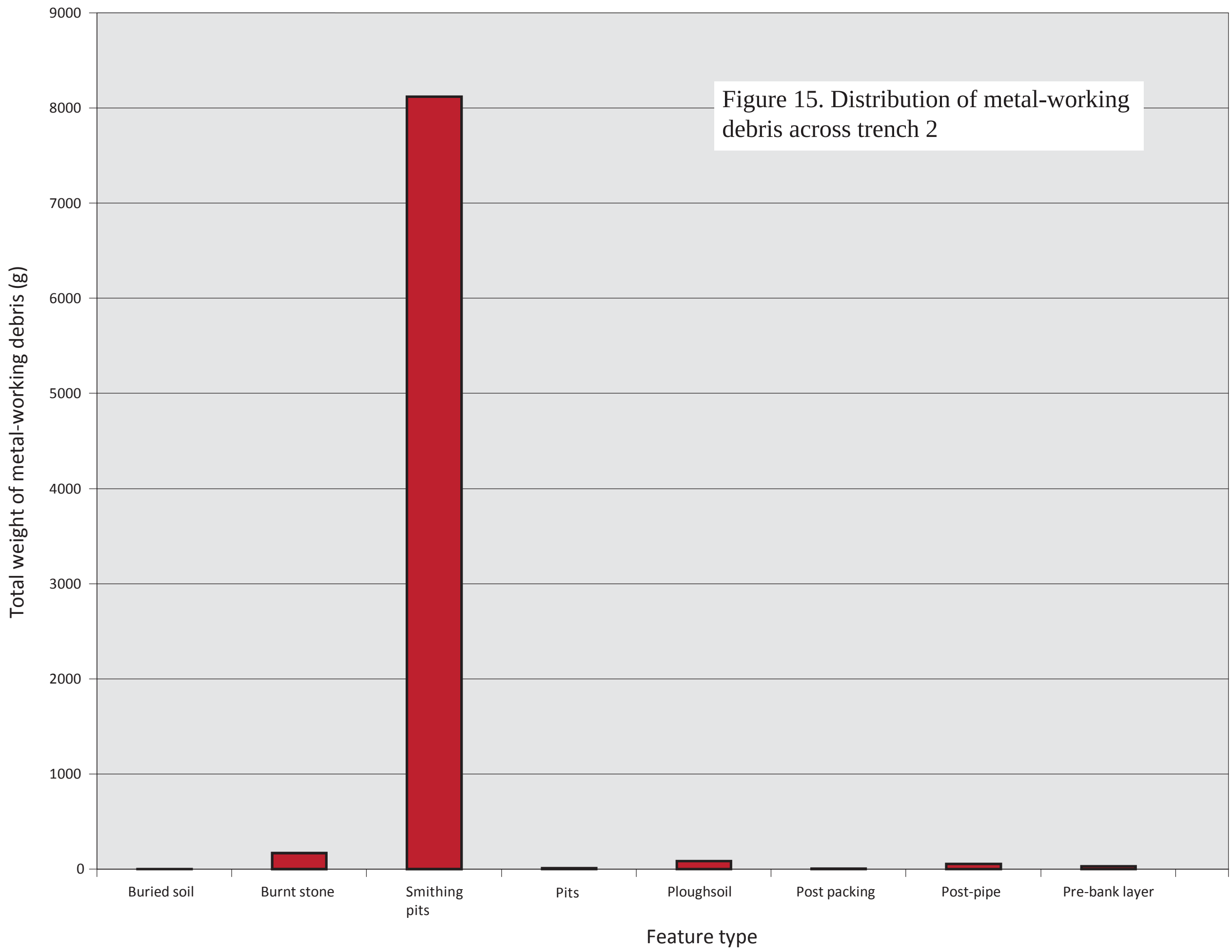


Figure 15. Distribution of metal-working debris across trench 2

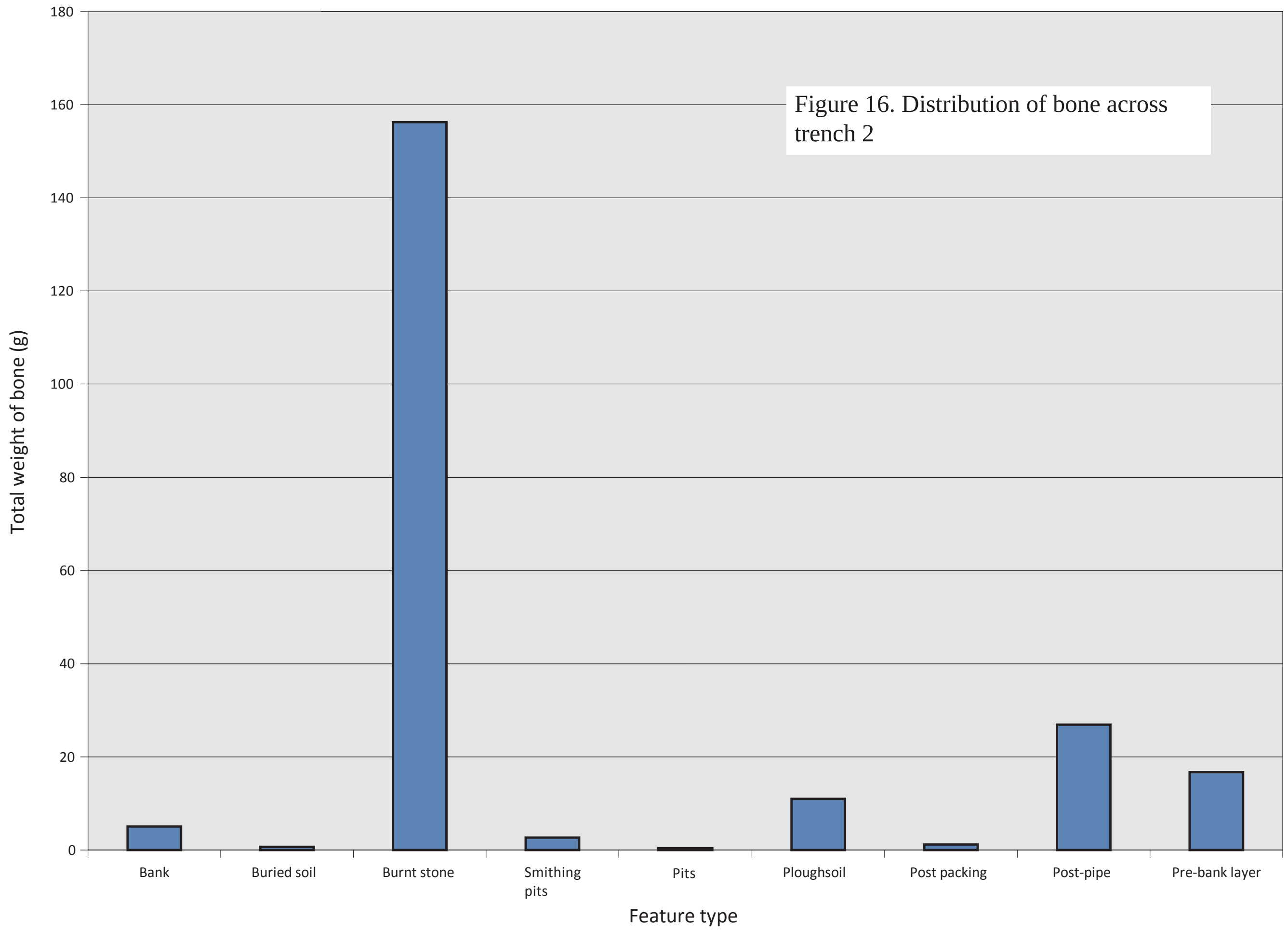


Figure 16. Distribution of bone across trench 2

mounts are of the same design and construction and are likely to have come from the same item. The mounts were essentially square-headed with decorative scalloped and nicked edges producing a four-armed or cruciform appearance but were heavily worn and the edges of the arms are now broken. They had been used to decorate a leather belt or other personal accessory. A small rivet shank (SF64), possibly part of a similar mount, had traces of gilding present indicating a relatively expensive decoration.

A simple folded strap end of copper alloy sheet (SF20) was found in a burnt soil deposit (2003). Strap ends of folded sheet are a common type being the simplest form to produce, this example (SF20) is relatively wide and has simple incised decoration. Of the examples from the city of London none came from contexts earlier than the late 13th century (Egan and Pritchard 1991, 129). The impression of woven textile present on both the interior and exterior surface may suggest that the strap end had been attached to a textile girdle rather than a leather strap but the large rivet holes would appear excessive if intended to rivet to anything other than a very coarse material. It may be that the fibres and textile impression are the result of post-depositional proximity to textile.

Small decorative mounts such as these were commonly used to decorate a range of personal dress accessories and leather fittings for horses, dogs and hawks in the later medieval period and early post-medieval period across north Western Europe, being at their most popular in the late 14th, 15th and 16th centuries (Egan and Pritchard 1991; Willemsen and Ernst 2012, 14). The radiocarbon dates for the contexts from which these came at Hen Gastell suggest a much earlier date.

Metal-working debris

Tim Young

The metal-working debris was a small assemblage, entirely of residues from the end-use working of iron, i.e. blacksmithing. The collection derived from a variety of contexts, with small amounts of hammerscale and other micro-residues being recovered from the postholes of the main structure and more significant amounts from a stony deposit overlying the bank. Most, however, were from a group of small pits interpreted as the remains of a forge (figure 15).

The macro-residues included seven smithing hearth cakes, of which five weighed less than 170g, a composite example 306g and a large example with an original weight of probably approximately 1kg. There was also a large quantity of sandy and gravelly slags with a very clinkery appearance. Tiny quantities of coal were recovered, although not from contexts in the forge.

Micro-residues included hammerscale, but also a large proportion of slag flats; thin films of slag that in many cases show evidence for having encrusted the tip of the smith's tongs.

The analysis suggests that blacksmithing was probably undertaken in a small hearth within the building at Hen Gastell. The hearth (pit [2078]) was a small, floor level, hearth less than 0.5m in diameter. A slightly larger pit [2076] just 0.25m south of the hearth may have been for a wooden anvil block. Object SF40 (plate 18), found adjacent to this pit, is a dense, cuboidal block of concretionary material containing hammerscale. The sides taper slightly inwards towards the base, with a void showing traces of wood impressions in the base. Young (appendix IX.2) interprets this as a concretion generated in a void, into which an object, probably the basal spike of an anvil, was wedged by narrow wooden wedges.

The small size of the hearth and the small size of the majority of the recovered smithing hearth cakes suggests that rather smaller items/batches of work were the norm. The presence of at least one large smithing hearth cake suggests that the smith undertook some heavy work. This pattern resembles that indicated by the residues found at several other blacksmithies of the period, in both rural and urban settings.

The chemical composition of the smithing hearth cakes provides no evidence that they were produced during the refining of raw blooms down to bar iron. Rather, the evidence suggests that the forge was supplied with finished iron.

Evidence for the air delivery system was limited to a single fragment of hearth ceramic containing a part of the blowhole margin. This was of unusually large diameter for such a blowhole but the presence of tiny blebs, apparently of slag spatter, on the inside of the bore suggest it was an open blowhole, although there is a possibility that it actually held an iron tuyère.

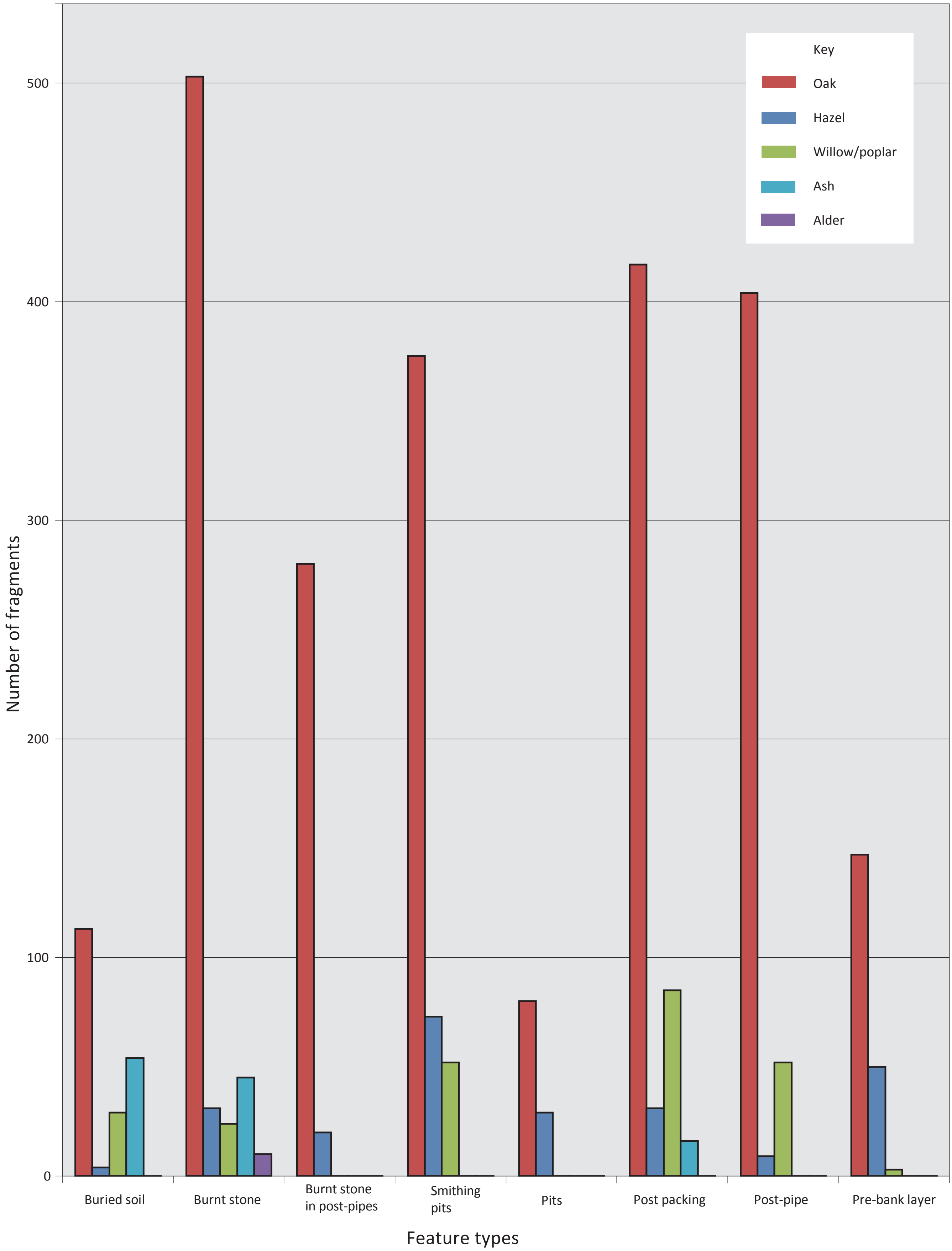


Figure 17. Distribution of charcoal by species across trenches 1 and 2

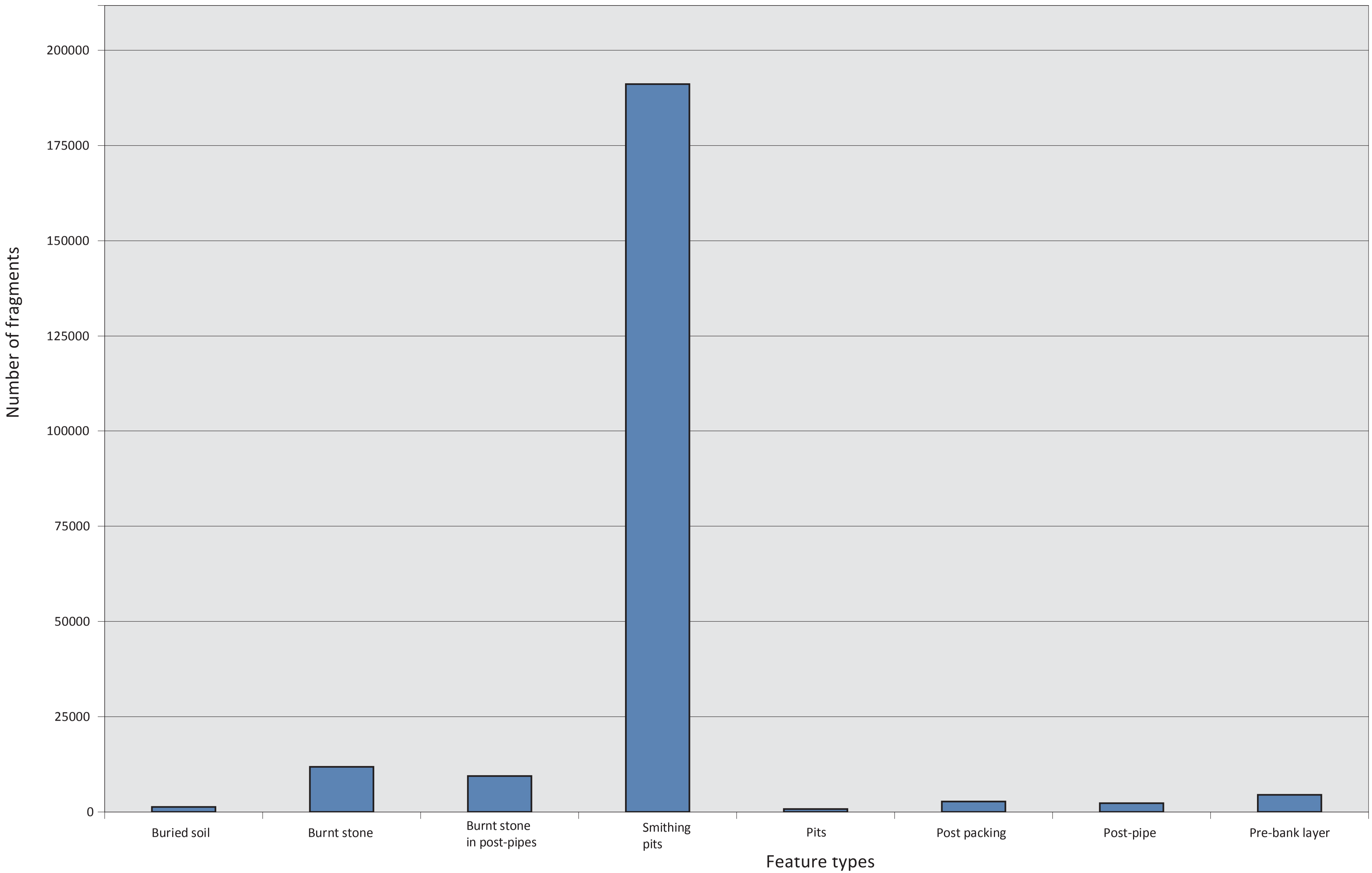


Figure 18. Distribution of total quantities of charcoal across trenches 1 and 2

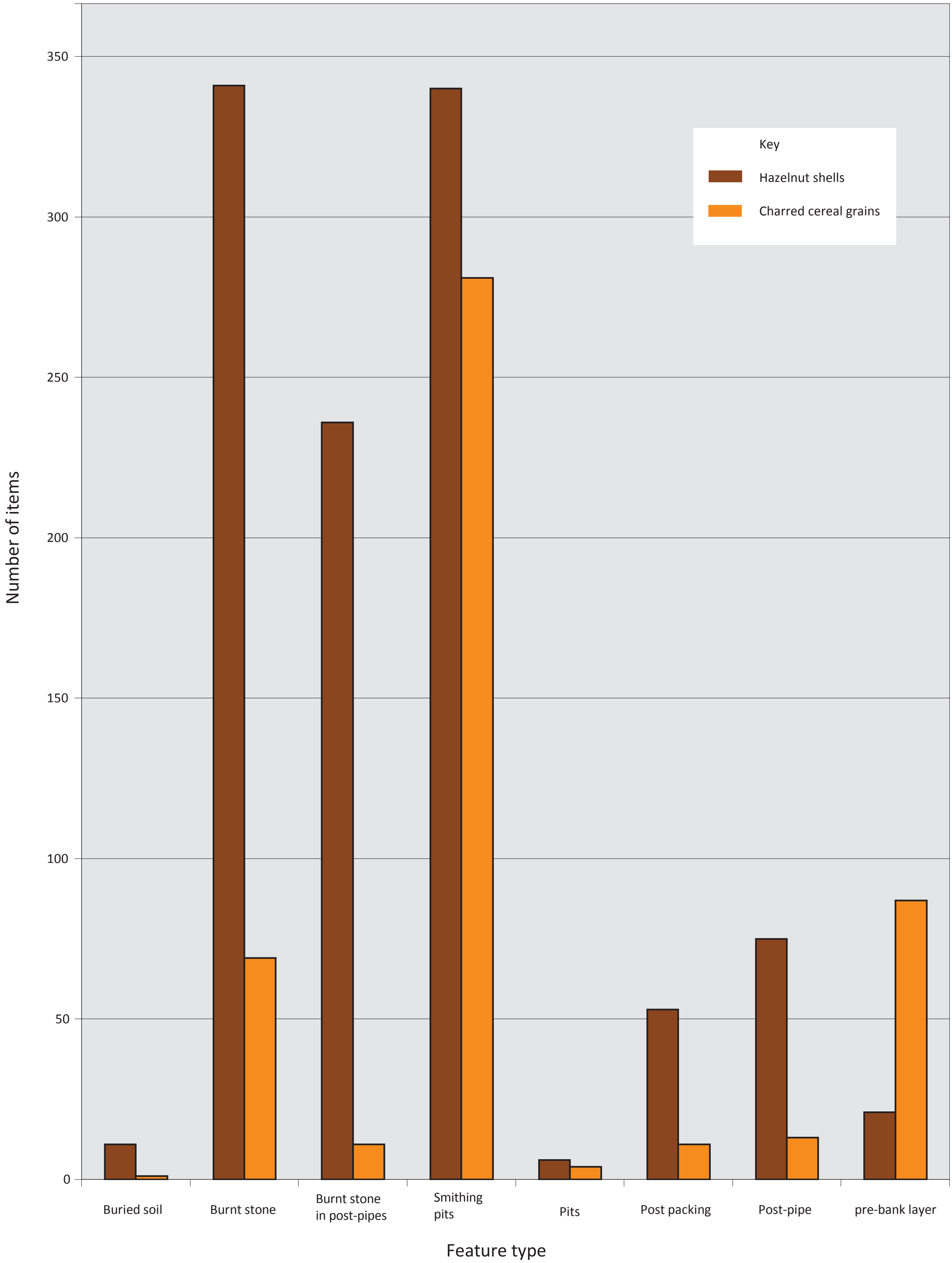


Figure 19. Distribution of charred hazelnut shells and cereal grains across trenches 1 and 2 (sample 29 from smithing pits excluded. This contains 3381 cereal grains and fragments of chaff.)

Elemental analysis provided suggestions that iron produced from bog iron ores was used. Such sources were probably utilised for the production of iron in the earlier medieval period at Cefn Graianog (Young 2015b), just 8km to the south of Hen Gastell.

Lithics
George Smith
There were few non-flaked stone objects. The most significant being a rubbing stone fragment (SF146) made of very coarse gritstone, probably broken by burning and recovered from the buried soil (2079).

The flaked stone assemblage includes a flint flake (SF 14) with a small area of possible secondary retouch, a retouched flint flake fragment (SF36) and an utilised flint blade (SF53). These came from the topsoil, a posthole and a burnt stone deposit respectively and must have been residual in their contexts.
There were also five natural fragments of flint originating from the glacial gravels (SF 67) and two broken natural fragments (SF 44 and 54).

SF14, 36 and 53 could be associated and suggest a minor presence of Mesolithic or Neolithic activity here. A briefly used flint knapping or camp site would be appropriate for the location on a knoll overlooking a stream.

Pottery
The small assemblage comprises 28 ceramic vessel sherds and eight clay tobacco pipe fragments, the majority of which were recovered from the ploughsoil. Pottery from the late 17th or early 18th century onwards is represented, including earthenware, blackware, pearlware and whiteware. Two of the clay pipe stems are marked as being made in Chester. A detailed catalogue is included in appendix XI.

A single medieval sherd was found. This sherd (SF151) came from the fill of a small pit [2076] associated with metal-working. It is of earthenware with a reduced grey/black core and interior surface and an oxidised red/brown exterior (figure 12). The pit that the sherd was recovered from is dated by association with the adjacent smithing hearth to the 11th or 12th century AD (see below). The fabric of the sherd is similar to pieces produced in Chester and Rhuddlan of a 13th or early 14th century date but its small size and eroded condition suggest that the sherd may be intrusive in this context (Edwards, appendix XII). However no other evidence was recovered for activity on the site in 13th and 14th centuries, so it must be considered possible that this sherd does date to the main period of use of the site and that pottery was very occasionally used in North Wales prior to the 13th century.

Animal bones
Nóra Bermingham
A small assemblage of mostly burnt animal bone was recovered mainly from wet sieving of soil samples, but also by hand collection. With the exception of a small number of teeth all of the bone recovered is unidentifiable to species, although is clearly animal rather than human in origin. Pig and cattle are represented by tooth fragments with the majority of fragments classified as unidentified mammal with medium and large-sized mammals represented in small amounts.

Animal bone was recovered from 31 individual contexts with most coming from the burnt stone deposits (figure 16). Most fragments measured less than 10mm long and in general the pieces were too small to allow for identification to species and/or skeletal element. The assemblage is poorly preserved with almost all of it burnt; unburnt tooth fragments occur in contexts (017) and (2003). Fragments derive from both the head and body suggesting that whole animals or carcases were butchered on site. Given that most of the pieces retrieved are burnt to white, and also small in size, it is likely that this material represents general waste from domestic fires.

The small size of the assemblage and its preservation mean that this material is of limited interpretative value. Nonetheless it demonstrates the presence of two major domesticates and is suggestive of general domestic waste.

5.7. Palaeoenvironmental Evidence

Charcoal remains and charred plant macrofossils were recovered from 38 of the 40 samples taken. The charcoal remains showed the exploitation of several species, with the oak being most commonly selected and used as fire wood. The species present indicate oak woodland close to the site with some hazel on the woodland edges or in clearings. The willow or poplar recovered probably came from trees growing in the damp conditions by the river (figure 17).

The other charred plant remains include hazelnut shells and cereal grains, mostly indeterminate but some identifiable as wheat and oats. There are also weed seeds, including grasses, goosefoot or orache, corn marigold, dock and members of the cabbage family. However the small number of cereal grains and associated weed seeds limits the interpretations possible from the assemblage. The only exception is the large assemblage from sample 29 collected from fill (2077) in the smithing hearth pit [2078]. This sample was analysed in detail.

The smithing activity stands out as having the greatest concentration of charcoal, with other deposits having relatively low amounts (figure 18). This is due to these deposits being the waste from fires and being relatively unmixed with other deposits. There is also a fairly large amount of charred cereal grains and chaff from the smithing pits (figure 19). The quantity is very much higher than shown in this diagram as sample 29 from the smithing hearth [2078] has been excluded because it is so much larger than the other samples that they cannot be clearly represented on the same scale. Sample 29 from (2077), the main fill of the pit, contains 37 charred oat grains, 156 rye grains, 22 barley grains, 349 wheat grains, and 2943 unidentifiable cereal grains. There was also chaff from all these species. The charred grains were also found in both the clay deposit (2098) and underlying black layer (2099) in the base of pit [2078]. Just over 30 litres of soil samples were recovered from the smithing pits, so the amounts of cereal grains are very significant.

The analysis of the charred plant remains in sample 29 gives more detail on what cereals were being grown and how they was used. The identifiable grains were dominated by free threshing wheat, with a small amount of rye, barley and oat grains. This is unusual for medieval Wales as oats are normally the most common cereal. Wheat was the preferred grain for bread and it is possible that, while on many sites other grains were used, the status of Hen Gastell meant that pure wheat bread was eaten. The small numbers of cereal chaff and weed seeds in comparison with the numbers of grains shows that this was cleaned grain, already threshed, winnowed and sieved before being introduced onto the site.

The absence of sprouting grains suggests that they were not malted for making beer. As the plant remains were found with charcoal in the smithing hearth it suggests that waste or spilt grain was put on the fire with other rubbish, possibly as part of a single depositional event relating to either a spoilt grain store, an accident whilst drying the grains or the remnants of a meal.

Significant numbers of charred cereal grains were recovered from the burnt stone deposits and from context (2082) from beneath the inner bank. It is likely that this is also processing waste but that chaff has not survived in these more disturbed contexts. Cereal grains are unlikely to become charred during normal use as food but they may possibly have been dried prior to milling or cooking and become accidentally charred in the process and so could represent food use. The cereal grains from the burnt stone layers were recovered from 80 litres of soil samples, but only 20 litres of soil samples were collected from context (2082) under the bank, so the quantity of charred cereal grains is more significant and probably indicates either crop processing or occupation activity.

The presence of hazelnut shells in several contexts may suggest their use as food. They are often prominent on sites of various periods because their shells are likely to be disposed of in domestic fires and therefore have a high chance of being charred. However, the hazelnut shell fragments show no marks associated with breaking the shells for food, and as there is hazel charcoal present across the site this may indicate that the hazelnut shells were introduced on branches burnt as fuel. The largest quantities of hazelnut shells were recovered from the smithing activity, the burnt stone deposits and the burnt stone fills of post-pipes; the latter two deposits probably being from the same source. In these the number of hazelnut shells was very significantly higher than elsewhere on site. Although the smithing activity seemed to have used slightly more hazel wood than other activities on the site, the burnt stone deposits, while containing some hazel charcoal, seemed to have no more than other deposits. This may suggest that the hazelnut shells were indeed food waste. It is possible that the smithing activity took place in autumn and that a large number of nutshells were present on branches used as fuel, although this seems very wasteful of nuts. The burnt stone deposit seems to have built up over an extended period of time and it is unlikely that this material was only produced in autumn. It therefore seems probable that hazelnuts were used as food on the site, even if some were accidentally introduced on branches.

Small samples of soil were taken from the buried soil under the banks from context 2079 under bank 2018 and context 2054 under bank 2116. The pollen within these samples was assessed by Dr Cath Langdon and Prof. R Scaife of University of Southampton and they concluded that the preservation of pollen was generally poor, particularly in the sample from context 2054. However the pollen did suggest an open environment prior to the construction of the bank, with both arable and pastoral activity close by. The presence of cereal pollen could indicate cereal cultivation on the site but it could alternatively suggest crop processing.

5.8. Radiocarbon dates

A total of 14 samples were submitted to the Scottish Universities Environmental Research Centre (SUERC) Radiocarbon Laboratory for accelerator mass spectrometry (AMS) dating (see appendix XIV.2 for full table of dates). All the samples were from short-lived entities and in most cases two samples were dated from each context allowing for a check on the dates produced and identifying any contamination or other mixing of materials of different dates.
Four samples were sent for dating in 2014 from the 2013 evaluation trench to obtain a general indication of the date of the site and inform a decision on further dating. The material dated was from the buried soil layer (021) under the inner bank and the burnt stone fill (017) of the possible slot [018] in the top of the inner bank.

After the larger excavation in 2014 another 10 samples were selected for dating. The aim was to establish more precisely the duration of use of the site, and to attempt to detect any activity significantly earlier or later than the main phase. It was also necessary to test whether the metal-working pits belonged to the main phase of activity.

As the burnt stone layers (2003 and 2023) were part of a stratigraphic sequence two dates were obtained on these layers to compare to the dates from the burnt stone deposit (017) previously dated. A layer (2082) from under bank 2116 was dated. This contained burnt material and appeared to represent pre-bank activity, potentially a significantly earlier phase of activity.

The date of the main structure was investigated by dating material from two postholes ([2068] and [2092]). In both cases material from both the packing deposit and the fill of the post-pipe was dated. Charred material is likely to be incorporated into the packing deposits during the use of the building as the floor is cleaned and rubbish swept into corners and around the base of posts. The fill of the post-pipe in posthole [2068] contained a high proportion of burnt stone, possibly from the same source as the main burnt stone layers and almost certainly introduced into the post-pipe after the post had been removed.

Two dates were obtained from pit [2078], which represented the remains of a smithing hearth to date the metal-working activity.

A simple visual comparison of dates can be misleading and imprecise. To enable a rigorous comparison of the dates chi-squared tests were done on pairs of dates from the same feature to establish whether they were statistically consistent or indicated a deposit with material of mixed dates. All the dates were then compared using Bayesian modelling in which stratigraphic relationships can be used to allow a more precise interpretation of the dates and suggest a duration of use of the site. The statistical analysis was carried out by Derek Hamilton of SUERC (see appendix XIV.1).

The chi-squared tests showed that the two dates from the buried soil (021) were not statistically consistent and mixing of material of different dates had occurred in the soil, as might be expected. However the two dates from the activity layer (2082) under the bank were shown to be statistically consistent and this layer could have been produced by a short-lived activity.

The two dates from the burnt layers (2003) and (2023) (one from each layer) were statistically consistent and these layers could be part of the same activity and of the same date. However some mixing of material of different dates was indicated in the other burnt stone deposit dated (017).

The two dates from each of the dated postholes were statistically consistent, despite one date being from the packing fill and one from the post-pipe in each case. The two dates from the smithing hearth [2078] were also statistically consistent, showing that this was used for a fairly short period of time.

Although the dates are all quite similar and many of the pairs statistically consistent if the pre-bank dates are removed and the others compared they are not statistically consistent showing that the pit, post-holes and the post-bank burnt deposits do not reflect a single ‘event’, but rather activity over a protracted period.

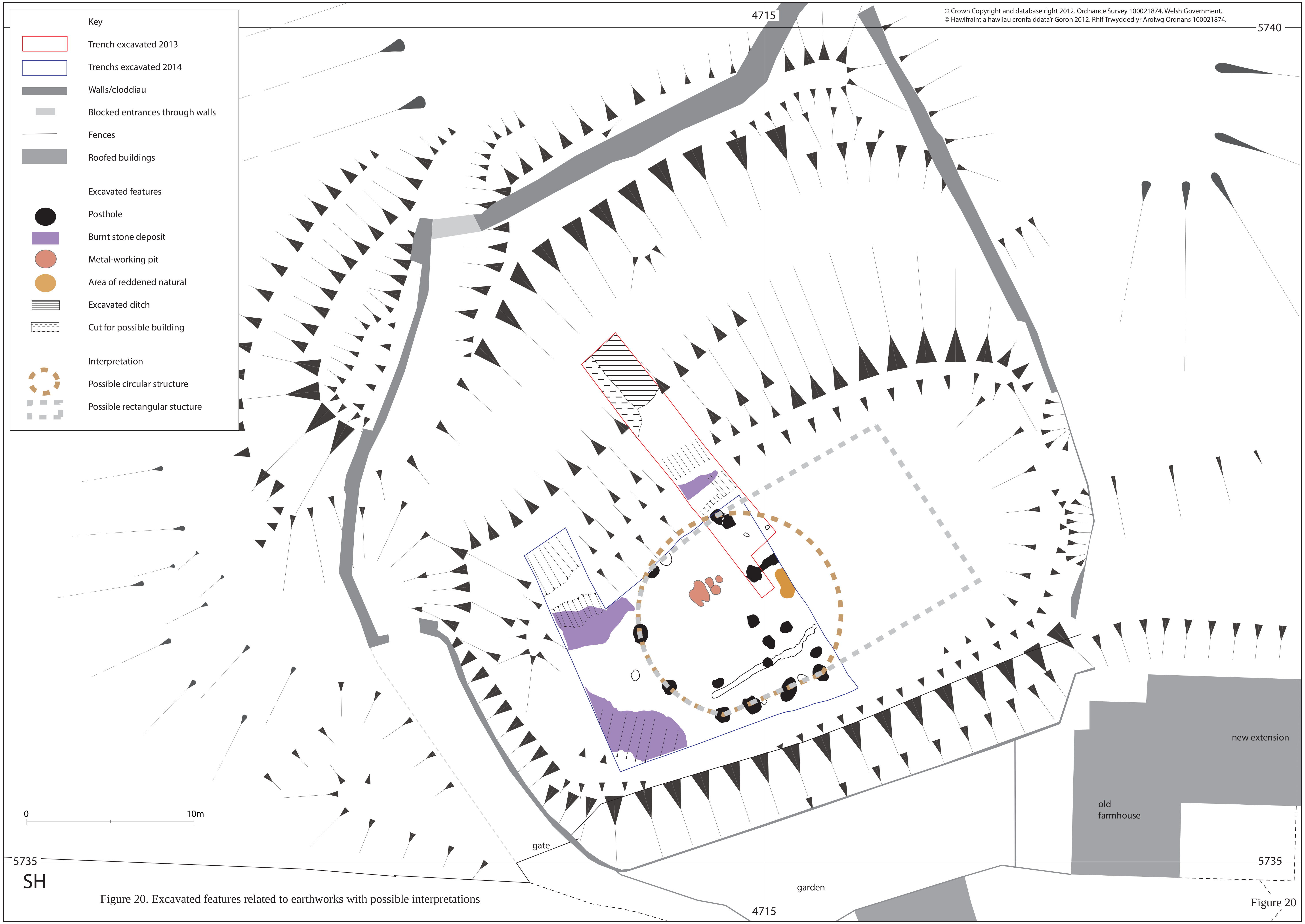


Figure 20. Excavated features related to earthworks with possible interpretations

Figure 20

A Bayesian model was set up taking into account stratigraphic relationships such as the pre and post bank deposits and the packing of the postholes being earlier than the fills of the post-pipes. This model has good agreement between the radiocarbon dates and the archaeology and estimates that the dated activity began in *cal AD 995–1145* (*95% probability*), and probably in either *cal AD 1010–1050* (*38% probability*) or *cal AD 1070–1115* (*30% probability*). The inner bank was constructed in *cal AD 1045–1155* (*95% probability*), and probably in *cal AD 1090–1150* (*63% probability*). Activity on the site ended in either *cal AD 1050–1115* (*18% probability*) or *cal AD 1120–1125* (*18% probability*) or *cal AD 1120–1225* (*77% probability*), and probably in *cal AD 1130–1210* (*68% probability*). The overall span of dated activity is *1–200 years* (*95% probability*), and probably *10–130 years* (*68% probability*).

The smithing hearth fits well within the main phase of activity and must have been in use at the same time as the structure. There was clearly some activity that took place before the bank was constructed but the radiocarbon dates suggest that this was not significantly earlier than the main phase of activity on the site and could have been related to preparations for the construction of the bank, or possibly the outer defences. There is no evidence of Iron Age activity.

It appears that the burnt stone deposits were deposited over an extended period during the use of the site. It is likely that these deposits were reused to fill in some of the post-pipes, but the dates of material filling the post-pipes would reflect the occupation of the building not its destruction. There was no evidence of later use of this inner platform from the dates obtained, although the probable building found in the ditch in the evaluation trench suggests that the site was a whole was later reused.

The modelling suggests that activity on the inner platform covered a period of three or four generations sometime in the 11th and 12th centuries cal AD. As no earlier activity was indicated that might support an earlier phase to the outer defences it is assumed that the whole monument was constructed during this period. The possibility of the monument being a Neolithic henge or Iron Age defensive site that was later modified is not supported by the dates obtained.

Dates suggested for some of the artefacts such as the copper alloy strap end (SF20) and the tiny sherd of medieval pottery are later than the dates suggested by the radiocarbon dating. The sherd is insufficiently diagnostic to provide firm dating and it is suggested that the radiocarbon dates might be used to date the strap end and suggest that decorated items of this sort might have been used earlier in north Wales than has been previously assumed.

Additional remodelling of the dates suggests that obtaining further dates would not improve the precision of the model or allow further separation of different phases of activity. This is due to a “wiggle” in the relevant section of the calibration curve (Hamilton pers. comm.). It must therefore be accepted that a date comparable to a historical date cannot be obtained and this site can only be fitted in a fairly general way within the documented history of the area. However the firm demonstration that there was no significant earlier or later activity on the site is very valuable for its interpretation.

6. DISCUSSION

6.1. Interpretations of excavated features

Main structure

The postholes revealed in the excavation suggest the presence of a large timber structure. As the full area of the inner platform was not excavated the plan of the building remains open to discussion. There are two probable alternatives for the building plan; sub-circular or sub-rectangular. A circular structure with one side flattened would fit the evidence well and would fit neatly in the space available with room for ancillary buildings in the eastern end of the platform (figure 20). In this reconstruction the structure would have been about 12m in diameter. However the flattened side suggests that this could alternatively be interpreted as the western end of a longer, rectangular structure with at least one curved end. This could have been up to between 18m and 20m long depending whether the eastern end was curved or straight.

In either case the large postholes with post-pipes up to 0.5m in diameter suggest that this was a substantial structure, possibly with a second storey. Both alternative interpretations leave several internal postholes unexplained. The

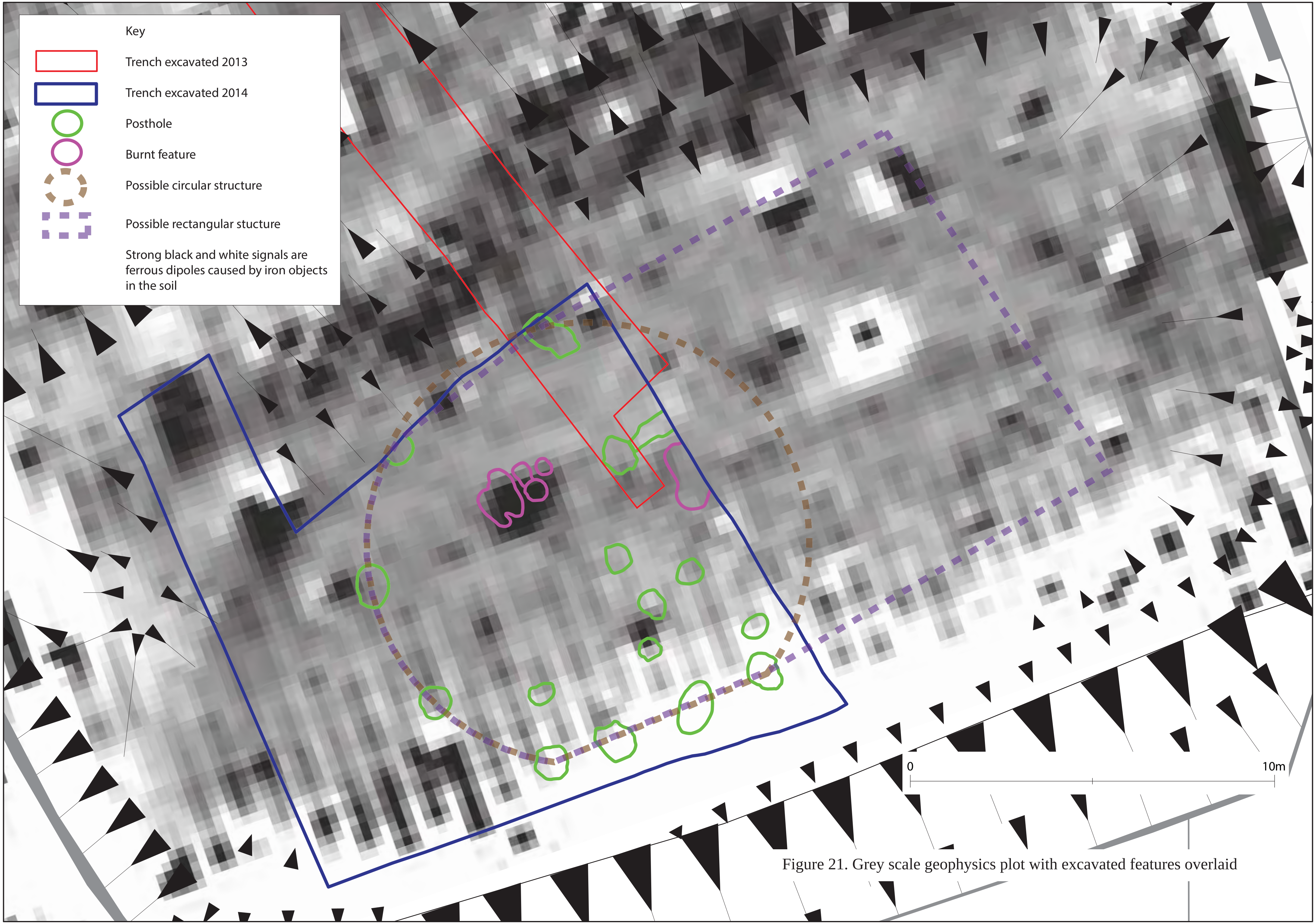


Figure 21. Grey scale geophysics plot with excavated features overlaid

similarity in character of these postholes and lack of coherent evidence for another structure on the site suggests that they were all contemporary. This is confirmed by the radiocarbon dates from one internal posthole and one of the main wall postholes which are essentially contemporary. The rectangular post-pipes, especially in some of the interior postholes, suggest squared timbers were used for some features in the structure, indicating that considerable time, effort and skill was used in the construction.

In the sub-circular reconstruction the beam slot [2104], running from posthole [2102], could possibly be related to an entrance on the eastern side, especially if there was originally a similar slot related to posthole [2011]. The flattened south-eastern side of the structure is parallel to the edge of the scarp and the bank must originally have run along this side just beyond the line of postholes. It is difficult to see how there could be an entrance in this side of the structure, so an entrance in the eastern side, possibly facing ancillary buildings, is probable. If the sub-rectangular reconstruction is considered there is more potential for internal partitions that may explain these interior postholes.

Unfortunately the geophysical survey gives no help in predicting what may be under the unexcavated part of the platform. While the survey clearly picked up the metal-working pits it did not detect the postholes found in the excavation, so a lack of apparent postholes in the remainder of the area cannot be taken to mean that there were no structures there (figure 21). If the building was sub-circular it is possible that the remainder of the platform was retained as a yard and that it contained no substantial structures. Only further excavation would solve the question of the shape of the structure and the presence of other structures on the platform but good practice means that such work should be left for future generations when techniques and questions may be different.

The radiocarbon dates are consistent with the traces of activity under the bank being related to the construction of the building rather than being part of an earlier phase of occupation on the site. The pollen evidence can be interpreted as suggesting that this construction took place on a field previously used for arable cultivation.

The radiocarbon dates suggest a duration of activity on the site of probably 10–130 years (*68% probability*), a fairly short period of time for a site interpreted as a high status dwelling. The building appears to have been deliberately demolished at the end of its life, as evidenced by the purposeful back-filling of some of the post holes. The material used for filling these holes was that most easily available, i.e. the burnt stone deposits around the inside of the bank. The post-pipes in postholes [2092] and [2052] were blocked with large stones, also suggesting that the posts had been removed and the postpacking disturbed or the stones deliberately used to fill the holes. The evidence from some of the post-holes was less easy to determine, and these post pipes may have resulted from posts rotting *in situ.*

Inner bank

The presence of the inner bank in the south-western corner of the trench strongly suggests that it had originally continued around the south-eastern side of the platform but has subsequently been largely eroded away. At about 0.7m above the original ground surface, even in an eroded state, this bank would have been quite substantial. In neither of the two sections of bank investigated in 2014 was there any evidence for a palisade or similar structure as found in the 2013 evaluation trench, context [018]. It was initially thought that the steeply eroded scarp at the foot of the bank (cuts 2057 and 2058) might be related to slot [018], however it is hard to see how these features at the base of the bank are related to one in the middle of the bank. It is possible that there was a palisade along the top of the bank but that the posts had been pulled out in the same manner as those forming the interior building. Where the resulting slot was backfilled with burnt stone material the trace of the palisade survived but where this did not occur perhaps the palisade slot became filled with stones from the bank and was not distinguishable. If this was combined with the reduction of the bank by later ploughing then it is possible that any traces of a former palisade would not have survived along much of the bank. The pulling out of timbers would help explain the confused and largely lost south-eastern side of slot [018] as the process could have entirely disturbed the slot on that side.

It was initially considered that the truncation scarps (2057 and 2058) on the bank were caused by ploughing inside the inner platform. However the close radiocarbon dates for the pre-bank activity and the burnt stone layer overlying the bank and sealing these scarps, makes it difficult to envisage ploughing taking place within the sequence of events. The only possibility would be if ploughing occurred after the bank was built but before the building was constructed, yet it seems most practical to build the structure before the bank, allowing easier access. If as suggested below the burnt stone deposit was generated during the use of the building there is no space chronologically for the inner platform to be open and free for ploughing between building the bank and the deposition of the burnt stone. The truncation must therefore have a cause other than ploughing, perhaps the passage of humans or animals between the building and the bank.

Smithing hearth and related features
Although some slag and other material was found in a variety of deposits the group of pits towards the northern side of the structure were clearly the focus of metal-working activity within the excavated area. Most of the slag and other residues came from an irregular hollow [2067], which seems not to have been a deliberately dug pit but is likely to have been a worn 'working hollow' that became filled with debris. The adjacent neatly dug circular pit [2076] had an assemblage particularly rich in hammerscale, and it could have held a wooden anvil block into the top of which a small metal anvil was placed. Next to this was a small sub-circular pit [2078] with remains of a possible clay lining. It is likely that this pit was the smithing hearth, although it was unusually small for a medieval forge hearth, and may have been intended only for the production of small objects. It is possible that the burnt clay deposit in this pit was part of the superstructure of the hearth, perhaps a wall between the hearth and the bellows, but it may alternatively have been an attempt to stabilise the sides of the pit. This arrangement of hearth and anvil would allow a smith sitting or squatting in the area of the worn hollow, to remove the metal from the hearth with the tongs in the left hand and rotate slightly right to use a hammer on the anvil with the right hand (Young, appendix IX).

The fills of the smithing hearth [2078] contained a large number of charred cereal grains, hazelnut shells and some burnt bone suggesting that food waste might have been burnt on the forge. Much of the main fuel used seems to have been oak.

The small amount of archaeometallurgical waste recovered from the rest of the site suggests that the waste from the smithy was disposed of outside the excavated area.

The radiocarbon dates demonstrate that the smithing hearth and related pits are approximately contemporary with the rest of the activity on the site and must have been used inside the structure. As smithies were generally inside buildings this would be perfectly practical but it presents a less domestic character to the building than would otherwise be the case. It suggests that part of the building was industrial or perhaps smithing took place on the ground floor while the upper floor was domestic.

Burnt stone deposit
The origin and nature of the burnt stone deposits is still not entirely clear but the radiocarbon dates suggest that it was produced at the same time as the rest of the activity on the site. This makes it likely that the deposit is waste from activity within the building.

The burnt stone deposits resemble those found on burnt mounds where hot stones were used to heat water for cooking or other purposes. While most of these features are Bronze Age in date an early medieval example was found near Pentrefelin, Criccieth. This produced dates of cal AD 590–670 (1414 ±30 BP, SUERC-46265) and cal AD 560–660 (1444 ±30 BP, SUERC-46266) at 2 sigma, which compared using Bayesian analysis produced a best estimate for the date of the feature of cal AD 620–655 (*68% probability*) (Hamilton 2014, 62; Kenney *et al* 2014, 5, 9). This is the latest dated burnt mound from north-west Wales but later examples are possible. However the burnt stone at Hen Gastell was not associated with troughs or pits for heating water and was up on the well-drained ridge away from the river, an atypical location for a burnt mound. It therefore appears that the shattered stone was not produced as part of classic burnt mound activity.

The only other example of a medieval burnt stone deposit in the area known to the author is from an excavation in the Deanery Yard, Bangor (Smith 2013 and 2015). Here a grey-coloured silty deposit containing charcoal and heat-shattered stones was found in two trenches. The deposit contained burnt bone, charred cereals and hazelnut shells suggestive of food waste. A hazel nut shell and a small twig of *salix*/*populus* from this deposit were dated and produced dates of cal AD 1020 to 1210 (970 +/- 40 BP, Beta – 255302) and Cal AD 1020 to 1210 (900 +/- 40 BP, Beta – 255303) at 2 sigma (Smith 2013, 40). These dates are similar to those produced from Hen Gastell. It was suggested that the Deanery deposit could have been derived from extensive cooking for the work force building Bangor cathedral (Smith 2013, 43).

It is possible that the activity that produced the heat-shattered stones at Hen Gastell was carried out away from the inner platform of the site and the stones were later brought on to the site. However a considerable effort in moving the stones would have been involved. A possible reason for expending this effort could have been to

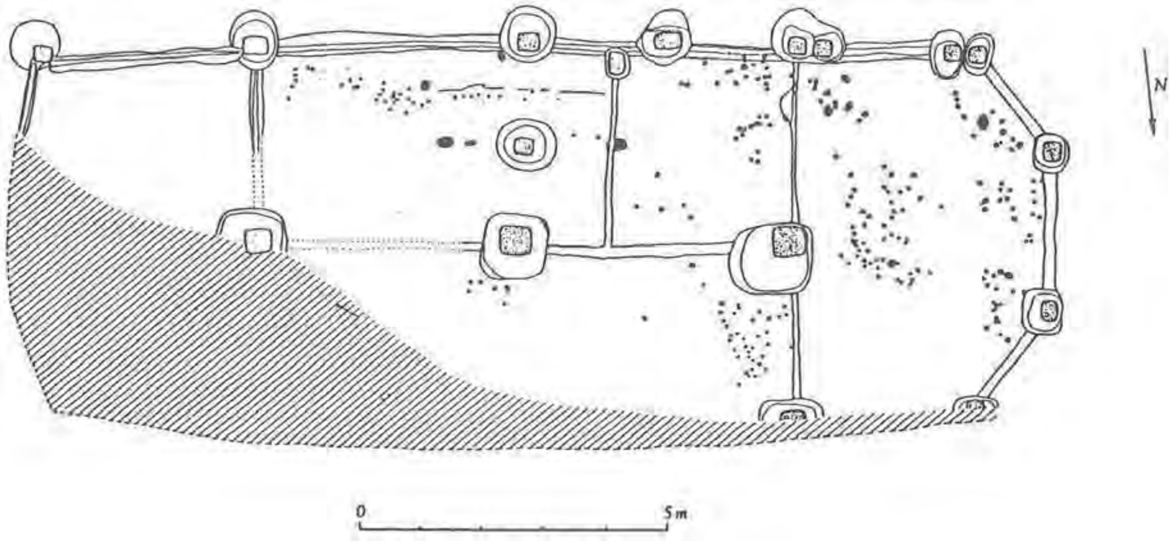


Figure 22. Plan of house VII, Mirville
(Figure 8.23b, from Higham, R. and Barker, P., 2006. Timber Castles, University of Exeter Press, Exeter, 264)

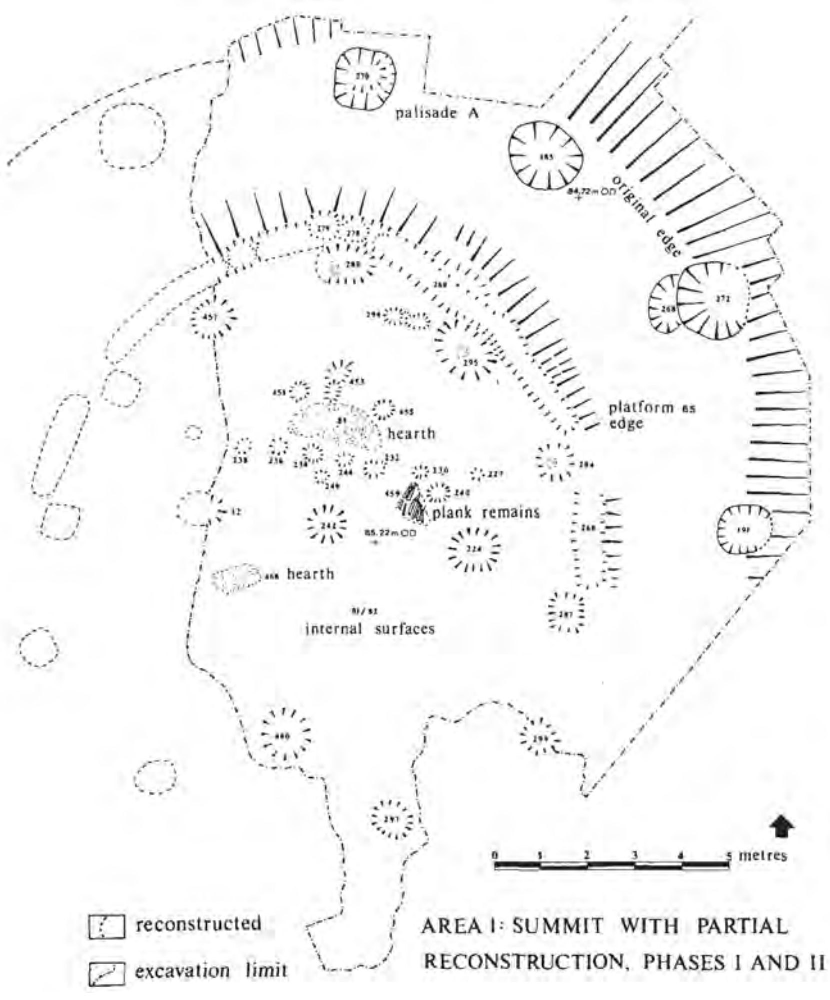


Figure 23. Plan of the summit of the motte at Castlehill of Strachan
(Illus. 3, from Yeoman, P. A., 1984. 'Excavations at Castlehill of Strachan, 1980-81', Proc Soc Antiq Scot, 114, 315-364)

reinforce the inner bank, but the stones seem to have been casually dumped against the inner face of the bank rather than being used to increase its height or more deliberately reinforce it. The position of the deposit is more consistent with waste material generated within the inner platform being dumped against the bank, as a convenient place for disposal.

The metal-working activity was the only significant area of burning picked up on the geophysics within the inner platform but the excavation did reveal an area of heat-altered natural substrata (2115). This could indicate the site of a fire most of the evidence of which has been lost due to the later ploughing of the area. This feature did not appear on the geophysical survey so other truncated fire sites might have existed in the unexcavated part of the inner platform. It is therefore proposed that the burnt stone originated from stones heated on small fires to boil water for cooking and that this activity took place inside the main building or adjacent buildings. The waste stone and food waste was then dumped outside the building along the inside of the bank. As there was no trace of pits or troughs dug into the ground to hold the water for cooking it seems probable that other containers were used such as leather bags held on wooden or metal supports, metal cauldrons or barrels. It is possible therefore that activities very similar to those that took place on burnt mounds were carried out here but that dug pits were not involved and water was carried up from the river. As with earlier burnt mounds this activity does not necessarily need to have been restricted to cooking and could have been related to other activities requiring boiling water such as beer brewing, clothes dying etc. Such collections of burnt stones are found on Iron Age sites without troughs and they are usually interpreted as the remains of cooking activities. It is therefore argued that the burnt stone deposits at Hen Gastell are the medieval equivalent of Bronze Age burnt mounds and represent the waste from cooking or other activities that were carried out on the inner platform.

When the main building was dismantled this burnt stone deposit seems to have been used to fill in some of the holes left by removing the posts of the building. Dates on the fill of the post-pipes therefore reflect the use of the building not its demolition. There are some hints of similar possible cooking processes being carried out before or while the building was being constructed as deposits under the inner bank also contained some burnt stone. A significant amount of burnt bone was found in the pre-bank activity deposit (2082) and some had even got mixed into the bank material. It is therefore suggested that similar cooking techniques were used to feed the men constructing the main building and then the inner bank, and presumably the outer defences, as were later used to feed the inhabitants of the site.

The technology for making substantial cauldrons suspended over fires was clearly available in the medieval period so this raises the question of why hot stones might still have been used for cooking. It may be that where large quantities of water were needed such cauldrons were too expensive for even someone of moderate status in Welsh society and that a barrel or similar container firmly resting on the ground may have been a much cheaper alternative. More archaeological evidence and experimental work is needed to explore this question and more securely demonstrate the origin of these heat-shattered stone deposits.

6.2. Parallels and comparisons

Dating

In GAT report 1167 (Kenney and Hopewell 2014) Hen Gastell was compared to sites of supposed Iron Age or Roman period date, but the radiocarbon dates indicate that the internal structure dates from the medieval period. The absence of any earlier dated activity on the inner platform strongly suggests that the ditch and outer bank can also be attributed to this date and that the whole monument was built in one phase. Without dates from the bank and ditch this cannot be proved, but such features are often hard to date. Earthen ramparts often contain little or no datable material and dates from material sealed beneath them can only give *terminus post quem* dates. Material eroding into a ditch might pre- or post-date the construction of the ditch by a long period and finding material relating to the use of the ditch can be difficult if the ditch has been cleaned out. Further work might therefore not answer this question. However the layout of the site is suggestive of a single phase and some trace of earlier activity, especially sealed under the inner bank, would be expected if the outer defences belonged to an earlier phase and were adapted in the medieval period. Comparisons with other sites have therefore been made with the assumption that Hen Gastell is essentially a single phase monument dating to the 11th or 12th centuries AD.

The internal structure

Two alternative designs are suggested above for the internal post-built structure, however parallels for either are not easy to find. Only one example of the first design, a timber hall with a curved or apsidal end is given in

Higham and Barker's (2006) list of excavated structures associated with medieval timber castles. This is a late 11th century timber hall on the castle at Mirville, Seine Maritime, France (ibid, 264-267), which measured 17m by 8m, and so was of a similar scale to the proposed sub-rectangular building at Hen Gastell. The Mirville hall had a fairly straight eastern end but the western end was bowed or apsidal. Four large posts had straight sections of wall running between them; the layout of the postholes being very similar to the arc of four postholes at Hen Gastell (figure 22). Although geographically this structure is far removed from north-west Wales, chronologically it is quite close and at least shows that such buildings could be associated with defended sites at a period when there were strong links between France and England, if not directly with Wales.

The flattened circular alternative seems harder to justify by comparison to medieval structures elsewhere. D-shaped towers, especially in stone, are quite common in Britain, including in Wales, but these are a very different shape to the proposed flattened circle at Hen Gastell. There is one possible parallel to the sub-circular reconstruction of Hen Gastell. A structure excavated on top of the motte at Castlehill of Strachan, Aberdeenshire, has many similarities. The 13th century structure had postholes 3m apart that were up to 1m deep, which defined an arc (figure 23). Some of the postholes retained post-pipes and packing stones (Yeoman 1984, 326). The structure was partially damaged and incomplete, allowing a variety of interpretations. Yeoman (1984, 344) suggests that it was 'boat-shaped', with dimensions of c.14m by 12m, and compares it to Viking buildings. Murray (1984, 346) argues for a circular plan and compares it to a 12th century circular building excavated on Castle Hill, Peebles. The Castle Hill structure, which measured c. 12.4m in external diameter, was constructed in a different fashion with a wall defined by a gully rather than a ring of postholes (Murray and Ewart 1980, 522). Higham and Barker (2006, 312-3) preferred a reconstruction as a single storey roundhouse despite its date. Whether this structure may have had a straight side like Hen Gastell is impossible to say from the surviving remains, but it supports the possibility of a sub-circular structure, although cultural links would be difficult to explain. If the putative sub-circular structure at Hen Gastell was two stories high and in effect a small tower, it would correct the disparity between the height of the outer bank and that of the interior, making the site work more effectively for defence.

There is a Welsh example of a medieval roundhouse as part of one was found at Maenclochog, Pembrokeshire, within a defensive site (Dyfed PRN 99501). However, this appears to have been a fairly slight structure with a post trench and stakeholes forming the wall, quite different to the substantial structure at Hen Gastell. A single date of AD 880 to 1020 (2 sigma calibrated) was obtained from under the defensive bank around the site, so it is possible that the Maenclochog roundhouse was of a similar date to Hen Gastell, although this structure was not directly dated (Schlee 2007).

The defensive earthworks

Trying to find parallels for such a small, oddly-shaped defended medieval site is also difficult. Hen Gastell is unusual in having a very large ditch for the size of the interior and a substantial bank outside the ditch. The interior platform on which the main building stands measures only about 30m by 14m and the overall dimensions of the site cannot be much more than 50m by 46m. Higham and Barker (2006, 49-56) list several Saxon private defended sites across England dating to the 10th and 11th centuries. These have all been adapted into later castles, so in most cases the form of their original defences is unclear. However remains of the rampart and ditch around the site at Goltho, Lincolnshire shows that some of these had substantial defences (ibid, 54-55). In all cases they are much larger than Hen Gastell, with several timber or stone buildings inside, but show that small, private defended sites did exist in southern Britain at this period.

Excavated sites within north Wales of a 11th to 12th century date, that are not *llys* sites, are rare. One example is Castell at Porth Trefadog, Anglesey, excavated in 1984 (Longley 1991). This site made use of natural features, in this case a cliff edge, and had a massive ditch and a much larger inner bank than Hen Gastell, surrounding a small interior. While not exactly the same in plan as Hen Gastell there are similarities in the small interior size and large ditch. Excavation in the interior revealed the remains of a rectangular stone building, which might have had the same function as the proposed sub-rectangular timber option for Hen Gastell. Iron-working hearths were found within the building. The five hearths were dug through the floor of the building, but it is assumed that they represent a later phase of activity after domestic occupation ended and before the roof collapsed. Seven radiocarbon dates were obtained from four of the hearths and these date range from cal AD 775-1030 (CAR-907, 1090±60 BP) to cal AD 1159-1390 (CAR-904, 750±60 BP) (95% probability)[1] (Longley 1991, 74).

Longley places the occupation of the house on this site in the 11th and 12th centuries AD followed by the iron-working hearths and then final abandonment in the 12th to 13th centuries. He considers the possibilities of Norman

1 Recalibrated using OxCal v4.2.4

or Norse influence on the site and the possible context in Gruffydd ap Cynan's struggle for power with the Normans from AD 1075. Ultimately the character of the house leads him to favour the suggestion of a land grant to Manx or Dublin Vikings leading to the creation of the defended site (Longley 1991, 79-84).

Another potential Viking site is the 'castle' of Bon y Dom mentioned in The History of Gruffydd ap Cynan as having a mound and a ditch. Its construction was attributed to Olaf, King of Dublin, who was Gruffydd's maternal grandfather.

> "*The pedigree of Gruflydd on his mother's side. King Gruflydd, son of Ragnaillt the daughter of Olaf, king of the city of Dublin and a fifth part of Ireland and the Isle of Man which was formerly of the kingdom of Britain. Moreover he was king over many other islands, Denmark, and Galloway and the Rinns, and Anglesey, and Gwynedd where Olaf built a strong castle with its mound and ditch still visible and called "The Castle of King Olaf." In Welsh, however, it is called Bon y Dom.*" (Jones 1910, 105)

The Royal Commission Inventory for Anglesey cannot identify any surviving remains associated with this site (RCHAMW 1937, cxlvi), but Hogg (1962) suggests Castell Bryn Gwyn, Llanidan (PRN 3140), with its impressive but largely undated ringwork, as the nearest defended site to the Bon y Don ferry, which may reflect the name of the Viking 'castle'. However Longley (1991, 82-3) suggests Dinas, Y Felinheli (PRN 3682), as this is also close to the Bon y Dom ferry but on the Gwynedd side, and The History does imply that the 'castle' was in Gwynedd not Anglesey. Olaf would have built his 'castle' around AD 1000 (Longley 1991, 82) and though the speculations above do not provide anything that can be closely compared to Hen Gastell it gives a context of what was happening in the area if the earlier end of the Hen Gastell date range is correct.

Vikings living in Llanwnda may be less likely than on the coast of Anglesey but the recent metal detector find of a Viking-style hoard in Llandwrog does suggest that there may have been a Viking presence nearby. The hoard (PAS reference NMGW-038729) contains both silver ingots and silver coins and a deposition date of about AD 1020-25 is suggested. With an estimated construction date for the inner bank at Hen Gastell of cal AD 1045–1155 (*95% probability*) this suggests that the site post-dated the deposition of the hoard, but this does not rule out continued Viking influence in the area.

Mottes in north Wales are generally assumed to have been built by the Normans. Some of the more remote sites far down the Llŷn peninsula, such as Tŷ Newydd, Nefyn and Abersoch may have different origins as English control of this area, with the exception a short foray in AD 1075, did not come until the Edwardian Conquest (Davies 2013a and b). Small mottes might therefore be part of the range of defended sites that were built by the native Welsh lords at the same period that Hen Gastell was built. There are also ringworks, such as Castell Crwn (PRN 3515), Llanrhwydrys, Anglesey (RCAHMW 1937, 108-9), which may be a 12th century native defended site. Tomen Fawr (PRN 1329), Llanystumdwy, is a ring motte without a bailey (RCAHMW 1960, 237) that was probably occupied by the Lord of Eifionydd in the 12th century (Gresham 1973, 338). None of these sites closely resemble Hen Gastell, but perhaps indicate that there was a range of options for a local lord to choose from when considering building a defensive site.

Only about 850m to the west of Hen Gastell is the site of Dinas y Prif (PRN 593). This is a small defended site with an interior measuring 40m by 40m. It is unlike Hen Gastell as it is nearly square in plan with mounds at the corners of the rampart, which may have supported towers. It has not been dated by excavation, but is suggested as possibly early medieval in date, although this seems largely to be based on a local tradition that it was the home of Gibor, a Goidel (Irishman) (RCAHMW 1960, 225). Hen Gastell and Dinas y Prif are however joined by a footpath that may indicate the route of an ancient trackway and excavations at the latter site would be of considerable interest to see if they might possibly have been contemporary.

A close comparison for Hen Gastell is located on the south coast of Anglesey. A defended enclosure near St Mary's Church, Llanfairpwllgwyngyll was investigated by geophysics and trial trenching (Smith 2012). The sub-rectangular enclosure resembles the inner platform of Hen Gastell, although it is a little longer and certainly wider. It has a fairly substantial ditch up to 1.8m deep in the trial trenches; this is a little shallower than the Hen Gastell ditch which is over 2m deep. The St Mary's site had an inner bank but no large outer bank was evident. Postholes suggested structures inside the enclosure but the excavations were too small to define the form of any buildings. Three dates were obtained from the ditch and a posthole: 1025-1169 cal AD (SUERC 37188, 930±30 BP), 1025-1158 cal AD (SUERC 37186, 945±30 BP) and 1025-1164 cal AD (SUERC 37187, 935±30 BP) (Smith 2012, 35). This suggests a very similar date to that for Hen Gastell. Smith suggests that the St Mary's enclosure was a response to the political instability of the 11th century in north Wales (Smith 2012, 36), and Hen Gastell could certainly be seen as a similar response that became unnecessary as stability increased in the late part of Gruffydd ap Cynan's reign and under Owain Gwynedd (Carr 1982, 40-44).

On the basis of the current evidence it seems reasonable to see Hen Gastell as the well-defended home of a local medieval Welsh lord with tenurial rights over the adjacent lands.

6.3. Further excavation

It would be interesting to investigate the possible building in the ditch found in 2013 (see GAT report 1167 (Kenney and Hopewell 2014)), and excavation of the ditch down to its base could not only determine its full depth but may reveal artefacts and ecofacts that could contribute to the understanding of the use of the site. However the excavation and post-excavation analysis carried out so far have successfully defined the date and function of the original monument and provide sufficient evidence for a decision on scheduling. It is therefore suggested that, while further excavation might be desirable, it is not necessary for the current requirement to provide evidence to inform scheduling. It is specifically recommended that no further excavation occurs inside the interior of the monument as a large proportion of this part of the site has already been excavated and it is consistent with best practice to leave the remainder for future generations to study as there is no current threat to it and scheduling will further reduce potential threats.

7. ARCHIVING AND DISSEMINATION

7.1. Archive

The artefacts from the excavations belong to the landowners, Tom and Barbara Ellis, and they have agreed to donate the finds to Gwynedd Museum. The finds have therefore be boxed in appropriate archive quality boxes, the accession number 2016/?? has been allocated to the collection and it has been donated to the Museum.

The digital archive, with appropriate metadata has been submitted to the Royal commission on the Ancient and Historical Monuments of Wales (RCAHMW) who can provide long term active curation of the digital files as well as access to the public.

The site records on paper and drawing film are also held by RCAHMW. A copy of this report has been submitted to the Gwynedd Historic Environment Record (HER) and will be made available on the Archwilio website (www.cofiadurcahcymru.org.uk) as well as on the GAT website (www.heneb.co.uk).

7.2. Publication

The final report has been converted into a paper for publication. The importance of this paper justifies submitting it to the international journal Medieval Archaeology, or if it is rejected to be submitted to Archaeologia Cambrensis.

To ensure a wider audience a summary report has been produced and translated into Welsh. This is available on the GAT website (www.heneb.co.uk/hengastell/info.html). A talk was held at the Llanwnda Community Centre on 24th November to disseminate the results of the work to the local community. Summary reports were also distributed on this occasion. Thirty five people attended the talk.

8. ACKNOWLEDGEMENTS

Thanks are due to the very many volunteers that worked on the excavation. The experienced volunteers that helped finish the recording of the site were John Burman, Clifton (Beaver) Hughes, Jeff Marples, Brian Milner, Avis Reynolds and George Smith. The photographs for the 3D model were taken by Neil McGuiness and the data was processed by David McNicol. Neil McGuiness and Sam Emmett supervised the volunteers and Anita Diamond ran the schools programme. Dan Amor supervised the work experience students. The careful machining was carried out by Meirion Davies. Thanks to the specialists who studied material from the site. The artefact illustrations were drawn by Tanya Williams. This report was edited by Andrew Davidson.

The Trust would like to extend to particular thanks to Tom and Barbara Ellis, the owners and farmers of the land,

for their permission to carry out the work and for their toleration and support while the excavations and Open Day caused considerable disruption to their work and daily routine.

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10. APPENDIX I: Site Records

Trench 1

Context sheet	46 sheets
Context register	2 sheets
Digital photographs	110 files
Site drawings	14 drawings on 8 sheets
Day records	8 sheets

Trench 2

Context sheet	124 sheets
Context register	7 sheets
Levels for plans and sections	5 sheets
Digital photographs	193 files
Site drawings	47 drawings on 14 sheets

Trenches 1 and 2 combined

Photo record sheets	12 sheets
Drawing sheet register	1 sheet
Drawing register	3 sheets
Finds register	6 sheets
Sample register	2 sheets
Finds deposition form	1

11. APPENDIX II: List of finds

Find numbers 1 to 19 are from the 2013 evaluation excavation and metal detecting survey.
Where there are many or several very small items no count of the items has been entered, just the total weight.

Find No	Context No	Material	Period	No of items	Weight (g)	Description
1	001	Iron	Post medieval	1	16	Iron buckle frame (metal detector find)
2	001	Copper alloy	probably 18th century	1	2	Button (metal detector find)
3	001	Copper alloy	20th century	1	4.5	Half penny dated 1951 (metal detector find)
4	001	Copper alloy	20th century	1	16	Copper alloy fitting, very good condition and presumably recent (metal detector find)
5	001	Copper alloy	20th century	1	8	Penny dated 1935 (metal detector find)
6	001	Copper alloy	probably 20th century	1	4	Badge (metal detector find)
7	001	Copper alloy	20th century	1	8	Penny dated 1948 (metal detector find)
8	001	Copper alloy	20th century	1	10	Modern key (metal detector find)
9	001	Copper alloy	probably late 18th/19th century	1	6	Half penny, possibly George III (metal detector find)
10	001	Copper alloy	20th century	1	6	Threepenny bit dated 1944 (metal detector find)
11	001	Copper alloy	20th century	1	9	Penny dated 1910 (metal detector find)
12	001	Copper alloy	20th century	1	3	Modern penny dated 1991 (metal detector find)
13	001	Iron	late med/post medieval	1	9	Timber nail
14	001	Flint	Prehistoric	1	2	Flint flake
15	001	Copper alloy	19th and 20th century	2	8	Half penny dated 1920 and thimble (metal detector find)
16	004	Ceramic	post medieval	2	2	Sherd of Buckley ware and clay pipe stem (stamped)
17	017	Bone	medieval	23	8	Burnt bone fragments
18	017	Copper alloy	medieval	1	0.2	Copper alloy rivet, sheet
19	004	Stone	medieval?	1	209	Fractured pebble, possibly heat-fractured
20	2003	Copper alloy	medieval	3	1	3 frags of copper alloy strap end
21	2003	Slag	medieval	1	36	Fragment of furnace lining
22	2004	Bone	medieval	1	2	Burnt bone fragment
23	Unstratified (T2)	Copper alloy	19th/20th century	2	5	Coin/token and button (metal detector find)
24	Unstratified (T2)	Ceramic	late C18/early late C18/early C19?	7	14	Clay pipe stems and pipe bowl frags
25	Unstratified (T2)	Iron	post medieval/ medieval	18	306	Various iron objects including hand-made nails (metal detector find)
26	Unstratified (T2)	Slag	medieval?	1	96	Fragment of smithing hearth cake
27	Unstratified (T2)	Lead	post medieval	1	16	Lead (metal detector find)
28	2003	Iron	11-12th century	2	11	Horseshoe nail and blade fragment.
29	2021	Bone	medieval	2	1	Burnt bone
30	2003	Bone	medieval	6	6	Tooth
31	2042	Charcoal	discarded	0	0	Charcoal fragment (discarded)
32	2023	Copper alloy	medieval	1	0.5	Decorative mount
33	2023	Bone	medieval	4	1	Burnt bone
34	2054	Copper alloy	medieval	1	1	Decorative mount
35	2023	Iron	medieval	1	0.5	Timber nail

Find No	Context No	Material	Period	No of items	Weight (g)	Description
36	2070	Flint	Prehistoric	1	2	Broken retouched blade
37	2072	Bone	medieval	7	1	Burnt bone fragments
38	2072	Iron	11-12th century	1	4	Horseshoe nail
39	2071	Iron	11-12th century	1	7	Horseshoe nail
40	2080	Iron?	medieval	1	455	Rectangular block, possibly caused by iron rich sediment collecting in a container or hollow, with some iron pieces
41	2075	Ceramic	late C17- early C18	1	3	Post-medieval pot sherd
42	2070	Bone	medieval	41	11	Burnt bone fragments
43	2069	Iron	medieval	1	8	Timber nail
44	2088	Flint	Prehistoric	1	2	Flint flake
45	2097	Bone	medieval	1	0.5	Burnt bone fragments
46	2066	Slag	medieval	0	4400	Two bags of slag
47	2003	Bone	medieval	77	53	Burnt bone fragments
48	2023	Bone	medieval	72	41	Burnt bone fragments
49	2077	Bone	medieval	1	1	Burnt bone fragment
50	2024	Bone	medieval	5	4	Burnt bone fragments
51	2082	Bone	medieval	21	9	Burnt bone fragments
52	2002	Bone	medieval?	20	11	Burnt bone fragments
53	2003	Flint	Prehistoric	1	2	Flint flake
54	2024	Flint	Prehistoric	1	0.5	Burnt fragment of scraper edge
55	2077	Iron	medieval	1	12	Iron knife
56	2002	Ceramic	post medieval	28	161	Various sherds of post med pot including Buckley ware
57	2075	Slag	medieval	7	42	Slag
58	2003	Slag	medieval	1	20	Slag
59	2002	Lead	unknown	1	4	Piece of lead rolled over (from cleaning over 2003)
60	001	Silver	19th century	1	1	Silver ferrule with end of cane
61	2023	Slag	medieval	2	13	Fragments of furnace lining
62	2066	Slag	medieval	3	13	Fragments of possible furnace lining
63	2023	Slag	medieval	4	78	Slag including fragment of smithing hearth cake
64	2080	Copper alloy	medieval	1	0.2	Rivet shank
65	2077	Slag	medieval	8	910	Smithing hearth base
66	2002	Slag	medieval?	4	86	Slag from cleaning over bank 2018
67	2002	Flint	Prehistoric	5	16	Small pieces of unworked flint from ploughsoil
68	001	Iron	post medieval	6	551	Iron objects from topsoil in trench 1
69	001	Copper alloy	post medieval	9	113	Various recent items recovered by metal-detecting across Hen Gastell
70	001	Lead	post medieval	4	14	Lead recovered by metal-detecting across Hen Gastell
71	001	Copper alloy	19th and 20th century	2	17	Pennies dated 1916 and 1883 (metal-detector find)
72	001	Lead	post medieval	1	38	Musket ball
73	2003	Bone	medieval	4	8.2	Burnt bone and teeth frags from soil sample 04
74	2003	Bone	medieval	0	7.1	Burnt bone frags from soil sample 05
75	2003	Bone	medieval	0	7.1	Burnt bone frags from soil sample 06
76	2015	Bone	medieval	0	0.3	Burnt bone frags from soil sample 07
77	2003	Bone	medieval	0	6.1	Burnt bone frags from soil sample 08
78	2036	Bone	medieval?	0	0.1	Burnt bone frags from soil sample 10

Find No	Context No	Material	Period	No of items	Weight (g)	Description
79	2042	Bone	medieval	16	1	Burnt bone frags from soil sample 12
80	2023	Bone	medieval	0	1.2	Burnt bone frags from soil sample 14
81	2014	Bone	medieval	0	0.3	Burnt bone frags from soil sample 15
82	2023	Bone	medieval	0	4.6	Burnt bone frags from soil sample 16
83	2056	Bone	medieval?	4	0.2	Burnt bone frags from soil sample 19
84	2070	Bone	medieval	0	3	Burnt bone frags from soil sample 20
85	2066	Bone	medieval	5	0.1	Burnt bone frags from soil sample 21
86	2072	Bone	medieval	0	3	Burnt bone frags from soil sample 22
87	2071	Bone	medieval	10	0.3	Burnt bone frags from soil sample 23
88	2053	Bone	medieval	2	0.2	Burnt bone frags from soil sample 24
89	2075	Bone	medieval	0	1	Burnt bone frags from soil sample 25
90	2079	Bone	medieval?	15	0.7	Burnt bone frags from soil sample 26
91	2082	Bone	medieval	0	4.5	Burnt bone frags from soil sample 28
92	2077	Bone	medieval	0	0.4	Burnt bone frags from soil sample 29
93	2069	Bone	medieval	4	0.2	Burnt bone frags from soil sample 31
94	2098	Bone	medieval	1	0.1	Burnt bone frags from soil sample 32
95	2099	Bone	medieval	2	0.1	Burnt bone frags from soil sample 33
96	2093	Bone	medieval	3	0.1	Burnt bone frags from soil sample 34
97	2090	Bone	medieval	10	0.6	Burnt bone frags from soil sample 35
98	2101	Bone	medieval	3	0.1	Burnt bone frags from soil sample 36
99	2097	Bone	medieval	2	0.1	Burnt bone frags from soil sample 38
100	2088	Bone	medieval?	2	0.1	Burnt bone frags from soil sample 39
101	2120	Bone	medieval	2	0.1	Burnt bone frags from soil sample 40
102	2082	Bone	medieval	0	3.2	Burnt bone frags from soil sample 41
103	2105	Iron	medieval	2	0.1	Stem/rivet from soil sample 42
104	2066	Slag	medieval	0	670	Coarse slag from soil sample 21
105	2066	Slag	medieval	0	380	Fine slag from soil sample 21
106	2066	Slag	medieval	0	526	Magnetic metalworking debris from soil sample 21
107	2075	Slag	medieval	0	80.5	Slag from soil sample 25
108	2075	Slag	medieval	0	307	Magnetic metalworking debris from soil sample 25
109	2077	Slag	medieval	0	42.4	Slag from soil sample 29
110	2077	Slag	medieval	0	70.1	Magnetic metalworking debris from soil sample 29
111	2099	Slag	medieval	0	195	Magnetic metalworking debris from soil sample 33
112	2003	Slag	medieval	0	9	Slag from soil sample 04
113	2003	Slag	medieval	0	2.8	Fine slag from soil sample 05
114	2003	Slag	medieval	0	1	Magnetic metalworking debris from soil sample 06
115	2015	Slag	medieval	0	2.1	Magnetic metalworking debris from soil sample 07 (mainly magnetic stones)
116	2003	Slag	medieval	0	0.4	Magnetic metalworking debris from soil sample 08
117	2012	Slag	medieval	0	1.7	Magnetic metalworking debris from soil sample 09 (mainly magnetic stones)
118	2036	Slag	medieval	0	7.4	Magnetic metalworking debris and coal from soil sample 10 (mainly magnetic stones)
119	2042	Slag	medieval	0	4.9	Magnetic metalworking debris from soil sample 12 (includes magnetic stones)

Find No	Context No	Material	Period	No of items	Weight (g)	Description
120	2048	Slag	medieval	0	0.3	Magnetic metalworking debris from soil sample 13 (includes magnetic stones)
121	2023	Slag	medieval	0	1.8	Magnetic metalworking debris from soil sample 14 (includes magnetic stones)
122	2014	Slag	medieval	0	4.4	Magnetic metalworking debris and coal from soil sample 15 (includes magnetic stones)
123	2023	Slag	medieval	0	2.1	Magnetic metalworking debris from soil sample 16 (includes magnetic stones)
124	2008	Slag	medieval	0	2.7	Magnetic metalworking debris and slag from soil sample 18 (includes magnetic stones)
125	2056	Slag	medieval	0	0.8	Magnetic metalworking debris from soil sample 19 (includes magnetic stones)
126	2070	Slag	medieval	0	4.7	Magnetic metalworking debris from soil sample 20 (includes magnetic stones)
127	2072	Slag	medieval	0	1.5	Magnetic metalworking debris from soil sample 22 (includes magnetic stones)
128	2071	Slag	medieval	0	1.1	Magnetic metalworking debris from soil sample 23 (includes magnetic stones)
129	2053	Slag	medieval	0	1.2	Magnetic metalworking debris from soil sample 24 (includes magnetic stones)
130	2079	Slag	medieval	0	1.4	Magnetic metalworking debris from soil sample 26 (includes magnetic stones)
131	2082	Slag	medieval	0	1.5	Magnetic metalworking debris from soil sample 28 (includes magnetic stones)
132	2098	Slag	medieval	0	9.8	Magnetic metalworking debris from soil sample 32 (includes magnetic stones)
133	2093	Slag	medieval	0	1.4	Magnetic metalworking debris from soil sample 34 (includes magnetic stones)
134	2090	Slag	medieval	0	1	Magnetic metalworking debris from soil sample 35 (includes magnetic stones)
135	2101	Slag	medieval	0	1.4	Magnetic metalworking debris from soil sample 36 (includes magnetic stones)
136	2097	Slag	medieval	1	0.1	Magnetic metalworking debris from soil sample 38
137	2098	Slag	medieval	0	0.1	Magnetic metalworking debris from soil sample 40 (includes magnetic stones)
138	2082	Slag	medieval	0	1.2	Magnetic metalworking debris from soil sample 41 (includes magnetic stones)
139	2082	stone	natural	0	26.4	Porous igneous rock, collected as possible metal-working debris
140	2105	Slag	medieval	0	10	Metalworking debris from soil sample 42 (in-cludes magnetic stones)
141	2105	Slag	medieval	0	8.8	Slag from soil sample 42
142	2015	Slag	medieval	1	10.6	Slag from soil sample 07
143	2023	Slag	medieval	1	4.4	Slag from soil sample 16
144	2099	Slag	medieval	0	14	Slag from soil sample 33
145	2099	Iron	medieval	1	3.1	Timber nail, very corroded, from soil sample 33
146	2079	Stone	medieval?	1	72.5	Piece of conglomerate with polished surfaces, frag of possible grinding stone
147	2015	Stone	natural	1	43.1	Perforated stone, probably natural
148	2066	Burnt clay	medieval	1	0.7	Frag of burnt clay from soil sample 21
149	2098	Burnt clay	medieval	7	2.9	Frags of burnt clay from soil sample 32
150	2105	Burnt clay	medieval	2	0.8	Frags of burnt clay from soil sample 42
151	2075	Ceramic	medieval	1	2.2	Small pot sherd with dark fabric and red slip
152	017	Bone	medieval	0	11	Burnt bone and a tooth from soil sample 01

Find No	Context No	Material	Period	No of items	Weight (g)	Description
153	2105	Bone	medieval	30	6.3	Burnt bone frags from soil sample 42
154	Unstratified (T2)	Iron	medieval	1	2.6	Socket possibly of an arrowhead
155	2066	Iron	medieval	2		Two pieces of bar iron (found amongst metal-working debris SF46)
156	2023	Iron	11-12th century	1		Horseshoe nail

12. APPENDIX III: List of samples and processing information

12.1. List of soil and stone samples

Sample No.	Context	Type of sample	No. of tubs	% of deposit sampled	Notes
1	017	Bulk soil	4	5	Taken 2013, processed 2014
2	014	Bulk soil	1	20	Taken 2013, processed 2014
3	021	Bulk soil	1.5	10	Taken 2013, processed 2014
4	2003	Bulk soil	1	<5	
5	2003	Bulk soil	1	<5	
6	2003	Bulk soil	1	<5	
7	2015	Bulk soil	1	100	
8	2003	Bulk soil	1	<5	
9	2012	Bulk soil	1	25	
10	2036	Bulk soil	1	40	
11	2023	Stone sample	2	5	
12	2042	Bulk soil	1	15	
13	2048	Bulk soil	0.33	25	
14	2023	Bulk soil	1	5	
15	2014	Bulk soil	1	25	
16	2023	Bulk soil	1	5	
17	2010	Bulk soil	1		
18	2008	Bulk soil	1		
19	2056	Bulk soil	1		
20	2070	Bulk soil	3	50	
21	2066	Bulk soil	2	25	
22	2072	Bulk soil	1	33	
23	2071	Bulk soil	1	33	
24	2053	Bulk soil	1	33	
25	2075	Bulk soil	2	50	
26	2079	Bulk soil	1	5	
27	2070	Stone sample	1	30	
28	2082	Bulk soil	1	<5	
29	2077	Bulk soil	1	50	
30	2006	Bulk soil	1	10	
31	2069	Bulk soil	1	20	
32	2098	Bulk soil	1 small bag	100	
33	2099	Bulk soil	1 small bag	100	
34	2093	Bulk soil	1		
35	2090	Bulk soil	1	100	
36	2101	Bulk soil	1	50	

37	2084	Bulk soil	1	50	
38	2097	Bulk soil	1 small bag	30	
39	2088	Bulk soil	1	10	
40	2120	Bulk soil	1	30	
41	2082	Bulk soil	1	<5	
42	2105	Bulk soil	1	25	
43	2079	Pollen sample	1	-	
44	2054	Pollen sample	1	-	

12.2. Soil sample processing

The soil samples were processed by Iwan Parry of Archaeoleg Brython Archaeology by double floatation to recover charcoal, charred plant remains and small finds of archaeological interest.

In line with current Historic England guidelines the un-processed samples were individually placed in a floatation tank in a 50µm nylon mesh and washed with circulating water, floating material was sieved from run-off and collected in a 250µm mesh (flot). The residue remaining in the 50µm mesh was passed through a 10mm sieve, to separate the coarse residue from the fine. All residues and 'flots' were thoroughly air dried. This process was then repeated with the fine residues to retrieve the optimum amount of charcoal and charred plants remains from the samples.

The coarse residues were checked by eye for any archaeologically significant material. All recovered material was grouped by material or typology and stored in plastic finds bags marked with project, context and sample numbers. 100% of the coarse residues were checked.

The fine residues were checked for macroscopic artefacts and charred plant remains by eye and scanned with a powerful neodymium magnet for ferrous material related to metalworking. All recovered material was grouped by material or typology and stored in plastic finds bags marked with project, context and sample numbers. 100% of the fine residues were checked.

Sample Number	Context Number	Number of Tubs	% of Context	Sample size (Litres)	Coarse Description	Material from Coarse (charred plant remains combined with 1st flot)	Material from Fine (charred plant remains individually bagged)
4	2003	1	<5	10	Angular stones >5cm, heat affected	Slag, burnt tooth, charred plant remains	Burnt bone and teeth, metalworking debris, charred plant remains
5	2003	1	<5	10	Sub-rounded to angular stones >5cm, some heat affected	Burnt bone, possible Iron/panning	Burnt bone, metalworking debris, charred plant remains
6	2003	1	<5	10	Sub-rounded to angular stones >5cm, some heat affected	Burnt bone, possible mortar/ concretions, charred plant remains	Burnt bone, metalworking debris, charred plant remains
7	2015	1	100	10	Sub-rounded to sub-angular >8cm	Slag, perforated? Sandstone (uncertain), charred plant remains	Burnt bone, metalworking debris, charred plant remains
8	2003	1	<5	10	Sub-rounded to angular >5cm, generally heat affected	Burnt bone	Burnt bone, metalworking debris, charred plant remains
9	2012	1	25	10	Sub-rounded to sub-angular generally 1cm	-	Metalworking debris
10	2036	1	40	10	Sub-rounded to sub-angular >5cm, small amount heat affected	Cinder/coal, charred plant remains	Burnt bone, metalworking debris, cinder/slag?, coal, charred plant remains
12	2042	1	15	10	Sub-rounded to Sub-angular >8cm, not obviously heat affected	-	Burnt bone, metalworking debris, charred plant remains

13	2048	0.33	25	3	Sub-rounded to sub-angular >3cm, not obviously heat affected	-	Metalworking debris, charred plant remains
14	2023	1	5	10	Generally angular >10cm, clearly fire-cracked	Charred plant remains	Burnt bone, metalworking debris, slag
15	2014	1	25	10	Very small amount of sub-rounded stone >2cm, not obviously heat affected	-	Burnt bone, metalworking debris, coal, charred plant remains
16	2023	1	5	10	Sub-rounded to angular >8cm, some heat affected including fire-cracked cobbles	Burnt bone, slag	Burnt bone, Iron?, metalworking debris, charred plant remains
17	2010	1		10	Sub-rounded to sub angular >5cm, possible mortar or concretions on some, not obviously heat affected	Possible mortar/concretions?	-
18	2008	1		10	Sub-rounded to sub-angular >8cm, not obviously heat affected	Possible mortar/concretions?	Metalworking debris
19	2056	1		10	Sub-rounded to sub angular >3cm, some possible heat affected	-	Burnt bone, metalworking debris
20	2070	3	50	30	Sub-rounded to sub-angular >5cm, some possibly heat affected	Slag, charred plant remains	Burnt bone, slag, possible metalworking debris/ concretions, charred plant remains
21	2066	2	25	20	Sub-rounded to sub-angular >5cm, not overly heat affected	Slag, abraded orange wear? Charred plant remains	Burnt bone, metalworking debris, charred plant remains, large amount of hammerscale
22	2072	1	33	10	Sub-rounded to sub-angular >8cm, not obviously heat affected	-	Burnt bone, metalworking debris, charred plant remains
23	2071	1	33	10	Sub-rounded to sub-angular >10cm, some fire-cracked	-	Burnt bone, slag?/cinder?, small amount of metalworking debris, charred plant remains
24	2053	1	33	10	Generally sub-rounded >8cm, not heat affected	-	Burnt bone, small amount of possible metalworking debris
25	2075	2	50	20	Sub-rounded to angular >5cm, some clearly heat affected	Metalworking debris, Iron?, small sherd of pot – orange exterior and black interior, charred plant remains	Burnt bone, metalworking debris, charred plant remains
26	2079	1	5	10	Sub-rounded to angular >10cm, some clearly fire-cracked cobbles	Fragment of quartzy conglomerate possibly rubbed – may be part of a quern or rubbing stone – may be nothing	Burnt bone, small amount of metalworking debris, charred plant remains

28	2082	1	<5	10	Sub-rounded to angular >12cm, some heat affected, occasional fire-cracked	Burnt bone, charred plant remains	
29	2077	1	50	10	Sub-angular to angular >3cm, appear heat affected	Metalworking debris/slag, charred plant remains	Burnt bone, metalworking debris, charred plant remains
30	2006	1	10	10	Sub-rounded >12cm generally 2cm, not heat affected	-	-
31	2069	1	20	10	Sub-rounded >5cm, not apparently heat affected	-	Burnt bone, charred plant remains
32	2098	1 small bag	100	0	Sub-angular to angular >3cm, not apparently heat affected	Small fragment of ceramic material – possibly pot or clay lining?	Burnt bone, metalworking debris, possible ceramic material
33	2099	1 small bag	100	0	Sub-rounded to sub-angular >5cm, not obviously heat affected	Slag, concretions – possible metalworking debris?	Burnt bone, metalworking debris, charred plant remains
34	2093	1		10	Sub-rounded >5cm, not obviously heat affected	-	Burnt bone, metalworking debris, charred plant remains
35	2090	1	100	10	Sub-angular >10cm, some possibly fire-cracked	-	Burnt bone, metalworking debris, charred plant remains
36	2101	1	50	10	Sub-rounded to sub-angular >5cm, not obviously heat affected	-	Burnt bone, metalworking debris
37	2084	1	50	10	Generally sub-rounded >8cm, 1 or 2 fire-cracked, generally not apparently heat affected	-	-
38	2097	1 small bag	30	0	Sub-rounded to sub-angular >5cm, not apparently heat affected	-	Burnt bone, slag
39	2088	1	10	10	Generally sub-rounded >5cm, not apparently heat affected	-	Burnt bone
40	2120	1	30	10	Sub-rounded to sub-angular >8cm, not apparently heat affected	-	Burnt bone, metalworking debris
41	2082	1	<5	10	Sub-rounded to angular >8cm, heat affected, some fire-cracked	Perforated stone/slag?	Burnt bone, possible metalworking debris, perforated stone/slag?, charred plant remains
42	2105	1	25	10	Sub-rounded to angular >12cm, heat affected, many fire-cracked	Slag, charred plant remains	Burnt bone, metalworking debris, 2 ferrous pins?, burnt clay, charred plant remains

13. APPENDIX IV: List of contexts

Context number	Type	Description	Interpretation	Dimensions
2001	Layer	Dark grey-brown silt with occasional stones	Topsoil	Up to 0.26m deep
2002	Layer	Grey-brown silt with occasional stones	Ploughsoil	Up to 0.54m deep
2003	Layer	Soft dark brown sandy silt with abundant stone. Stones are angular and heat-fractured	Burnt stone deposit	c. 5m x 3m, up to 0.3m deep
2004	Layer	Same as 2003, part of 2003		
2005	Cut	Ovoid, almost polygonal cut with steep sides and a concave base	Posthole, with post-pipe	1.19 x 0.85m, 0.45m deep
2006	Fill	Firm orange brown sandy silt with occasional stones	Packing fill in [2005]	
2007	Cut	Sub-rectangular/polygonal cut with vertical sides and flat base	Posthole, with post-pipe	0.85m x 0.60m, 0.40m deep
2008	Fill	Firm dark brown coarse sand with frequent stones, some fairly large and suggestive of disturbed packing-stones	Packing fill in [2007]	
2009	Cut	Sub-rectangular cut with near vertical sides and fairly flat base	Posthole, with post-pipe	0.7 x 0.65m, 0.40m deep
2010	Fill	Strongly cemented greyish brown silty sand with frequent stones, some fairly large, in situ packing-stones	Packing fill in [2009]	
2011	Cut	Sub-circular cut with steep sides and uneven, rounded base	Posthole, with possible post-pipe	0.74m x 0.68m, 0.29m deep
2012	Fill	Dark grey brown loamy silt with occasional stones	Possible post-pipe fill in [2011]	
2013	Layer	Very loose brown silt with 90% rounded cobbles and gravel	Stony deposit forming part of bank 2116	
2014	Fill	Dark brown, organic sandy silt with moderate stones	Fill of post-pipe [2025] in posthole [2009]	0.72 x 0.28m, 0.38m deep
2015	Fill	Dark grey brown sandy silt with flecks of charcoal and moderate stones	Fill of post-pipe [2026] in posthole [2007]	
2016	Fill	Soft dark brown sand silt with occasional charcoal	Lower fill of post-pipe [2019] in posthole [2005]	
2017	Fill	6 large sub-angular stones up to 0.34m long, set in a rough circle around post-pipe.	Packing stones in posthole [2005]	
2018	Group	Group number for bank in NW corner of trench	Inner bank	c.5m wide
2019	Cut	Rectangular cut with steep sides and a flat base	Post-pipe in posthole [2005]	0.65 x 0.22m, 0.33m deep
2020	Layer	Firm but friable yellow-brown gravelly silt with medium sub-angular stones. The S side of the deposit slopes down at an angle of 45 degrees.	Gravelly deposit in bank 2018	0.5m deep
2021	Layer	Friable dark brown sandy silt with c.75% rounded stones.	Stony deposit in bank 2018	0.6m deep
2022	Layer	Friable dark brown sandy silt with c.25% rounded stones.	Soily deposit over bank 2018	0.2m deep
2023	Layer	Friable very dark brown sandy silt with occasional flecks of charcoal and c.75% angular heat-shattered stones.	Burnt stone deposit over bank 2018	0.25m deep
2024	Layer	Friable dark brown sandy silt with c.75% rounded stones.	Stony deposit in bank 2018	0.25m deep
2025	Cut	Rectangular steep sided cut with fairly flat base.	Post-pipe in posthole [2009]	0.5 x 0.4m, 0.38m deep
2026	Cut	Rectangular steep sided cut with fairly flat base.	Post-pipe in posthole [2007]	0.30 x 0.24m, 0.30m deep
2027	Cut	Shallow sub-oval feature with gently sloping sides	Natural hollow	0.4 x 0.3m, 0.1m deep
2028	Fill	Soft, very dark brown silt with occasional stones	Fill of natural hollow [2027]	

Context number	Type	Description	Interpretation	Dimensions
2029	Cut	Shallow sub-rectangular feature with both steeply and gently sloping sides, and a flat base.	Natural hollow	0.7 x 0.5m, 0.25m deep
2030	Fill	Soft, very dark brown silt with very occasional stones	Fill of natural hollow [2029]	
2031	Cut	Very shallow sub-oval feature with both steeply and gently sloping sides, and an uneven base.	Natural hollow	0.60 x 0.45m, 0.15m deep
2032	Fill	Soft, very dark brown silt with very occasional gravel	Fill of natural hollow [2031]	
2033	Cut	Very shallow sub-oval feature with gently sloping sides, and an uneven base.	Natural hollow	0.60 x 0.50m, 0.05m deep
2034	Fill	Soft, very dark brown silt with very occasional gravel	Fill of natural hollow [2033]	
2035	Cut	Sub-oval cut with steep sides and a rounded base.	Possible small pit	0.55 x 0.48m, 0.20m deep
2036	Fill	Dark red-brown, loose silty sand with occasional flecks of charcoal	Fill of pit [2035]	
2037	Cut	Very shallow sub-circular feature with gently sloping sides, and a flat base.	Natural hollow	0.2m diameter, 0.02m deep
2038	Fill	Soft, very dark brown silt with very occasional gravel. A large flat stone rested in the top of the fill.	Fill of natural hollow [2037]	
2039	Cut	Oval hollow with irregular sides and uneven base. Undercut on one side and burrow leads from it to N.	Rabbit burrow	0.51 x 0.50m, 0.30m deep
2040	Fill	Soft, very dark brown clayey silt with 5 stones. Lenses of orange brown silt.	Fill of rabbit burrow [2039]	
2041	Cut	Oval cut with steep sides and flat base.	Post-pipe in posthole [2118]	0.64 x 0.48m, 0.53m deep
2042	Fill	Soft, very dark brown sandy silt with occasional flecks of charcoal and small stones.	Fill of post-pipe [2041]	
2043	Cut	Sub-circular cut with steep sides and a flat base.	Disturbed post-pipe within large posthole [2122]	0.56 x 0.60m, 0.40m deep
2044	Fill	Loose brown silt with occasional flecks of charcoal and small rounded, sometimes burnt, stones.	Fill of post-pipe [2043]	
2045	Cut	Irregular sub-circular cut with irregular sides and an uneven base.	Rabbit burrow	0.50 x 0.50m, 0.40m deep
2046	Fill	Soft, fine grained dark brownish black silt with orange silt lenses, moderate small stones and a large stone at its base.	Fill of rabbit burrow [2045]	
2047	Layer	Loose brown sandy gravel with occasional flecks of charcoal.	Gravelly deposit forming part of bank 2116	
2048	Fill	Firm mid brownish grey silty sand, with large sub-angular stones set around the sides against cut [2011].	Packing fill in posthole [2011]	
2049	Cut	Shallow ovoid cut feature with steep sides and an irregular base.	Cut of possible pit	0.56 x 0.54m, 0.24m deep
2050	Fill	Fine grained, friable mid greyish brown gravelly silt with occasional sub angular stones up to 9cm long.	Fill of possible pit [2049]	
2051	Fill	Soft, fine grained dark brown sandy silt.	Fill of possible packing stone hole in posthole [2007]	
2052	Cut	Ovoid cut feature with steep sides and a concave base.	Cut of posthole	0.80 x 0.50m, 0.43m deep
2053	Fill	Loose, mid greyish brown silty sand with frequent small sub-rounded pebbles and a larger stone at the south east.	Packing deposit in posthole [2052]	
2054	Layer	Soft, friable, slightly sandy dark brown silt with frequent small stones.	Relict ploughsoil under bank 2116	
2055	Cut	Irregular shaped, steep sided cut feature with an irregular base.	Cut feature, unknown function	0.75 x 0.30m, 0.29m deep
2056	Fill	Firm, fine grained dark brown sandy clay with occasional small rounded cobbles, <10cm long	Fill in cut [2055]	
2057	Cut	Vertical cut that truncates bank deposits, visible in section across bank 2116	Truncation of bank 2116	0.12m deep.

Context number	Type	Description	Interpretation	Dimensions
2058	Cut	Break of slope at a 45° angle through foot of bank 2018, visible in section.	Truncation of bank 2018	0.20m deep
2059	Cut	Shallow, irregular ovoid shaped cut with irregular sides and an uneven irregular base.	Natural scoop	0.66 x 0.42m, 0.14m deep
2060	Fill	Strongly cemented, brownish black silt with occasional small stones.	Fill of natural scoop [2059]	
2061	Cut	Shallow, NE-SW orientated linear cut feature with irregular sides and an irregular base.	Cut of gully, possible plough scar or hollow in top of ice wedge	c.4.10m x 0.60-0.20m, 0.03-0.06m deep
2062	Fill	Fine grained, soft dark brown sandy silt with occasional small stones up to 2cm long and occasional small fragments of charcoal and burnt stone.	Fill of [2061]	
2063	Layer	Mid yellowish grey to light brownish orange, sandy silty clay with abundant gravel and rounded cobble inclusions, up to 25cm long	Natural subsoil deposit, overcut during the excavation of [2055]	
2064	Cut	Sub circular cut, with steep irregular sides and an irregular uneven base.	Natural hollow in stony natural	0.45 x 0.47m, 0.32m deep
2065	Fill	Firm dark brown slightly sandy silt with abundant sub-angular and sub-rounded cobbles up to 18cm long	Fill of [2064]	
2066	Fill	Friable, dark greyish brown sandy silt with 25% smaller stones (up to 10cm long) and occasional larger stones up to 20cm long. Lenses of charcoal present throughout and abundant fragments of metal slag.	Slag-rich fill of shallow hollow [2067]	
2067	Cut	Irregularly shaped shallow hollow, steep sided to the N, more gently sloping elsewhere.	Hollow associated with smithing activity, possible working hollow	1.60 x 1.10m, 0.15m deep
2068	Cut	Ovoid, almost polygonal cut with straightish, almost vertical sides and a flattish base.	Cut of a large posthole	0.99 x 0.98m, 0.49m deep
2069	Fill	Firm, mid greyish, slightly orangey, brown gravelly silty sand. Occasional to moderate sub-rounded and rounded stones (7-10cm long). One large sub angular stone 25cm long.	Packing deposit in posthole [2068]	
2070	Fill	Loose, dark greyish brown sandy silt. Occasional-moderate small fragments of burnt bone and moderate small flecks and fragments of charcoal. Frequent angular, heat affected stones (average 8cm long) concentrated towards the top of the deposit.	Fill of post void [2073] in posthole [2068]	
2071	Fill	Loose, friable dark greyish brown sandy silt with frequent small flecks of charcoal and moderate small sub rounded stones up to 5cm long.	Fill of post void [2074] in posthole [2052]	
2072	Fill	Soft dark brownish brown slightly sandy silt with frequent sub-rounded and sub angular stones up to 8cm long. Moderate angular heat affected stones up to 8cm long. Occasional small fragments of charcoal and very occasional small fragments of burnt bone.	Upper fill of post void [2019] in posthole [2005]	
2073	Cut	Sub-circular cut with steep, straight and smooth sides which break sharply to a flattish base.	Cut of post void created by removal of post in posthole [2068]	0.52 x 0.40m, 0.41m deep
2074	Cut	Ovoid cut with steep sides that break gradually to a concave base.	Cut of post void created by removal of post in posthole [2052]	0.38 x 0.24m, 0.30m deep
2075	Fill	Very friable, very dark greyish brown sandy silt with c. 25% charcoal inclusions. Moderate sub-rounded and sub angular stones up to 15cm long.	Charcoal rich fill of small pit [2076]	
2076	Cut	Circular cut, with steep sides that break fairly sharply to a flat base.	Pit associated with smithing activity, possible foundation cut for wooden anvil block	0.60m diameter, 0.30m deep

Context number	Type	Description	Interpretation	Dimensions
2077	Fill	A deposit of dark brown, with very dark brown patches, firm but friable sandy silt. C.30% mainly angular stones up to 10cm long, many heat shattered. Moderate charcoal fragment inclusions and occasional fragments of metalworking slag.	Upper fill of pit [2078]	
2078	Cut	Sub-circular cut, with steep sides that break fairly gradually to a flat base.	Pit associated with smithing activity, probable smithing hearth	0.47 x 0.40m, 0.20m deep
2079	Fill	Friable dark brown sandy silt with c. 50% gravel inclusions. Occasional small and medium rounded and sub-rounded stones up to 10cm long. Occasional small flecks of charcoal.	Buried soil 'A' horizon under bank 2018	0.1m deep
2080	Fill	Friable mid brown gritty silt with 10% small sub-rounded stones up to 5cm long.	Fill of hollow [2081]	
2081	Cut	Ovoid shallow cut feature with generally gradually sloping sides.	Cut of a shallow hollow, probably natural but cut and disturbed by smithing activity	0.62 x 0.45m, 0.15m deep
2082	Layer	Dark greyish brown gritty sandy silt with yellowish brown patches. Moderate sub angular and angular stones and cobbles, many heat affected and fractured. Occasional fragments of charcoal and burnt bone.	Layer containing burnt bone and charcoal that underlies bank 2116	
2083	Cut	Ovoid shaped cut with steep irregular sides that break gradually to a slightly concave base, deeper at the N end.	Cut of a possible posthole	1.35 x 0.80m, 0.30m deep
2084	Fill	Friable, loose mid greyish brown sandy silt. Frequent sub-rounded stones, up to 15cm long.	Post packing deposit in posthole [2083]	
2085	Layer	Friable brown sandy silt with 20% small and medium stones and small quantities of gravel.	Lower part of buried soil under bank 2018	0.15m deep
2086	Fill	Firm but friable brown silty sand with occasional small stones.	Erosion deposit in the base of pit [2076]	
2087	Cut	Sub-circular cut with generally steep sides that break sharply to a flattish but irregular base.	Cut of posthole	1.04 x 0.92m, 0.35m deep
2088	Fill	Firm mid greyish brown silty with moderate small sub-rounded stones.	Fill in posthole [2087]	
2089	Cut	Sub rectangular cut feature with rounded corners and slightly concave sides that break gradually to as concave base.	Small cut feature, unknown function	0.35 x 0.33m, 0.11m deep
2090	Fill	Firm/soft, mid greyish brown sandy silt with moderate flecks of charcoal and small sub-angular, angular and rounded stones, 2-7cm long. Very occasional small fragments of burnt bone.	Relatively charcoal rich fill of pit [2089]	
2091	Fill	Firm, mid to light yellowish greyish brown sandy gritty silt. Abundant small sub-rounded and sub-angular stones (5-10cm long) and larger sub-angular, rounded and sub-rounded stones (15-40cm long).	Deposit of stones seemingly dumped in posthole [2087]	
2092	Cut	Ovoid shaped cut feature with generally steep sides that break gradually to a flattish but uneven base.	Cut of a posthole	0.66 x 0.53m, 0.30m deep
2093	Fill	Soft dark orangey brown silty clay, occasional to moderate gravel and rounded small stone inclusions, occasionally angular, burnt and heat affected. Occasional larger examples. Stones 3-15cm long.	Packing deposit in posthole [2092]	
2094	Layer	Yellowish brown slightly clayey silt. Abundant stones up to 15cm long, with occasional larger examples.	Natural subsoil over W part of Trench 2	
2095	Layer	Friable dark brown sandy silt with 40% stones up to 10cm long. Many of the stones are heat fractured. Occasional fragments of charcoal and very occasional burnt bone fragments.	Burnt stone deposit under bank 2018	
2096	Cut	Sub-circular cut feature with steep sides that break gradually to a flattish but uneven base.	Cut of a post void created by removal of post in posthole [2092]	0.40 x 0.34m, 0.30m deep
2097	Fill	Soft, dark brown silty sand with moderate rounded stone inclusions (2-10cm long). Occasional fragments of burnt bone. Single large rounded cobble 40cm long in the top of the fill.	Fill of post void [2096] in posthole [2092]	

Context number	Type	Description	Interpretation	Dimensions
2098	Fill	Slightly malleable reddish brown silty, slightly gritty, clay. Flecks of more reddish coloured clay and occasional flecks of charcoal throughout. Occasional small stones.	A lump of heat reddened clay in the base of pit [2078], possibly part of a lining a collapsed superstructure	
2099	Fill	Very dark grey slightly gritty silt. Colour derived mostly from charcoal but few identifiable fragments. Occasional small stone inclusions.	Thin, dark, silty charcoal rich fill in the base of pit [2078]	
2100	Layer	Very compact, friable orangey brown gravelly, slightly clayey, sand with c. 50% rounded and sub rounded stones up to 40cm long.	Natural subsoil in E part of Trench 2	
2101	Fill	Friable loose dark greyish brown silty sand with frequent sub-rounded stones up to 30cm long.	Fill of a possible post void at NW end of posthole [2083]	
2102	Cut	Polygonal cut with steep sides that break fairly sharply to a flat base.	Cut of a possible posthole	1.10 x 0.90m, 0.20m deep
2103	Fill	Very friable brown silty sand with c.20% sub-rounded stones up to 25cm long. Occasional angular stones.	Packing fill of possible beam slot [2104]	
2104	Cut	Tapered, straight linear cut with rounded end at the SW. Runs off into the baulk at NE. Generally steep, almost vertical sides that break fairly sharply to a flattish base.	Cut of a possible beam slot	>1.26 x 0.35-0.66m, 0.30m deep
2105	Fill	Very loose dark grey sandy silt with c.50% medium stones, mostly heat fractured and up to 10cm long. Small gravel component, occasional small flecks of charcoal and burnt bone.	Fill of post void [2106] in posthole [2108]	
2106	Cut	Sub-circular cut feature with steep, near vertical sides that break fairly sharply to a flat base.	Post void in posthole [2108] created by removal of post	0.40m diameter, 0.50m deep
2107	Fill	Friable brown sandy silt with approximately 10% rounded and sub-rounded stones up to 10cm long	Packing fill in posthole [2108]	
2108	Cut	Apparently circular cut (only half excavated as the other half lies under baulk to the NW) with steep, near vertical sides that break fairly gradually to a flattish base	Cut of a large posthole	0.85m diameter, 0.77m deep
2109	Fill	Dark greyish brown sandy silt with c.50% stones up to 25cm long. Stones include both sub-rounded and angular, possibly heat shattered, examples.	Fill of hollow [2110]	
2110	Cut	Ovoid hollow with variably sloping sides with occasional steep sections, that break gradually to a concave base.	Cut of a small pit or hollow of unknown function.	0.68 x 0.33m, 0.25m deep
2111	Layer	Friable brown sandy silt with occasional small stones and some gravel.	Lower horizon of buried soil under bank 2116	
2112	Fill	Friable brown sandy silt with occasional rounded and sub-rounded stones up to 10cm long.	Fill of pit [2113]	
2113	Cut	Apparently circular cut feature (only half excavated as it continues under baulk to the NW) with fairly steep sides that break gradually to a flattish base	Shallow pit of unknown function	0.80m diameter, 0.25m deep
2114	Layer	Friable brown silt with c.20% small rounded stones.	Early ploughsoil or relict soil visible in N baulk at edge of excavated area in Trench 2	
2115	Layer	Irregular area of reddened natural compacted sandy silt subsoil (2100). Colour varies from strong reddish brown to yellowish brown. Contains occasional, redder, possibly heat affected stones in contrast to (2100) generally	Area of heat affected natural subsoil	
2116	Group	Group number for the bank that cuts across the SW corner of Trench 2.		
2117	Fill	Brown friable sandy silt with abundant sub-rounded stones up to 20cm long.	Packing fill of posthole [2118]	
2118	Cut	Circular cut with near vertical sides which break gradually to a flat base.	Cut of a large posthole	0.90m diameter, 0.60m deep
2119	Cut	Sub-circular cut with sides that are steep and irregular on the E side, more gently sloping on the W. Sides break to a slightly concave base, with a deeper socket in the SW corner.	Small posthole set within gully [2061]	0.58 x 0.57m, 0.26m deep

Context number	Type	Description	Interpretation	Dimensions
2120	Fill	Firm mid greyish brown sandy silt with occasional small rounded, angular and sub-angular stones (1-5cm long). Three flat stones sit at the top of the fill, each 3cm thick and 15-16cm long. One heat affected stone with sharp, angular faces, 9cm long. Occasional small fragments of charcoal.	Disturbed packing fill of post-hole [2119]	
2121	Fill	Very loose brown sandy silt with moderate stones up to 20cm long.	Packing deposit in posthole [2122]	
2122	Cut	Ovoid cut with near vertical sides that slope relatively gradually to a fairly flat base. Undercut on the western side.	Cut of a large posthole	1.05 x 0.86m, 0.65m deep
2123	Fill	Clean, soft reddish brown silt with patches of gravel and c.30% small stones. Some larger stones often sloping down into cut.	Fill of natural ice wedge [2124]	
2124	Cut	Narrow irregular linear shaped cut with steep sides, base not reached.	Cut of natural ice wedge	c. 4.90m by 0.18m wide, >0.35m deep
2125	Cut	Linear feature with fairly straight, steep sides and flat base.	Possible natural hollow with very stony fill	1.3 x 1.1m, 0.31m deep

14. APPENDIX V: Palaeoenvironmental Analysis

14.1. Assessment of the palaeoenvironmental potential of deposits from evaluation trench (trench 1)

Rosalind McKenna, freelance palaeoenvironmental specialist

Introduction

Bulk soil samples were recovered during the evaluation excavation in 2013 from deposits that had evidence of charred plant remains. Three deposits were considered to be worth sampling. These were the buried soil layer (021) under the inner bank, the fill (017) of the possible slot [018] in the top of the inner bank, and (014), the upper fill of cut [015]. These samples were wet sieved and floated and the flots were submitted to Rosalind McKenna for assessment.

Methods

The bulk soil samples were processed using the GAT standard water flotation methods. The flot (the sum of the material from each sample that floats) was sieved to 0.3mm and air dried. The heavy residue (the material which does not float) was not examined by Rosalind McKenna, and therefore the results presented here are based entirely on the material from the flot. The flot was examined under a low-power binocular microscope at magnifications between x12 and x40.

A four point semi-quantitive scale was used, from '1' – one or a few specimens (less than an estimated six per kg of raw sediment) to '4' – abundant remains (many specimens per kg or a major component of the matrix). Data were recorded on paper and subsequently on a personal computer using a Microsoft Access database.

Identification was carried out using published keys (Jacomet 2006, Biejerinkc 1976, Jones – unpublished and Zohary & Hopf 2000), online resources (http://www.plantatlas.eu/za.php), the authors own specimens and the reference collection housed at Birmingham Archaeology's laboratory. The full species list appears in Table V.1.2 at the end of this report. Taxonomy and nomenclature follow Stace (1997).

The flot was then sieved into convenient fractions (4, 2, 1 and 0.3mm) for sorting and identification of charcoal fragments. Identifiable material was only present within the 4 and 2mm fractions. A random selection of ideally 100 fragments of charcoal of varying sizes was made, which were then identified. Where samples did not contain 100 identifiable fragments, all fragments were studied and recorded. This information is recorded with the results of the assessment in table V.1.3. Identification was made using the wood identification guides of Scweingruber (1978) and Hather (2000). Taxa identified only to genus cannot be identified more closely due to a lack of defining characteristics in charcoal material.

Results

Three samples were submitted. Of these, charred plant macrofossils were present in two of the samples and were quite poorly preserved, with few identifying morphological characteristics present. The results of this analysis can be seen in table V.1.2. The samples produced small assemblages of plant remains both in volume and diversity. The most common and abundant remain was hazel nut shell fragments, which were present in both of the samples in varying amounts. One of the samples (Sample 1) contained nine charred cereal grains, some of which lacked identifying morphological characteristics, and were therefore recorded as 'indeterminate cereal'. A further six of these could be identified as probable oat, but it was impossible to distinguish if these were of the cultivated variety. Several weed / wild seeds were also present in very small numbers in this sample – grass seeds, a dock and unidentifiable members of the cabbage family. In sample 3, charred buds were present alongside several indeterminate plant macrofossils.

Charcoal remains were present in all three of the samples and scored between '2' and '4' on the abundance scale. There were identifiable remains in all of the samples. The preservation of the charcoal fragments was relatively variable even within the samples. Some of the charcoal was firm and crisp and allowed for clean breaks to the material permitting clean surfaces where identifiable characteristics were visible. However, some of the fragments were very brittle, and the material tended to crumble or break in uneven patterns making the identifying characteristics harder to distinguish and interpret. Table V.1. 3 shows the results of the charcoal assessment. Two of the samples were dominated by ash, and one of the samples was dominated by willow/poplar charcoal. Oak was also present in all three samples, alder in a single sample and hazel in a single sample.

The total range of taxa comprises oak (*Quercus*), ash (*Fraxinus*), willow/poplar (*Salix*/*Populus*), alder (*Alnus*) and hazel (*Corylus*). These taxa belong to the groups of species represented in the native British flora. A local environment with a range of trees and shrub is indicated from the charcoal of the site. As seen in table V.1. 3, ash is by far the most numerous of the identified charcoal fragments, and it is possible that this was the preferred fuel wood obtained from a local environment containing a broader choice of species. Ash is probably the first choice, and with a local abundance it may have been used instead of oak, thereby providing more by-product fire fuel.

All of the samples produced varying amounts of charcoal, indicating the use of a mixture of species being utilised for firewood, although with a preference to using ash. Bark was also present on some of the charcoal fragments, and this indicates that the material is more likely to have been firewood, or the result of a natural fire.

Generally, there are various, largely unquantifiable, factors that effect the representation of species in charcoal samples including bias in contemporary collection, inclusive of social and economic factors, and various factors of taphonomy and conservation (Thery-Parisot 2002). On account of these considerations, the identified taxa are not considered to be proportionately representative of the availability of wood resources in the environment in a definitive sense, and are possibly reflective of particular choice of fire making fuel from these resources.

Root / rootlet fragments were also present within the samples. This indicates disturbance of the archaeological features, and this may be due to the nature of some features being relatively close to the surface, as well as deep root action from vegetation that covered the site. The presence of earthworm egg capsules in all of the samples, together with insect fragments in two of the samples further confirms this disturbance.

From sample 1 (17) oat grains and hazel nut shell fragments have been prepared for two radiocarbon dates. From sample 3 (21) two hazel nut shell fragments have been prepared for radiocarbon dates.

Conclusion

The samples produced some environmental material, with the charcoal remains from all three samples and the plant macrofossils from two of the samples.

These charcoal remains showed the exploitation of several species native to Britain, with the prevalence of ash being selected and used as fire wood. Ash is strong and tough, and makes excellent firewood producing both heat and flame. It will also burn when green (Grogan et al. 2007, 30). Willow/Poplar are species that are ideal to use for kindling. They are anatomically less dense than for example, oak and ash and burn quickly at relatively high temperatures (Gale & Cutler 2000, 34, 236, Grogan *et al.* 2007, 29-31). This property makes them good to use as kindling, as the high temperatures produced would encourage the oak to ignite and start to burn. Oak is a particularly useful fire fuel as well as being a commonly used structural/artefactual wood that may have had subsequent use as a fire fuel (Rossen and Olsen 1985). Hazel is recorded as a good fuel wood and was widely available within oak woodlands, particularly on the fringes of cleared areas (Grogan *et al.* 2007, 30). Oak has good burning properties and would have made a fire suitable for most purposes (Edlin 1949).). Alder is a wood that burns quickly when used for firewood, but has been found suitable for charcoal production, but given that it is not the most abundant taxa, may merely represent a selection of available firewood

Dryland wood species indicates the presence of an oak-ash woodland close to the site. This would have consisted of oak and ash which would be the dominant large tree species (Gale & Cutler 2000, 120, 205). On the marginal areas of oak-ash woodlands or in clearings hazel thrives. The evidence of carr fen woodland indicates a damp environment close to the site. This type of woodland would have consisted of alder, willow and poplar which are all trees that thrive in waterlogged and damp soils, particularly in areas close to streams or with a high water table (Stuits 2005, 143 and Gale & Cutler 2000), perhaps indicating such an environment within close proximity to the site.

As asserted by Scholtz (1986) cited in Prins and Shackleton (1992:632), the "Principle of Least Effort" suggests that communities of the past collected firewood from the closest possible available wooded area, and in particular the collection of economically less important kindling fuel wood (which was most likely obtained from the area close to the site), the charcoal assemblage does suggest that the local vegetation would have consisted of an oak woodland close to the site.

The archaeobotanical evidence found in the samples shows hazelnut shell, together with several indeterminate cereal grains, several oat grains, and several weed/wild species such as grass, dock and members of the cabbage family. Due to the small number of cereal grains and associated weed seeds, there is limited interpretative information other than to state their presence. The fact that oats are the only identified species of cereal may indicate that sample 1, from the palisade slot in the top of the inner bank, is of Medieval date as this species is a common crop of that period.

Hazel-nuts are valuable nutritionally, as well as being readily available. In addition, the nut shell is hard and resistant to decay ensuring its survival in some quantities. The hazelnut shells recovered may be indicative of a food source being consumed, perhaps as a snack and their husks being added to the fires as a method of waste disposal. However, the hazelnut shell fragments show no marks typically associated with processed shells. Together with the high portion of hazel charcoal, this may indicate that they are merely representative of hazel wood trees being burnt, which could be either a natural or a man-made process.

It is thought to be problematic using charcoal and plant macrofossil records from archaeological sites, as they do not accurately reflect the surrounding environment. Wood was gathered before burning or was used for building which introduces an element of bias. Plant remains were also gathered foods, and were generally only burnt by accident. Despite this, plant and charcoal remains can provide good information about the landscapes surrounding the sites presuming that people did not travel too far to gather food and fuel.

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Appendix V.1 Tables

Table V.1.1. Components of the subsamples from deposits recovered at Hen Gastell
Semi quantitative score of the components of the samples is based on a four point scale, from '1' – one or a few remains (less than an estimated six per kg of raw sediment) to '4' – abundant remains (many per kg or a major component of the matrix).

Sample Number	**1**	**2**	**3**
Context Number	**17**	**14**	**21**
Context Type	**Palisade slot in top of inner bank**	**Shallow pit**	**Buried soil horizon beneath inner bank**
Bone fgts.			
Charcoal fgts.	4	2	4
Earthworm egg capsules	2		2
Insect fgts.	1		2
Plant macrofossils (ch.)	1		1
Root/rootlet fgts.	4	4	3
Sand	2		3

Table V.1.2: Plant Macrofossils. Complete list of taxa recovered from deposits recovered at Hen Gastell. Taxonomy and Nomenclature follow Stace (1997).

Sample Number	**1**	**3**	
Context Number	**17**	**21**	
Context type	**Palisade slot in top of inner bank**	**Buried soil horizon beneath inner bank**	
LATIN BINOMIAL			**COMMON NAME**
Corylus avellana **(fgts.)**	5	2	**Hazelnut shell fgts.**
Rumex **spp.**	1		**Dock**
BRASSICACEAE	2		**Cabbage Family**
POACEAE	4		**Grass family**
Avena **spp.**	6		**Oat**
Indeterminate cereal	3		**Indeterminate cereal**
Unidentified			**Unidentified**
Indeterminate	14	10	**Indeterminate**
Indeterminate buds		4	**Indeterminate buds**

Table V.1.3: Charcoal. Complete list of taxa recovered from deposits at deposits Hen Gastell
Taxonomy and nomenclature follow Schweingruber (1978). Numbers are identified charcoal fragment for each sample.

Sample Number		**1**	**2**	**3**
Context Number		**17**	**14**	**21**
Context type		**Palisade slot in top of inner bank**	**Shallow pit (interior of site)**	**Buried soil horizon beneath inner bank**
No. of fragments		**2000+**	**100+**	**700+**
Max. size (mm)		**31**	**9**	**16**
Latin	**Common Name**			
Alnus glutinsa	**Alder**	10		
Corylus avellana	**Hazel**			4
Salix / Populus	**Willow/ Poplar**	24	23	29
Fraxinus excelsior	**Ash**	45	16	54
Quercus	**Oak**	21	5	13
	Indeterminate		56	

14.2. Assessment of the palaeoenvironmental potential of deposits from the main excavation (trench 2)

Rosalind McKenna, freelance palaeoenvironmental specialist

Introduction

A series of thirty seven samples were submitted in August 2015 from deposits excavated at Hen Gastell, Llanwnda, for an evaluation of their environmental potential. The excavation was centred on NGR SH 4713 5737. The excavation was carried out by Gwynedd Archaeological Trust in October 2013 and July 2014. The site itself is an atypical defended enclosure, with a ditch and bank around the northern side of the site. The samples came from a range of layers encountered during the excavation. Samples from the site that were previously assessed have produced radiocarbon dates that date to the Medieval period.

The samples studied here are as of yet undated, and it is hoped this assessment will provide material for dating, as well as clarifying the function of the site.

A programme of soil sampling from sealed contexts was implemented during the excavation. The aim of the sampling was to:

- assess the type of preservation and the potential of the biological remains
- provide C14 material for assistance in dating features
- identify if any human activities were undertaken on the site
- reconstruct the environment of the surrounding area

Methods

The initial material was submitted to the author in a processed state. It was processed by staff at Archaeoleg Brython Archaeology using their standard water flotation methods. The flot (the sum of the material from each sample that floats) was sieved to 0.25mm and double floated. They were processed once, the residues left to dry, and then the residues were floated again. This was carried out on the advice of James Rackham, to ensure that smaller charred items are not lost. The heavy residue (the material which does not float) was not examined, and therefore the results presented here are based entirely on the material from the flot. The flot was examined under a low-power binocular microscope at magnifications between x12 and x40.

A four point semi quantative scale was used, from '1' – one or a few specimens (less than an estimated six per kg of raw sediment) to '4' – abundant remains (many specimens per kg or a major component of the matrix). Data were recorded on paper and subsequently on a personal computer using a Microsoft Access database.

Identification was carried out using published keys (Jacomet 2006, Biejerinkc 1976, Jones – unpublished and Zohary & Hopf 2000), online resources (http://www.plantatlas.eu/za.php), and the authors own specimens. The full species list appears in table V.2.2 at the end of this report. Taxonomy and nomenclature follow Stace (1997).

The flot was then sieved into convenient fractions (4, 2, 1 and 0.3mm) for sorting and identification of charcoal fragments. Identifiable material was only present within the 4 and 2mm fractions. A random selection of ideally 100 fragments of charcoal of varying sizes was made, which were then identified. Where samples did not contain 100 identifiable fragments, all fragments were studied and recorded. This information is recorded with the results of the assessment in table V.2.3 below. Identification was made using the wood identification guides of Scweingruber (1978) and Hather (2000).
Taxa identified only to genus cannot be identified more closely due to a lack of defining characteristics in charcoal material.

Results

Thirty seven samples were submitted. Of these, charred plant macrofossils were present in thirty five of the samples and were quite well preserved, with few identifying morphological characteristics present. The results of this analysis can be seen in table V.2.2 below. The samples produced small assemblages of plant remains both in volume and diversity. The most common and abundant remain was hazel nut shell fragments, which was present in thirty three of the samples in varying amounts.

Indeterminate cereal grains – grains which lacked identifying morphological characteristics, were present in twenty two of the samples. Identifiable cereal grains were present in the form of poorly preserved wheat grains that were present in two samples and oat grains that were present in a single sample. Awns from oats were also recorded in a further sample that lacked any oat grains within it. Grass seeds were present in thirty one of the samples. Many of these were poorly preserved but with further analysis it may be possible to identify these to a species level, and it is also possible that some of them may be oat grains. Several weed / wild seeds were also present in small numbers in eight of the samples – such as dock, unidentifiable members of the cabbage family, goosefoot / orache and corn marigold.

Charcoal remains were present in all of the samples and scored between '2' and '4' on the abundance scale. There were identifiable remains in thirty five of the samples. The preservation of the charcoal fragments was relatively variable even within the samples. Some of the charcoal was firm and crisp and allowed for clean breaks to the material permitting clean surfaces where identifiable characteristics were visible. However, some of the fragments were very brittle, and the material tended to crumble or break in uneven patterns making the identifying characteristics harder to distinguish and interpret. Table V.2.3 below shows the results of the charcoal assessment. Oak was the most abundant remain recorded and was present in all thirty five of the samples. Hazel was present in eleven of the samples and willow / poplar was recorded in seven of the samples.

The total range of taxa comprises oak (Quercus), willow/poplar (Salix/Populus), and hazel (Corylus). These taxa belong to the groups of species represented in the native British flora. A local environment with a range of trees and shrub is indicated from the charcoal of the site. As seen in table V.2.3, oak is by far the most numerous of the identified charcoal fragments, and it is possible that this was the preferred fuel wood obtained from a local environment containing a broader choice of species. Oak is probably the first choice structural timber, and with a local abundance it may have been used instead of ash, thereby providing more by-product fire fuel.

All of the samples produced varying amounts of charcoal, indicating the use of a mixture of species being utilised for firewood, although with a preference to using oak. Bark was also present on some of the charcoal fragments, and this indicates that the material is more likely to have been firewood, or the result of a natural fire.

Generally, there are various, largely unquantifiable, factors that effect the representation of species in charcoal samples including bias in contemporary collection, inclusive of social and economic factors, and various factors of taphonomy and conservation (Thiery-Parisot 2002). On account of these considerations, the identified taxa are not considered to be proportionately representative of the availability of wood resources in the environment in a definitive sense, and are possibly reflective of particular choice of fire making fuel from these resources.

Root / rootlet fragments were also present within the samples. This indicates disturbance of the archaeological features, and this may be due to the nature of some features being relatively close to the surface, as well as deep root action from vegetation that covered the site. The presence of earthworm egg capsules, together with insect fragments in some of the samples further confirms this disturbance.

The following material has been submitted for radiocarbon dates:

Sample Number	Context Number	Material submitted
8	2003	Cereal gains (unidentifiable)
16	2023	Hazel nut shell fragments
31	2069	Hazel nut shell fragments
20	2070	Hazel nut shell fragments
28	2082	Hazel nut shell fragments
41	2082	Cereal grains (unidentifiable)
34	2093	Hazel nut shell fragments
38	2097	Hazel nut shell fragments
32	2098	Hazel nut shell fragments
33	2099	Cereal grains (unidentifiable)

Conclusion

The samples produced some environmental material, with the charcoal remains and charred plant macrofossils from thirty five of the samples.

These charcoal remains showed the exploitation of several species native to Britain, with the prevalence of oak being selected and used as fire wood. Oak is a particularly useful fire fuel as well as being a commonly used structural/artefactual wood that may have had subsequent use as a fire fuel (Rossen and Olsen 1985). Hazel is recorded as a good fuel wood and was widely available within oak woodlands, particularly on the fringes of cleared areas (Grogan *et al.* 2007, 30). Oak has good burning properties and would have made a fire suitable for most purposes (Edlin 1949).).Willow/Poplar are species that are ideal to use for kindling. They are anatomically less dense than for example, oak and ash and burn quickly at relatively high temperatures (Gale & Cutler 2000, 34, 236, Grogan *et al.* 2007, 29-31). This property makes them good to use as kindling, as the high temperatures produced would encourage the oak to ignite and start to burn.

Dryland wood species indicates the presence of an oak dominant woodland close to the site. This would have consisted of oak which would be the dominant large tree species (Gale & Cutler 2000, 120, 205). On the marginal areas of oak-ash woodlands or in clearings hazel thrives. The evidence of carr fen woodland through the presence of willow / poplar indicates a damp environment close to the site. This type of woodland would have consisted of willow and poplar and possible alder which are all trees that thrive in waterlogged and damp soils, particularly in areas close to streams or with a high water table (Stuijts 2005, 143 and Gale & Cutler 2000), perhaps indicating such an environment within close proximity to the site.

As asserted by Scholtz (1986) cited in Prins and Shackleton (1992:632), the "Principle of Least Effort" suggests that communities of the past collected firewood from the closest possible available wooded area, and in particular the collection of economically less important kindling fuel wood (which was most likely obtained from the area close to the site), the charcoal assemblage does suggest that the local vegetation would have consisted of an oak woodland close to the site.

The archaeobotanical evidence found in the samples shows hazelnut shell, together with indeterminate cereal grains, wheat and oat grains, grasses and several weed/wild species such as goosefoot / orache, corn marigold, dock and members of the cabbage family. Due to the small number of cereal grains and associated weed seeds, there is limited interpretative information other than to state their presence.

Hazel-nuts are valuable nutritionally, as well as being readily available. In addition, the nut shell is hard and resistant to decay ensuring its survival in some quantities. The hazelnut shells recovered may be indicative of a food source being consumed, perhaps as a snack and their husks being added to the fires as a method of waste disposal. However, the hazelnut shell fragments show no marks typically associated with processed shells. Together with the presence of hazel charcoal, this may indicate that they are merely representative of hazel wood trees being burnt, which could be either a natural or a man-made process.

It is thought to be problematic using charcoal and plant macrofossil records from archaeological sites, as they do not accurately reflect the surrounding environment. Wood was gathered before burning or was used for building which introduces an element of bias. Plant remains were also gathered foods, and were generally only burnt by accident. Despite this, plant and charcoal remains can provide good information about the landscapes surrounding the sites presuming that people did not travel too far to gather food and fuel.

An assessment of archaeobotanical remains from a previous evaluation at the site (McKenna 2014) produced three samples with identifiable remains. Small quantities of hazel nut shell fragments, indeterminate cereal grains, Oat grains, grass seeds, docks and unidentifiable members of the cabbage family were recorded from two samples. The remains are very similar to those recovered from the samples submitted for this assessment. Charcoal remains were also present in the evaluation samples – they were dominated by ash with smaller numbers of oak, willow/ poplar, alder and hazel also recorded. Ash and alder were absent from the samples studied for this assessment.

Recommendations

The samples have been assessed, and any interpretable data has been retrieved. No further work is required on the majority of the samples. The plant macrofossils from sample 29 from a pit feature should be fully identified and quantified. It is possible that some of the smaller remains of cereal chaff and weed seeds were missed in this initial assessment, and more time may recover higher numbers. Any material recovered by further excavations should be processed to 0.3mm in accordance with standardised processing methods such as Kenward *et al.* 1980, and the English Heritage guidelines for Environmental Archaeology. A thorough research into comparable sites must also be made at this stage. When the radiocarbon dates from the material listed above are returned, sites of a similar period should also be subjected to a comparable study.

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http://www.plantatlas.eu/za.php

Appendix V.2 Tables

Table V.2.1. Components of the subsamples from deposits recovered at Hen Gastell
Semi quantitative score of the components of the samples is based on a four point scale, from '1' – one or a few remains (less than an estimated six per kg of raw sediment) to '4' – abundant remains (many per kg or a major component of the matrix).

Sample Number	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**13**
Context Number	**2003**	**2003**	**2003**	**2015**	**2003**	**2012**	**2036**	**2042**	**2048**
Context Type	**Burnt stone deposit**	**Burnt stone deposit**	**Burnt stone deposit**	**Post-pipe fill**	**Burnt stone deposit**	**Post-pipe fill**	**Pit**	**Post-pipe fill**	**Post hole**
Bone fgts.									
Charcoal fgts.	4	4	3	3	3	3	3	3	2
Earthworm egg capsules	1	1	1	1	1	1	1	1	1
Insect fgts.		1	1				1		
Plant macrofossils (ch.)	2	2	2	1	1	1	1	1	1
Root/rootlet fgts.	2	3	3	3	2	3	4	4	4
Sand	3	4	4	4	4	4	3	3	3
Snails	1		1						

Sample Number	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Context Number	**2023**	**2014**	**2023**	**2010**	**2008**	**2056**	**2070**	**2066**	**2072**
Context Type	**Burnt stone deposit**	**Post-pipe fill**	**Burnt stone deposit**	**Post hole**	**Post hole**	**Un-known feature**	**Post-void fill**	**Metal working feature**	**Post void fill**
Bone fgts.			1						1
Charcoal fgts.	4	3	4	3	2	3	3	3	2
Earthworm egg capsules	1	1	1	1	1	1	1	1	1
Insect fgts.	1	1	1		1		1	1	1
Plant macrofossils (ch.)	1	1	1	1	1	1	2	1	1
Root/rootlet fgts.	3	4	2	3	3	3	3	2	4
Sand	3	3	4	4	4	4	4	4	3
Slag fgts.								2	
Snails			1						

Sample Number	23	24	25	26	28	29	30	31	32
Context Number	2071	2053	2075	2079	2082	2077	2006	2069	2098
Context Type	Post void fill	Post hole	Pit	Buried soil horizon	Layer	Pit	Post hole	Post hole	Reddened clay in base of pit
Charcoal fgts.	3	3	4	4	4	4	1	3	3
Earthworm egg capsules	1	1	1	1	1	1	1	1	1
Insect fgts.	1	1	1	1	1	1	1		
Plant macrofossils (ch.)	1	1		1	1	3		1	1
Root/rootlet fgts.	4	4	2	3	3	3	2	4	3
Sand	3	3	1	3	4	3	4	2	4
Snails				1					

Sample Number	33	34	35	36	37	38	39	40	41
Context Number	2099	2093	2090	2101	2084	2097	2088	2120	2082
Context Type	Pit	Post hole	Pit	Post void fill	Post hole	Post void fill	Pit	Post hole	Layer
Charcoal fgts.	3	3	3	2	2	3	2	4	3
Earthworm egg capsules	1	1		1	1	1	1	1	1
Insect fgts.	1	1	1		1	1		1	1
Plant macrofossils (ch.)	3	1	1	1	1	1	1	1	1
Root/rootlet fgts.	2	4	3	4	4	4	4	3	3
Sand	4	3	4	3	3	3	3	4	4
Slag fgts.	1		1						
Snails						1			

Sample Number	42
Context Number	2105
Context Type	Post void fill
Charcoal fgts.	4
Earthworm egg capsules	1
Insect fgts.	1
Plant macrofossils (ch.)	2
Root/rootlet fgts.	3
Sand	3

Table V.2.2: Plant Macrofossils. Complete list of taxa recovered from deposits recovered at Hen Gastell Taxonomy and Nomenclature follow Stace (1997).

Sample Number	**4**	**5**	**6**	**7**	**8**	
Context Number	**2003**	**2003**	**2003**	**2015**	**2003**	
Context type	**Burnt stone deposit**	**Burnt stone deposit**	**Burnt stone deposit**	**Post-pipe**	**Burnt stone deposit**	
LATIN BINOMIAL						**COMMON NAME**
***Corylus avellana* (fgts.)**	86	114	73	6	25	**Hazelnut shell fgts.**
***Chenepodium / Atriplex* spp.**		1	1			**Goosefoot / Orache**
***Carex* spp.**					1	**Sedge**
POACEAE	13	4	7	1	21	**Grass family**
Indeterminate cereal	24	9	4	4	23	**Indeterminate cereal**

Sample Number	**9**	**10**	**12**	**13**	**14**	
Context Number	**2012**	**2036**	**2042**	**2048**	**2023**	
Context type	**Post-pipe**	**Pit**	**Post-pipe**	**Post hole**	**Burnt stone deposit**	
LATIN BINOMIAL						**COMMON NAME**
***Corylus avellana* (fgts.)**	7	4	21	4	12	**Hazelnut shell fgts.**
***Chenepodium / Atriplex* spp.**	40					**Goosefoot / Orache**
***Rumex* spp.**			1			**Dock**
POACEAE	2		4	2		**Grass family**
Indeterminate cereal	3	2	6			**Indeterminate cereal**

Sample Number	**15**	**16**	**17**	**18**	**19**	
Context Number	**2014**	**2023**	**2010**	**2008**	**2056**	
Context type	**Post-pipe**	**Burnt stone deposit**	**Post hole**	**Post hole**	**Unknown feature**	
LATIN BINOMIAL						**COMMON NAME**
***Corylus avellana* (fgts.)**	11	26	1	1	2	**Hazelnut shell fgts.**
POACEAE	4		1	2	6	**Grass family**
Indeterminate cereal					2	**Indeterminate cereal**

Sample Number	**20**	**21**	**22**	**23**	**24**	
Context Number	**2070**	**2066**	**2072**	**2071**	**2053**	
Context type	**Post void fill**	**?Metal working feature**	**Post void fill**	**Post void fill**	**Post hole**	
LATIN BINOMIAL						**COMMON NAME**
***Corylus avellana* (fgts.)**	120	32	20	18	2	**Hazelnut shell fgts.**
BRASSICACEAE				1		**Cabbage Family**
***Chrysanthemum segetum* L.**	1					**Corn marigold**
POACEAE	87		3	8	4	**Grass family**
Indeterminate cereal	21		6	4		**Indeterminate cereal**
Indeterminate	1	1				**Indeterminate**

Sample Number	26	28	29	31	32	
Context Number	2079	2082	2077	2069	2098	
Context type	Buried soil horizon	Layer	Pit	Post hole	Reddened clay in base of pit	
LATIN BINOMIAL						COMMON NAME
Corylus avellana (fgts.)	9	20	269	4	16	Hazelnut shell fgts.
Chenepodium / Atriplex spp.			25			Goosefoot / Orache
Polygonum spp.			1			Knotweed
Rumex spp.			3			Dock
Chrysanthemm segetum L.			5			Corn Marigold
POACEAE	11	5	15	3		Grass family
Avena spp.				2		Oat
Avena spp. awn fgts.			2			Oat awn fgts.
Triticum spp.			342			Wheat
Triticum spp. spikelet fork			5			Wheat spikelet fork
Indeterminate cereal	1	43	2943		66	Indeterminate cereal
Indeterminate cereal detached embryo			3			Indeterminate cereal detached embryo
Unidentified cereal chaff fgts.			86			Unidentified cereal chaff fgts.
Unidentified			3			Unidentified
Indeterminate		1				Indeterminate

Sample Number	**33**	**34**	**35**	**36**	**37**	
Context Number	**2099**	**2093**	**2090**	**2101**	**2084**	
Context type	**Pit**	**Post hole**	**Pit**	**Post-void fill**	**Post hole**	
LATIN BINOMIAL						**COMMON NAME**
Corylus avellana **(fgts.)**	23	8	21			**Hazelnut shell fgts.**
Chenepodium / Atriplex **spp.**	1					**Goosefoot / Orache**
POACEAE	2		1	4	4	**Grass family**
Triticum **spp.**	28					**Wheat**
Indeterminate cereal	185	1	3		5	**Indeterminate cereal**
Unidentified chaff fgt.	1					**Unidentified chaff fgt.**

Sample Number	**38**	**39**	**40**	**41**	**42**	
Context Number	**2097**	**2088**	**2120**	**2082**	**2105**	
Context type	**Post-void fill**	**Pit**	**Post hole**	**Layer**	**Post-void fill**	
LATIN BINOMIAL						**COMMON NAME**
Corylus avellana **(fgts.)**	12	1	11	1	96	**Hazelnut shell fgts.**
POACEAE	1			1	18	**Grass family**
Indeterminate cereal				44	10	**Indeterminate cereal**

Table V.2.3: Charcoal. Complete list of taxa recovered from deposits at deposits Hen Gastell.
Taxonomy and nomenclature follow Schweingruber (1978). Numbers are identified charcoal fragment for each sample.

Sample Number		**4**	**5**	**6**	**7**	**8**	**9**
Context Number		**2003**	**2003**	**2003**	**2015**	**2003**	**2012**
Context type		**Burnt stone deposit**	**Burnt stone deposit**	**Burnt stone deposit**	**Post pipe fill**	**Burnt stone deposit**	**Post pipe fill**
No. of fragments		**4000+**	**1000+**	**1500+**	**400+**	**1200+**	**100+**
Max. size (mm)		**24**	**19**	**15**	**17**	**15**	**9**
Latin	**Common Name**						
Corylus avellana	**Hazel**		31				
Quercus	**Oak**	13	69	100	100	100	28

Sample Number		**10**	**12**	**13**	**14**	**15**	**16**
Context Number		**2036**	**2042**	**2048**	**2023**	**2014**	**2023**
Context type		**Pit**	**Post pipe fill**	**Post hole**	**Burnt stone deposit**	**Post pipe fill**	**Burnt stone deposit**
No. of fragments		**300+**	**600+**	**150+**	**700+**	**700+**	**1400+**
Max. size (mm)		**16**	**9**	**15**	**23**	**16**	**23**
Latin	**Common Name**						
Corylus avellana	**Hazel**		7				
Quercus	**Oak**	17	93	24	100	100	100
	Indeterminate	83		76			

Sample Number		17	18	19	20	21	22
Context Number		**2010**	**2008**	**2056**	**2070**	**2066**	**2072**
Context type		**Post hole**	**Post hole**	**Unknown feature**	**Post void fill**	**Metal working feature**	**Post void fill**
No. of fragments		**80+**	**100+**	**500+**	**6000+**	**120000+**	**400+**
Max. size (mm)		**5**	**15**	**18**	**19**	**12**	**18**
Latin	**Common Name**						
Corylus avellana	**Hazel**		3	29			8
Quercus	**Oak**	14	27	63	100	100	92
	Indeterminate	66	70	8			

Sample Number		23	24	25	26	28	29
Context Number		**2071**	**2053**	**2075**	**2079**	**2082**	**2077**
Context type		**Post void fill**	**Post hole**	**Pit**	**Buried soil horizon**	**Layer**	**Pit**
No. of fragments		**200+**	**250+**	**50000+**	**600+**	**1000+**	**20000+**
Max. size (mm)		**20**	**13**	**26**	**15**	**22**	**15**
Latin	**Common Name**						
Corylus avellana	**Hazel**					50	38
Salix / Populus	**Willow / Poplar**	42					
Quercus	**Oak**	58	32	100	100	50	62
	Indeterminate		18				

Sample Number		**31**	**32**	**33**	**34**	**35**	**36**
Context Number		**2069**	**2098**	**2099**	**2093**	**2090**	**2101**
Context type		**Post hole**	**Reddened clay in base of pit**	**Pit**	**Post hole**	**Pit**	**Post void fill**
No. of fragments		**250+**	**500+**	**600+**	**300+**	**500+**	**25+**
Max. size (mm)		**13**	**14**	**12**	**6**	**21**	**9**
Latin	**Common Name**						
Corylus avellana	**Hazel**	28	35				
Salix / Populus	**Willow / Poplar**			52	25	37	2
Quercus	**Oak**	72	65	48	75	63	6
	Indeterminate						17

Sample Number		**37**	**38**	**40**	**41**	**42**
Context Number		**2084**	**2097**	**2120**	**2082**	**2105**
Context type		**Post hole**	**Post void fill**	**Post hole**	**Layer**	**Post void fill**
No. of fragments		**75+**	**300+**	**900+**	**3500+**	**3000+**
Max. size (mm)		**5**	**9**	**20**	**18**	**24**
Latin	**Common Name**					
Corylus avellana	**Hazel**		2			12
Salix / Populus	**Willow / Poplar**		8		3	
Quercus	**Oak**	5	19	100	97	88
	Indeterminate	70	71			

14.3. Detailed investigation of plant macrofossil remains from sample 29, from the smithing hearth

Rosalind McKenna, freelance palaeoenvironmental specialist

Introduction

An archaeological investigation was carried out by Gwynedd Archaeological Trust (GAT) at Hen Gastell, Llanwnda, centred on NGR SH 81657592 in October 2013 and July 2014. The site itself is an atypical defended enclosure, with a ditch and bank around the northern side of the site. The samples came from a range of layers encountered during the excavation. Samples from the site that were previously assessed have produced radiocarbon dates that date to the Medieval period.

Thirty seven samples were assessed for their bio-archaeological potential by McKenna (appendix V.2). Based on this assessment, one sample was selected for further investigation and this forms the basis of this report.

Methods

The material was submitted to the author in a processed state. It was processed by staff at Archaeoleg Brython Archaeology using their standard water flotation methods. The flot (the sum of the material from each sample that floats) was sieved to 0.25mm and double floated. They were processed once, the residues left to dry, and then the residues were floated again. This was carried out on the advice of James Rackham, to ensure that smaller charred items are not lost. The heavy residue (the material which does not float) was not examined, and therefore the results presented here are based entirely on the material from the flot. The flot was examined under a low-power binocular microscope at magnifications between x12 and x40.

Data were recorded on paper and subsequently on a personal computer using a Microsoft Access database. Actual counts of the remains were made.

Identification was carried out using published keys (Jacomet 2006, Biejerinkc 1976, Jones – unpublished and Zohary & Hopf 2000), online resources (http://www.plantatlas.eu/za.php), the authors own specimens]. The full species list appears in Table 1 at the end of this report. Taxonomy and nomenclature follow Stace (1997).

For technical reasons the convention ‘sp(p)’ to denote that more than one species was or may have been present, is used throughout, even where only one specimen of the taxon was recorded (and thus only one species could have been present), and ‘cf.’ is used to indicate a ‘best guess’ as to the identity of fossil specimens.

Results

Table V3.1 below presents the results of the plant macrofossil analysis with the complete list of taxa. Table V.3.2 present the habitat data based on the remains recovered from the sample which will assist with interpretation. Table 3 presents the components present within the sample.

Sample 29 (2077)

This sample yielded a large suite of remains. The sample was dominated by indeterminate cereal grains – however the vast majority were warped or had exploded through charring and lacked identifying morphological characteristics. Where identification of grains was possible due to better preservation, barley, rye, free threshing wheat, and probable cultivated oat was recorded.

Cereal chaff was also present within the samples, however in small numbers in comparison to the number of grains recorded. Rye rachis nodes and glume bases were present, as well as free threshing wheat internodes and rachis nodes. Wheat glume bases recovered were highly fragmented and therefore only identification could only be made to ‘glume wheat’, which in England and Wales tend to be limited to emmer (*Triticum diococcum*) or spelt (*Triticum spelta*). Some of the unidentified chaff fragments were observed to be very like barley rachis fragments, however positive identification was hindered by extremely poor preservation.

The majority of the weed / wild taxa recovered are recognisable weeds of arable crops or cultivated ground. These weeds most likely were incorporated into the deposit along with crop remains. The deposit contains a mixture of grain and similar sized weed seeds, such as bedstraws (*Galium aparine*), corn marigold (*Chrysanthemum segetum*), goosefoot / orache (*Chenepodium / Atriplex*) and docks (*Rumex* sp.). There were also a number of remains from the grass family recorded within the sample. The most numerous was indeterminate grass, where identification was unable to be made to species due to poor preservation and the lack of identifying morphological characteristics. Where it was possible to identify these grasses, oat (some probably the wild variety), bromes and rye grass were recorded.

A significant amount of hazel nut shell fragments were present with two hundred and sixty nine fragments recorded from this sample.

Discussion

Survival and preservation

The preservation of the archaeobotanical remains was variable. The majority of the charred macrofossils were generally relatively well preserved. However, most cereal grains were warped or exploded through charring and lacked identifying morphological characteristics. A significant amount was preserved well enough to still exhibit morphological characteristics and thus enable identification, even if only to species level.

Root / rootlet fragments were present in the sample, which indicated the disturbance of the archaeological feature, wither through close proximity of the deposit to the surface (e.g. exposing them to possible plough damage or bioturbation), or from deep root action through vegetation growing at the site. This disturbance is further confirmed through the presence of earthworm egg capsules and insect fragments within the sample.

Eating and drinking

Two groups of plant remains were most prominent in the assemblages: those likely to represent food waste of various kinds, and those originating in weeds likely to have been brought with cereal crops.

Cereals

This is a 'typical' medieval assemblage (Greig 1991) showing the cultivation and use of a range of cereals with free-threshing wheat the most abundant among the identified remains, but with rye, barley and oats also present in the sample. The four cereals in the samples may have been used for food (bread, pottage) and oats and barley for animal feed. Wheat was the preferred bread-making grain while poorer quality rye bread was consumed largely by the poor (Hammond 1995, 28). All the cereals, particularly barley, may have been used for ale and beer although poor grain preservation meant that it was not possible to establish if any had germinated as evidence for on-site brewing.

Indeterminate cereal grains dominated the sample with 2943 recorded. The majority of the identified grains were of wheat (*Triticum* sp.), mainly of the characteristic short broad shape of free-threshing wheat which could be either bread wheat (*Triticum aestivum*), or a second type of free-threshing wheat called rivet wheat (*Triticum turgidum*). A few wheat chaff fragments (rachis nodes and internodes) were found, and these are also consistent with the free threshing wheats.

Rye (*Secale cereale*) is likely to have formed a minor component of the crops present. It may have occurred, like the oats, as a crop weed, although it is known from documentary sources that rye was sometimes grown with wheat as a mixed crop of 'maslin'. Rye is a winter sown cereal and is tolerant of poor light soils, drought and temperature extremes. It will grow on sandy soils, which were available locally, where other crops would grow less well.

Remains of barley (*Hordeum* sp.) were less frequent than the wheat and preservation was poor – 22 grains were recorded. The grains were generally deformed or the surface had been lost, so it was not possible to characterise ear and row form. No chaff could be securely identified as barley due to poor preservation. While wheat is likely to have been the preferred food grain, barley sown as a spring grown crop could have been used as a supplement to wheat or made into ale. However, the idea of malting is not supported by evidence of sprouting on any of the grains.

Oats were also traditionally cultivated as a spring crop because they are not very frost hardy, and were sometimes planted with barley for use both as human food or animal fodder. Oats grow best on water-retentive soils such as loams and clays. They are valued for the high energy fodder they provide to livestock, particularly draught animals. Oats form an important source of animal feed, particularly for horses, but are also an important human food. Markham, writing in the 17th century, writes 'of the excellency of oats and the many singular virtues and uses of them in a family' (Markham 1668, 175-180) which include malt for ale, and as oatmeal used in place of salt, for a variety of foods including bread, oaten biscuits, haggis and greets, as well as animal feed. Many of the oat grains in the samples were in poor condition, but the recovery of some oat grains (17) with a detachment scar at the top suggests the presence of the hexaploid, common cultivated oat (*Avena sativa*). A few other pedicels showed the distinctive reverse scar of the 'sucker mouth' characteristic of the wild hexaploid oat (*Avena* sp.). Two floret bases with its characteristic disarticulation scar close to the lemna-base also confirmed the presence of cultivated oats. These may have been growing as crop weeds, along with brome (*Bromus* sp.), rye-grass (*Lolium* sp.) stinking chamomile (*Anthemis cotula*) and cleavers (Galium *aparine*) also found in the sample.

Parallel historical evidence for the later medieval period (Dyer 1989) shows that the actual food grains that were used varied according to what was available and were made into pottage.

Taphonomy
The cereals found here are almost all free threshing cereals, in which the grain is easily separated from the ear by first threshing. The grain is then winnowed to remove small light weed seeds and the light chaff. The grain would then be coarse sieved to remove the larger rachis fragments and the fine sieved to remove small weed seeds (Hillman 1981, Jones 1990). The chaff here consists only of small rachis fragments. In the cereal ear the rachis is the central stalk which in free threshing wheat has on average three grains attached to each segment (Jones 1990). In this sample the expected number of wheat rachis fragments to wheat grains falls well short of those found in the whole ear of cereal suggesting that some have been removed. In addition the cereal grains outnumber the weed seeds, which also suggests that this is cereal product. It is possible therefore that this deposit consists of threshed and winnowed grain partly cleaned for use but with the last contaminants remaining.

The deposit contains a mixture of grain and similarly sized weed seeds, such as grasses (POACEAE), which most likely represent the fine sieve product (i.e. the cereal grain and larger sized weed seeds retained by a fine sieve) in the crop processing sequence (Hillman 1981; 1984; 1985 and Jones 1984). Fine sieving was most likely performed just before milling (Jones 1984, 46) or some other use, such as malting or parching (Hillman 1981, 137). Large seeded weeds of crops were most likely removed by hand prior to preparing the grain for use in milling, parching, malting, cooking etc. (Jones 1984, 46). There was no sign of sprouting on the grains, so it does not seem to have been charred during roasting of the malt. It is therefore probable that the plant macrofossils represent the waste from a cooking accident. It is likely that this sample represents secondary deposition of domestic waste on site. The use of cereal processing waste as fuel is well attested (Hillman 1981; 1984; 1985; Jones 1984; van der Veen and Jones 2006) and the disposal of spent fuel either into features, or directly dumped onto the site seems a likely explanation for the formation of these deposits.

Weed / Wild taxa
Another, although indirect, indicator of cultivation is the proportion of remains of arable weeds that were found in most of the samples. Of the plant taxa recorded in the samples, goosefoot/orache, dock, stinking chamomile, corn marigold, and bedstraws all seem likely to have arrived as crop weeds, and the remains of various grass species such as rye grass and brome, identified only to genus, may also fall in this group. All these species would almost certainly have been brought to the site together with harvested cereals.

Hazel-nuts are valuable nutritionally, as well as being readily available. In addition, the nut shell is hard and resistant to decay ensuring its survival in some quantities. The hazelnut shells recovered are indicative of a food source being consumed, perhaps as a snack and their husks being added to the fires as a method of waste disposal.

Crop Husbandry
The cereals in the samples may grow in a range of soils although bread wheat and oats grow best on heavier soils and rye is often found on sandy soils while barley prefers lighter well drained soils. All the cereals in the samples may be sown in both autumn and spring although wheat and rye are usually winter sown.

The environment
A number of 'weed' seeds were present within some of the samples, and a limited amount of data can be gained relating to the surrounding environment. The largest percentage of the 'weed' seeds recovered probably originated from areas of cultivated ground; cornfields and arable land. Species such as *Bromus* (bromes), *Lolium* (rye-grass), *Chrysanthemum segetum* (corn marigold), *Anthemis cotula* (stinking chamomile), *Galium aparine* (cleavers), *Rumex* (docks) and *Cehenpodium/Atriplex* (goosefoot/orache), are examples of this. Species commonly found on waste or rough ground were the next most represented group, stinking chamomile and rye grass. The presence of trees / scrubland can be seen with the presence of hazel nuts and hawthorn.

It is likely that these remains are indicative of the surrounding environment, and were brought into the site with the cultivated cereal crops.

Comparable sites
In the Medieval period there is a shift in cereal use away from spelt, barley and emmer towards bread wheat, rivet wheat, barley, rye and oats (van der Veen 2013). These grains are all free threshing cereals. These are processed differently than the traditional hulled cereals, and often this is done away from the settlement. This means that the by-product of the harvest (weeds and chaff) are less frequently found within Medieval settlements. The composition of this sample seems to adhere to this hypothesis.

Comparisons with other sites in Wales suggest that it was fairly typical for Medieval rural and urban sites to be consuming predominantly oats, which completely differs from the results of this investigation. Recent work by the author at Llanbeblig Road, Caernarfon, Gwynedd (McKenna 2012) shows a dominance of oats with small amounts of barley and wheat also present. Work at Parc Bryn Cegin, Llandygai (Kenny 2008) also produced samples dominated by oats with barley, naked wheat and rye also present. Dark Age samples from Capel Maelog (Caseldine, 1990, p.102) and in a 12th century sample from Loughor Castle, West Glamorgan (Carruthers, 1994), both common cultivated oat (*A. sativa*) and bristle oat (*A. strigosa*) were present. A similar grain assemblage, containing oat, rye and bread wheat, was recovered from another early medieval site at Rhuddlan, North Wales (Williams 1985). The charred seeds of weeds of cultivated ground were also present, and had presumably been harvested with the crop. Other sites such as Ty Mawr were dominated by emmer and spelt wheat (Caseldine 1990) which also differs from the dominance of oat in samples dating to the Medieval period. Remains from medieval corn driers at Collfryn, Llansantffraid Deuddr, Powys (Jones and Milles 1984) were dominated by oats, and also quantities of seeds from common weeds of cereal fields, which must have been harvested together with the crop. These included brome (Bromus), amongst other species apparently indicating fields on acid and sandy soils.

Oats also dominate the record at Saxon and medieval sites in England, often forming the bulk of deposits or present as large deposits in association with barley, for example at late Saxon sites in Oxford (Robinson 2000; Pelling 2006), and similarly at sites in Ipswich (Murphy 1987; 1991). The preservation of oats in large quantities frequently appears to be a product of chance. An 11th century AD deposit of charred oats from Foundation Street in Ipswich (Murphy 1991) was found with a horse-shoe and spur suggesting that the deposit represented horse fodder which had been burnt by chance. As a crop oats were undoubtedly important in the late Saxon and medieval period, as supported by the historical evidence but their under-representation in relation to wheat and barley particularly and also rye is likely to be related to their common usage as a fodder crop and, therefore the reduced likelihood of them coming into contact with fire as a result of roasting prior to milling, or use in ovens.

Oats appear to be particularly prevalent in assemblages dating to the early medieval period onwards in northern England, Scotland and Wales (Greig 1991; Huntley and Stallibrass 1995; Carruthers 2010), which is probably due to it being particularly well suited to the wetter conditions and the shorter growing season of these areas (Moffett 2006).

Concluding remarks
A large number of seeds were present in the sample, and although the majority were recorded as indeterminate cereal (based on their morphological characteristics and shape), where identification was possible free threshing wheat dominated, with a small amount of rye, barley and oat grains. There was no sign of sprouting on the grains, so it does not seem to have been charred during roasting of the malt. There were small numbers of cereal chaff and weed seeds which would have been incorporated with the grain during the harvesting process, but due to the low numbers in comparison with the grains, it is unlikely that the sample represents the disposal of crop processing debris associated with threshing and winnowing, and instead represents the fine sieve by-product which is almost fully processed and ready to be used for milling, parching, malting, cooking, etc. The remains recorded here differ from those which are typical of Medieval period records of plant macrofossils in Wales. These are normally dominated by oats, with a small number of other species of cereal grains and chaff, as well as large quantities of grasses and seeds associated with cultivation.

As the plant remains were found together with charcoal remains, it may suggest that waste or spilt grain which did not make it into pottage were put on the fire with other rubbish and a small fraction became charred without burning up, and joined the domestic ash on the rubbish heap.

In terms of taphonomy, it is likely that this sample represents secondary deposition of charred plant remains. This probably occurred through intentional dumping. The use of cereal processing waste as fuel is well attested

(Hillman 1981; 1984) and disposal of spent fuel either into features such as pits or ditches/gullies or directly dumped onto the site seems a likely explanation for the arrival of this material on site. It is likely that this sample represents a single depositional event, possibly relating to either a spoilt grain store, an accident whilst drying the grains or the remnants of a meal. The preservation of the grains tended to be poor.

It is thought to be problematic using charcoal and plant macrofossil records from archaeological sites, as they do not accurately reflect the surrounding environment. Wood was gathered before burning or was used for building which introduces an element of bias. Plant remains were also gathered foods, and were generally only burnt by accident. Despite this, plant and charcoal remains can provide good information about the landscapes surrounding the sites presuming that people did not travel too far to gather food and fuel.

Recommendations

The sample has now been fully assessed, and any interpretable data has been retrieved. No further work is required. Any material recovered by further excavations at or in close proximity to the site, should be processed to 0.3mm in accordance with standardised processing methods such as Kenward *et al.* 1980, and the English Heritage guidelines for Environmental Archaeology.

Archive

All extracted fossils and flots are currently stored with the site archive in the stores at Gwynedd Archaeological Trust, along with a paper and electronic record pertaining to the work described here.

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Appendix V.3 Tables

Table V.3.1.1: Complete list of taxa recovered from sample 29, Hen Gastell. Taxonomy and Nomenclature follow Stace (1997).

Sample Number	**29**	
Feature Number		
Context Number	**2077**	
Feature Type	**Pit**	
LATIN BINOMIAL		**COMMON NAME**
Corylus avellana L. (fgts.)	269	Hazel nut shell fgts.
Chenopodium spp./ *Atriplex* spp.	48	Goosefoot / Orache
Polygonum spp.	3	Knotgrass
Rumex spp.	9	Dock
BRASSICACEAE	8	Cabbage family
Crataegus monogyna Jacq.	1	Hawthorn
Melilotus / Medicago / Trifolium	4	Melilots / Medicks / Clovers
Galium aparine L.	7	Cleavers
Anthemis cotula L.	1	Stinking chamomile
Chrysanthemum segetum L.	10	Corn marigold
CYPERACEAE	5	Sedge family
Carex spp.	2	Sedge
POACEAE (indeterminate)	15	Grass (Indeterminate)
cf. *Lolium* L.	3	Rye-grasses
cf. *Avena sativa* L.	17	Possible Cultivated oat
Avena sativa L. (awn fgts.)	5	Oat awn fgts
Avena satva L. (floret base)	2	Oat floret base
Avena spp.	37	Oat
cf. *Bromus* L. spp.	28	Bromes
Secale cereale L.	156	Rye
Secale cereale L. glume base	28	Rye glume base
Secale cereale L. rachis node	9	Rye rachis node
Hordeum spp.	22	Barley
Triticum spp.	349	Free threshing wheat
Triticum spp. internodes	17	Free threshing wheat internodes
Triticum spp. nodes	8	Free threshing wheat nodes
Triticum spp. spikelet fork	5	Wheat spikelet fork
Indeterminate cereal	2943	Indeterminate cereal
Indeterminate cereal glume base	2	Indeterminate cereal glume base
Indeterminate cereal detached embryo	6	Indeterminate cereal detached embryo
Indeterminate cereal culm node	8	Indeterminate cereal culm node
Indeterminate cereal chaff fgts.	14	Indeterminate cereal chaff fgts.
Unidentified	3	Unidentified

Table V.3.2: Habitats of plant macrofossils from Hen Gastell. (Habitat information based on Stace 1997)

HABITAT	Water	Waterside	Wet/ Damp Ground	Open Ground	Grassland	Cornfields/ Arable Land	Cultivated Ground	Waste Ground	Rough Ground	Hedgerow/ Scrub	Woodland Clearings/ Edge	Woodland	Acid Soils	
Latin Binomial														
Corylus avellana L.										x		x		Hazel
Rumex spp.				x	x		x						x	Sheep's sorrel
Galium aparine L.				x		x	x			x				Cleavers
Anthemis cotula L.						x		x	x					Stinking chamo-mile
Chrysanthemum segetum L.						x		x						Corn marigold
Carex spp.			x											Sedge
Lolium spp.					x	x		x	x					Rye-grass
Bromus spp.					x	x	x	x						Bromes

Table V.3.3. Components of the subsamples from sample 29, Hen Gastell
Semi quantitative score of the components of the samples is based on a four point scale, from '1' – one or a few remains (less than an estimated six per kg of raw sediment) to '4' – abundant remains (many per kg or a major component of the matrix).

Sample	29
Cut	2078
Deposit	2077
Feature type	Pit
Charcoal fgts.	4
Earthworm egg capsules	1
Insect fgts.	1
Plant macros. (ch.)	3
Root/rootlet fgts.	3
Sand	3

15. APPENDIX VI: Pollen Assessment

Dr Cath Langdon and Prof. R Scaife, Geography and Environment, University of Southampton with comment by James Rackham, Environmental Consultancy

Introduction

A pollen assessment has been carried out on two samples derived from buried soils beneath a probable medieval defensive bank at Hen Gastell, Caernarfon. The study was undertaken to establish whether sub-fossil pollen and spores are preserved and, if so, to provide some basic preliminary palaeo-environmental data.

Pollen method

Sediment sub-samples of 2ml volume were prepared using standard techniques for extracting and concentrating the sub-fossil pollen and spores (Moore and Webb 1978; Moore *et al*. 1992). Micromesh sieving (10 micron) was also used to aid removal of the clay and fine silt content. An assessment count of 300 pollen grains plus spores and other miscellaneous taxa was made where possible. Where preservation was poor smaller numbers only were obtained. Sample preparation was carried out in the Palaeoecology Laboratory of the School of Geography, University of Southampton. Results are tabulated below and presented as raw counts in table VI.1.

The pollen data

Context 2079 <sample 43>

The only tree pollen type included in pollen sample 2079 <43> is *Alnus* (alder) in relatively small quantities, meanwhile *Corylus avellana* type (hazel) and *Salix* (willow) appear with 1 and 2 grains recorded respectively. Herb pollen types in sample 2079 <43> are dominated by Lactucoideae (dandelion types) and grasses with some *Plantago lanceolata* and Cereal type pollen also relatively significant within the assemblage. Other herb pollen types present include Brassicaceae, Caryophyllaceae *Artemisia* and *Anthemis* types. Ferns (*Pteropsida*) are part of the spore assemblage with some *Polypodium vulgare* and *Pteridium aqulinum*. Sample preservation was generally poor as evidenced by the high values of robust Lactucoideae pollen although concentrations reasonable.

Context 2054 <sample 44>

Pollen preservation was generally very poor in context 2054 <44> and concentrations significantly lower than in the previous sample described. Again, the only tree taxon recorded was *Alnus* whilst 8 grass pollen grains were recorded and only a single cereal. Two herb pollen types were recorded, 1 Caryophyllaceae and 82 Lactucoideae, the latter attesting to the poor preservation of the sample.

Table VI.1. Pollen data – Hen Gastell

Pollen type	***Context 2079 <43>***	***Context 2054 <44>***
Alnus glutinosa	*4*	*1*
Corylus avellana type	*1*	
Salix	*2*	
Brassicaceae undiff.	*1*	
Hornungia type	*1*	
Caryophyllaceae	*2*	*1*
Bidens type	*1*	
Artemisia	*1*	
Anthemis type	*1*	
Lactucoideae	*188*	*82*
Plantago lanceolata	*7*	
Scrophulariaceae	*1*	
Poaceae	*87*	*8*
Cereal type	*14*	*1*

Pollen type	*Context 2079 <43>*	*Context 2054 <44>*
Large Poaceae >50 micron	*5*	*1*
Cyperaceae	*2*	
Pteropsida (monolete) undiff.	*7*	*5*
Polypodium vulgare	*4*	*1*
Pteridium aqulinum	*3*	
Unidentified degraded	*11*	
Total pollen	*330*	*94*

Interpretation
Due to the relatively poor nature of the pollen preservation only limited assumptions can be made about the surrounding environment. Context 2079 <43> provides the most detailed picture of the landscape during this time. Only a few *Alnus* (alder) type pollen grains perhaps represent alder growing regionally, whilst the presence of a relatively large amount of grass type pollen and a not insignificant number (14) of Cereal type pollen grains, which tend to have a limited range of dispersal, suggests that the environment was open with cereal cultivation local to the site. Other herbs that may be attributed to an open environment and perhaps also some pastoral activity include *Plantago lanceolata* and Caryophyllaceae. The abundance of Lactucoideae (dandelion types) is further evidence of an open disturbed environment although the abundance of this is also as a result of preferential preservation of this pollen type.

An open environment may also be inferred from context 2054 <44> due to the high quantities of Lactucoideae pollen present, just a single incidence of alder pollen and some grass type pollen. However, it is not possible to conclude further than this due to the poor nature of preservation in the sample and thus the paucity of pollen types present.

Summary and Conclusions

- Context 2079 <43> provided the most detailed information regarding the nature of the vegetation and suggests an open environment with some arable and pastoral activity close to the sampling site. Despite reasonable pollen concentrations in this sample preservation was generally poor.

- Pollen preservation, diversity and concentrations were quite poor in context 2054 <44> and as such it is difficult to make meaningful inference from this sample.

- Additional stratigraphic samples would normally be required to put these samples into further context. Counts of 400 or more grains per level should be made where absolute pollen numbers and suitable preservation permits. This would add greater taxonomic detail and statistical significance to the data. However with clear evidence for the poor and relatively poor preservation of pollen in both samples such additional work is not recommended unless better preservation can be found beneath the earthwork bank.

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Additional comments by James Rackham
The very high proportion of Lactuoideae pollen in both samples is a clear indication of poor preservation. Dandelion family pollen is resilient and robust and as other pollen degrades it concentrates in the deposit. With proportionately 87 and 57% in the two samples much pollen must have been lost from the deposits introducing an irresolvable bias against less robust pollen types. Under these circumstances further work on the deposit could not

be justified unless an area where, through local circumstances, pollen is better preserved could be located.

Despite this significant handicap these data can present an outline picture of the landscape. The biased data would indicate an open landscape of grasslands or pasture, with relatively few trees and shrubs. The cereal pollen indicates arable cultivation but could have been incorporated in the deposits from local crop processing activities being undertaken at the site, rather than adjacent cereal fields. Cereal pollen is heavy and its presence reflects local rather than long distance sources. Bearing in mind the preservational problems a relatively treeless landscape, with some evidence for cereal cultivation in the area is consistent with the medieval period but not sufficient to confidently ascribe such a date to the pollen assemblage in this palaeosol.

16. APPENDIX VII: Animal Bones

Nóra Bermingham, freelance animal bone specialist

Introduction

A small assemblage of mainly burnt animal bone was recovered from excavations at Hen Gastell, Llanwnda. Most of the bone was retrieved during wet sieving of soil samples taken from various features with 31 individual contexts represented within the assemblage. With the exception of a small number of teeth all of the bone recovered is unidentifiable to species, although is clearly animal rather than human in origin. Pig and cattle are represented by tooth fragments with the majority of fragments classified as unidentified mammal with medium and large-sized mammals represented in small amounts.

Methodology

A simple fragment count and weight (in grams) were used to quantify the assemblage. Unidentifiable elements were classified in terms of mammal size (UM: Unidentified Mammal; UMM: Unidentified Medium Mammal; ULM: Unidentified Large Mammal). Unidentifiable elements were also categorised as cranial and/or post-cranial in origin with the presence/absence of trabecular and/or cortical fragments also noted. Where possible, identifiable elements were recorded in terms of species, skeletal element, fragmentation and preservation. Identifications made with reference to Schmidt (1972), Hillson (1992) and the author's comparative collection. All data were catalogued using Excel and summary results tables are included below. An Excel spreadsheet of all data recorded has been provided separately.

Results

Animal bone was recovered from 31 individual contexts (Tables VII.1 and VII.2). A minimum of 491 small fragments and crumbs, weighing at least 172 g are represented. Most fragments measured less than 10mm long with a handful of fragments reaching up to 15mm. In general, however, the pieces were too small to allow for identification to species and/or skeletal element. The assemblage is poorly preserved with almost all of it burnt, specifically calcined. Unburnt tooth fragments occur in contexts 17 and 2003. The small size of the assemblage and its preservation mean that this material is of limited interpretative value. Nonetheless it demonstrates the presence of two major domesticates and is suggestive of general domestic waste.

Cattle and pig are represented in the assemblage by tooth fragments. Most other pieces, however, can only be categorised as UM, UMM and/or ULM. Fragments derive from both the head and body area suggesting animals (or carcases) rather than prepared joints for example were slaughtered and/or butchered on site. Given that most of the pieces retrieved are burnt to white, and also small in size, it is likely that this material represents general waste from domestic fires likely inadvertently redistributed across the site over its lifetime.

Despite the limitations of the assemblage it is apparent that conditions at Hen Gastell allow for the preservation of animal bone. The array of features from which bone was recovered suggests there is significant potential for additional bone finds to be made in future excavations at this site. Recovery may well be dependent on wet sieving but the small number of unburnt pieces retrieved demonstrates the potential for unburnt larger fragments to be recovered, albeit not necessarily in great numbers.

The assemblage is of limited interpretative value and its research potential has been realised by completing the analysis reported on here. A final decision on its retention or discard should be made pending results of any further excavations at the site and this decision should be recorded in the final report on the excavation itself. Should further excavations take place at this location and any new data should be combined with the existing results.

References

Hillson, S. 1992. Mammal Bones and Teeth. An introductory guide to methods of identification. Institute of Archaeology, London.

Schmid, E. 1972. Atlas of Animal Bones. Elsevier, Amsterdam, London, New York.

Tables

Table VII.1: Contexts inclusive of burnt bone.

Contexts with animal bone	Description
17	Fill of linear feature in bank
2002	Ploughsoil
2003	Remains of bank (possible)
2004	Remains of bank (possible)
2014	Post-pipe fill of posthole 2025
2015	Post-pipe fill of posthole 2001
2021	Stony deposit southside of bank
2023	Deposit against bank 2018
2024	Bank 2018 deposit
2036	Fill of possible pit 2035
2042	Fill of posthole 2041
2053	Fill of posthole 2052
2056	Fill of posthole 2055
2066	Fill of hollow 2067
2069	Fill of posthole 2068
2070	Post-pipe fill of posthole 2068
2071	Post-pipe fill of posthole 2053
2072	Post-pipe fill of posthole 2019
2075	Fill of pit 2076
2077	Fill of pit 2078
2079	Buried soil horizon 'A' under bank 2018
2082	Buried layer under bank
2088	Fill of posthole 2087
2090	Fill of pit 2089
2093	Fill of posthole 2092
2097	Post-pipe fill of posthole 2096
2098	Oxidised clay in base of cut 2078
2099	Basal fill of cut 2078
2101	Post-pipe fill of posthole 2083
2105	Post-pipe of posthole 2108
2120	Fill of posthole 2119

Table VII.2: Fragment count, weight and species representation from Hen Gastell.

Context	Find no.	Quantity	Weight	Element	Species	Preservation
17	152	1	1g	Tooth	**PIG**	Unburnt
17	17, 152	52	10g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2021	29	2	1g	Post-Cranial	UMM	Burnt (Calcined)
2002	52	20	11g	Cranial and Misc.	UMM/ ULM	Burnt (Calcined)
2003	73	4	1g	Tooth	**PIG**	Burnt (Calcined)
2003	74, 75, 77	1	12g	Mandibular Tooth	**PIG**	Burnt (Calcined)

Context	Find no.	Quantity	Weight	Element	Species	Preservation
2003	30	6	6g	Tooth	**COW**	Burnt (Calcined)
2003	47, 30	90	49g	Cranial, Post-Cranial and Misc.	UM	Burnt (Calcined)
2004	22	1	1g	Post-Cranial	UM	Burnt (Calcined)
2014	81	6	<1g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2015	76	3	<1g	Misc.	UM	Burnt (Calcined)
2023	48	5	<1g	Tooth	**COW**	Burnt (Calcined)
2023	33, 48, 80, 82	63	37g	Cranial, Post-Cranial and Misc.	UM	Burnt (Calcined)
2024	50	5	2g	Cranial	UMM/ ULM	Burnt (Calcined)
2036	78	8	<1g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2042	79	16	1g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2053	88	2	<1g	Misc.	UM	Burnt (Calcined)
2056	83	4	<1g	Misc.	UM	Burnt (Calcined)
2066	85	5	<1g	Misc.	UM	Burnt (Calcined)
2069	93	4	1g	Misc.	UM	Burnt (Calcined)
2070	42, 84	55	13g	Cranial, Post-Cranial and Misc.	UM	Burnt (Calcined)
2071	87	10	<1g	Misc.	UM	Burnt (Calcined)
2072	37, 86	8	3g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2075	89	3	1g	Misc.	UM	Burnt (Calcined)
2077	49, 92	4	1g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2079	90	15	1g	Misc.	UM	Burnt (Calcined)
2082	51, 91, 102	42	15g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2088	100	2	<1g	Misc.	UM	Burnt (Calcined)
2090	97	10	<1g	Misc.	UM	Burnt (Calcined)
2093	96	3	<1g	Misc.	UM	Burnt (Calcined)
2097	45, 99	3	1g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2098	94	1	<1g	Misc.	UM	Burnt (Calcined)
2099	95	2	<1g	Misc.	UM	Burnt (Calcined)
2101	98	3	<1g	Misc.	UM	Burnt (Calcined)
2105	153	30	4g	Post-Cranial and Misc.	UM	Burnt (Calcined)
2120	101	2	<1g	Misc.	UM	Burnt (Calcined)
Total		**491**	**172g min.**			

17. APPENDIX VIII: Metal Objects

17.1. Conservation

All iron and copper alloy objects were submitted to Cardiff Conservation Services, Cardiff University for x-raying. All the copper alloy objects were conserved and iron objects selected by Quita Mould as of importance were also conserved. The x-ray and conservation on the copper alloy objects was carried out in June 2015 (Lab No 6323) and the conservation of the iron objects was done in January 2016 (Lab No 6338). All the work was carried out by Phil Parkes.

Copper alloy objects

Lab No	Find No	Find Type	Description of conservation process
6323/01	18	Fragment of a rivet	Cleaned mechanically using a scalpel to remove overlying dirt and corrosion to reveal a smooth oxide layer.
6323/02	20	Strap end	One smaller fragment was cleaned mechanically using a scalpel to remove overlying dirt and corrosion to reveal a smooth oxide layer. The two larger pieces were re-adhered using HMG cellulose nitrate. Examination under a microscope showed that much of the surface had remains of fibres preserved against the copper alloy surface. The decision was made to leave these on the object prior to examination by a finds specialist, although it is likely that the fibres on one side are not in-situ but from burial against a fibrous material. The surface was fragile and could easily be damaged at the edges, so the whole was consolidated by application of a 7% Paraloid B72 (ethyl acrylate / methyl methacrylate co-polymer) in acetone applied by brush. The object is likely to be a strap end, folded over at one end but with the other side missing. The small fragment may be a part of this missing side as it has incised decoration matching that of the larger pieces. There is evidence of fibre remains on both sides of the 'strap end'. Following identification work could be carried out to remove overlying material from the decorated outer surface of the object to enhance the incised decoration if this was deemed necessary.
6323/03	32	Decorative mount	Cleaned mechanically using a scalpel to remove overlying dirt and corrosion to reveal a smooth oxide layer, damaged at the edges revealing metal core.
6323/04	34	Decorative mount	Cleaned mechanically using a scalpel to remove overlying dirt and corrosion to reveal a smooth oxide layer, damaged at the edges revealing metal core.
6323/05	64	Rivet shank	The object is extremely corroded, with little or no discernible metal core remaining from the x-ray. Examination under a microscope revealed small fragments of a gold coloured material on the surface of the object. A small sample was taken for examination using a scanning electron microscope with an electron dispersive x-ray analyser. The object was consolidated by application of a 7% Paraloid B72 in acetone applied by brush. The object appears to be the end of an object with a square cross-section tapering to a rounded point. Examination using the SEM-EDX showed that the object has a covering of gold (Au) as indicated by the spectra attached. Closer examination of the spectra shows that mercury (Hg) is also present, possibly indicating that the object may have been fire-gilded (Figures VIII.1.1 to 3).

Iron Objects

Lab No	Find No	Find Type	Description of conservation process
6338/01	28	Two objects, a broken knife tip and a fiddle key nail	Cleaned mechanically using an airabrasive machine with aluminium oxide powder to reveal a magnetite ($Fe3O4$) surface. Repackaged using plastazote foam and placed in a box with silica gel to maintain a low relative humidity environment. See Figure VIII.1.4.
6338/02	55	Small knife	Cleaned mechanically using an airabrasive machine with aluminium oxide powder to reveal a magnetite ($Fe3O4$) surface. A small knife with what appear to be mineral preserved organic remains on the tang, indicating possibly a wooden handle / grip. The object broke during cleaning due to the large corrosion blister on one side, but was readhered using approx. 30% Paraloid B72 (Ethylymethacrylate / Methylacrylate copolymer) in acetone. Repackaged using plastazote foam and placed in a box with silica gel to maintain a low relative humidity environment. See Figure VIII.1.4.
6338/03	103	Pin or rivet	Cleaned mechanically using an airabrasive machine with aluminium oxide powder to reveal a magnetite ($Fe3O4$) surface. The object was in two pieces. Two attempts to join the pieces were made, using approx. 30% Paraloid B72 (Ethylymethacrylate / Methylacrylate copolymer) in acetone but the join area is very small and did not survive handling. During cleaning the more pointed 'tip' of the object, to the left of the wire as seen in the box, disintegrated and could not be replaced. Repackaged using plastazote foam and placed in a box with silica gel to maintain a low relative humidity environment. See Figure VIII.1.4.
6338/04	154	Possible arrowhead socket	Cleaned mechanically using an airabrasive machine with aluminium oxide powder to reveal a magnetite ($Fe3O4$) surface. Repackaged using plastazote foam and placed in a box with silica gel to maintain a low relative humidity environment. See Figure VIII.1.4.

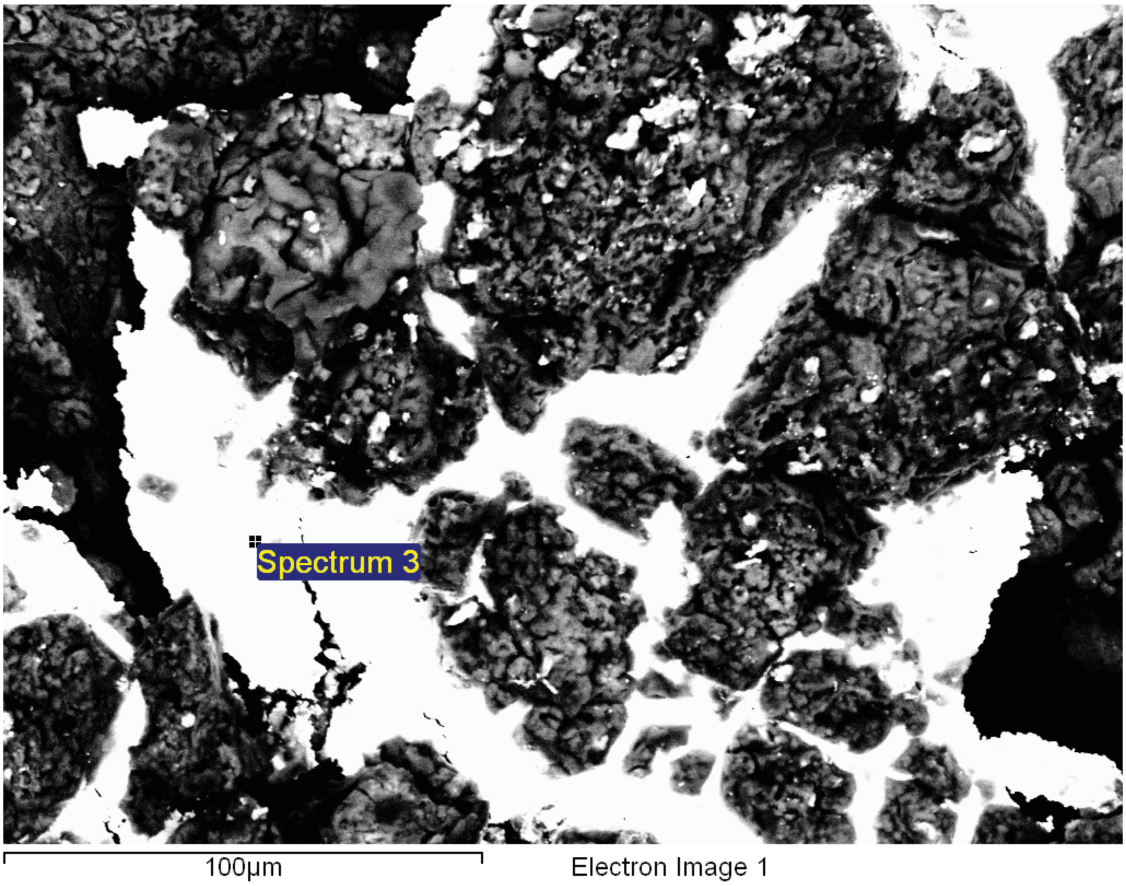


Figure VIII.1.1. Backscattered electron image of gold-coloured metallic remains on Hen Gastell object find no. 64, indicating location of sample spectrum.

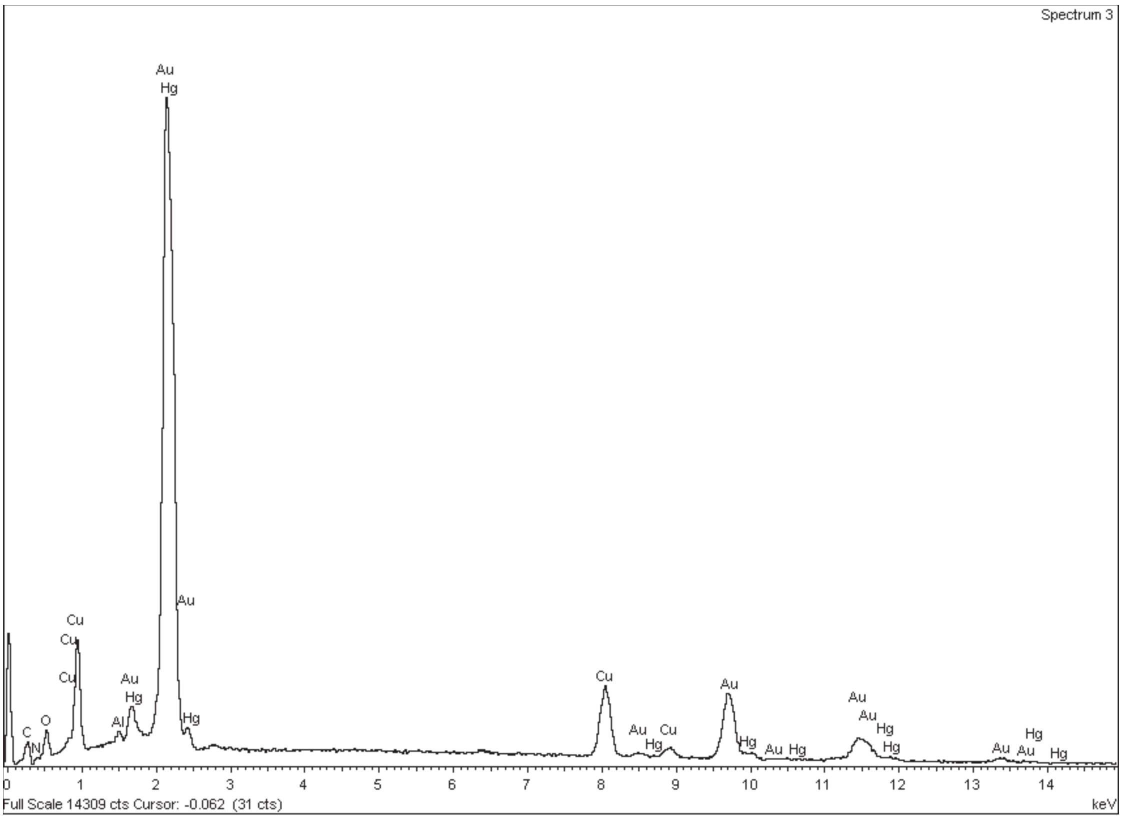
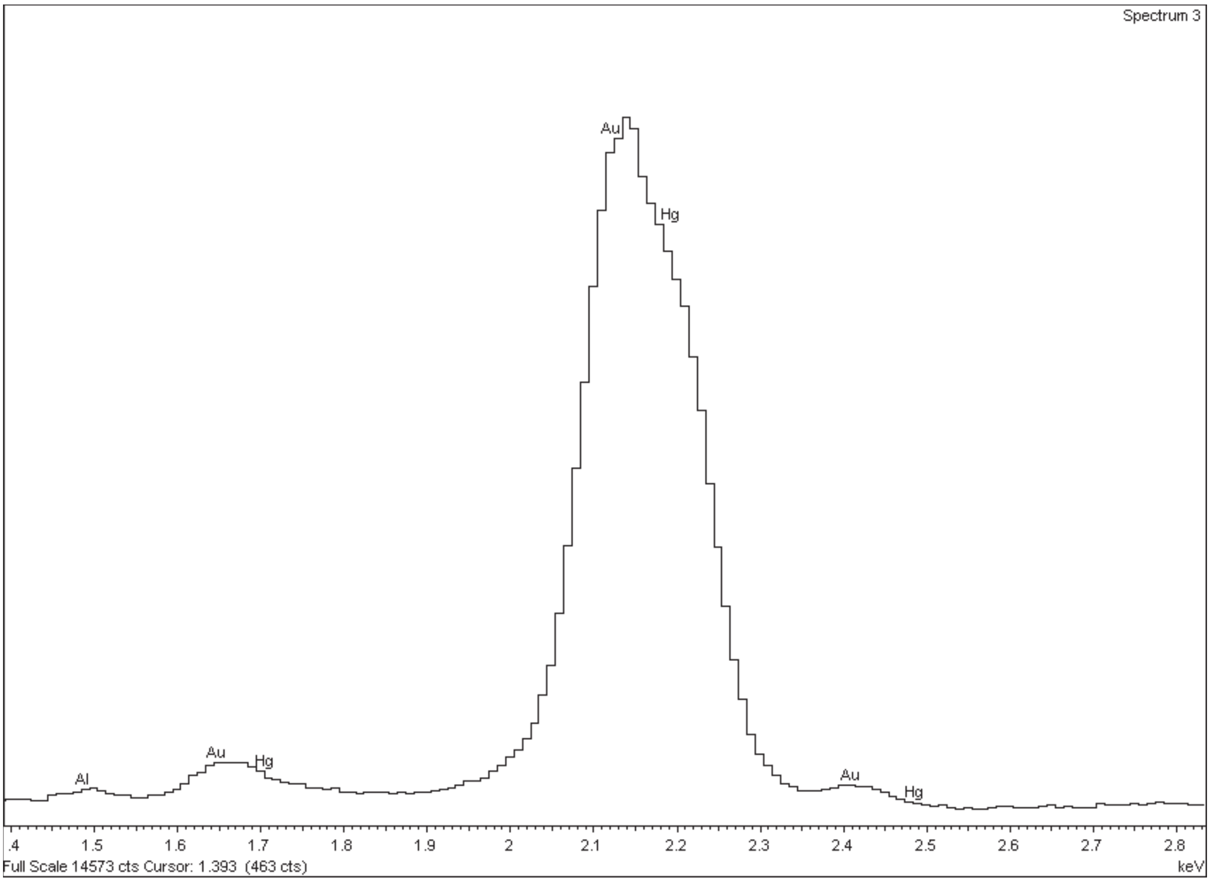


Figure VIII.1.2. Energy-dispersive x-ray spectrum of gold-coloured metallic remains on Hen Gastell object find no. 64.



.Figure VIII.1.3. Closer examination of the Au (gold) peak shows a 'shoulder' on the right hand side, indicating the presence of Hg (mercury).

Figure VIII.1.4. Images of iron objects

Find No 28: knife tip and fiddle-key nail

Find No 55: small knife

Find No 103: pin or rivet

Find No 154: possible arrowhead socket

X-rays of iron and copper alloy objects


J376


J377


J498

17.2. Assessment of the portable metal finds

Quita Mould, freelance finds specialist

Methodology
This assessment is based on examination of the material and the accompanying X-radiographs. A basic record of the material examined has been made and the catalogue appears as Table VIII.1. The information gathered has been correlated with the current contextual information available (Kenney with McKenna 2015) and the finds considered in the light of the specific aims of the project that have been supplied. In addition, it was requested that three copper alloy objects (SF20, 32, and 34) be fully catalogued and they have been fully recorded and discussed in the text below.

Condition
The material is currently packed in self-sealed polythene bags within air-tight storage boxes containing silica gel. The condition of the metal finds is recorded in the basic record. If a more detailed assessment of condition is required this should be commissioned from an archaeological conservator.

Basic quantification and provenance
76 objects from the site were examined and a basic record provided (Table VIII.1); they are quantified by material below.

Material	Count
Iron	37
Copper alloy	31
Lead	6
White metal	1
Silver	1
	76

The majority of the objects were recovered by metal detecting topsoil/turf in Trench 1 (2013 evaluation trench) and unstratified deposits in Trench 2 (the main excavation) and were clearly 19th or 20th century items principally occurring as a result of casual loss. A small number of metal detected items were datable to the 11-12th century, late medieval or early post medieval periods and are itemised below.
19 objects came from stratified contexts of potentially direct relevance to the interpretation of the site. The principal contexts are:

- Post holes 2005, 2052, large postholes 2068, 2108
- Metalworking pits (pit 2078, shallow hollows 2067 and 2081)
- Relict plough soil 2054 under inner bank 2116
- Slot 17 in inner bank
- burnt stone deposits 2003 and 2023 (over inner bank 2018)

Range and date of the material
***The stratified material*:**
Dress accessories: Two copper alloy mounts (SF32, 34) and a decorated strap end (SF20) of late medieval date (14^{th}-early 16^{th} centuries) are separately catalogued and discussed below (section 6), as requested. A small broken tip from a gilded copper alloy rivet/pin (SF64) came from fill (2080) of a hollow [2081] while a piece broken from a rivet cut from copper alloy sheet (SF18) came from a slot (17) in the inner bank in Trench 1. Two iron stem/ rivet fragments (SF103) from a metal mount or possibly pins/needles were recovered from fill (2105) of post void (2106) in post hole [2108].

Knives: A small knife (SF 55) was found in the upper fill of pit [2078] associated with metalworking activity. A fragment broken from the tip of a second example (SF28.2) was found along with a fiddlekey horseshoe nail

Illustration: It is suggested that the principal objects from stratified deposits be illustrated either by line drawing or good quality photography.

- copper alloy decorated buckle plate SF20 (2003)
- copper alloy mounts SF32 (2023) and SF34 (2054)
- iron knife SF55 (2077)
- iron fiddlekey horseshoe nail SF28 (2003)

Metallurgraphic analysis: The iron rectangular block/concretion (SF40) from shallow hollow [2081] associated with metal working should be considered along with the slag during metallographic analysis of the metalworking debris.

References

Clark, J. (ed.) 1995 *The Medieval horse and its equipment c. 1150-c. 1450. Medieval finds from excavations in London: 5*. London: HMSO

Kenney J. with R. McKenna 2015 *Evaluation of Scheduling Proposals 2014-2015 Hen Gastell, Llanwnda. Preliminary Excavation Report*. Gwynedd Archaeological Trust

(SF28.1) in a burnt stone deposit (2003) along with the copper alloy strap end (SF20).

Horseshoe nails: Four fiddlekey horseshoe nails of a type used with horseshoes of Clark's Type 2 (Clark 1995) and datable to the 11th-12th centuries were found in stratified deposits:

- SF28.1 and SF156 were found in a burnt stone deposit (2003)
- SF 38 upper fill (2072) of post void 2019 in post hole [2005]
- SF39 fill (2071) of post void 2074 in post hole [2052]

Timber nails: Two timber nails were recovered from stratified deposits and a broken shank from a third: SF43 from packing deposit (2069) in post hole [2068], SF145 from charcoal rich fill (2099) in the base of pit [2078] associated with metalworking activity, nail shank SF35 from a burnt stone deposit 2023 over bank [2018].

Concreted block: A rectangular block (SF40) weighing 438g with irregular surfaces, including an upstanding flange and a vertical slot or groove in one side, was found in fill (2080) of a shallow hollow [2081], probably a natural feature, thought to have possible relevance to metalworking on the site. Not an iron object, it would appear to be an iron-rich concretion formed in a rectangular sectioned depression. Tim Young (GeoArch) has suggested it 'may have been formed by accretion of iron-rich deposits in the corner of an organic container' (Kenney with McKenna 2015, 8) and this seems a likely explanation for its formation.

Bar iron: two small pieces of rectangular strip (SF155.1, 155.2) were found in the slag-rich fill (2066) of an irregular, shallow hollow [2067] adjacent to the feature [2081] containing the concreted block (SF40). Slag and other metal-working debris including remains of a 'smithing floor' and fragments of furnace lining (SF62) were present in the fill [2066] and it is likely that the strip fragments (SF155.1, 155.2) are pieces of bar iron (as defined by Ottaway 1992, 492-3) and also metal-working debris.

***The unstratified material*:**
The unstratified material comprised principally of coins and small personal items (buckles, buttons, badge, thimble, silver ferrule, modern key, heel irons) of chiefly 19th and 20th century date and apparently the result of casual loss. A smaller quantity of household items (furniture knob, window catch, window lead, copper alloy miscellaneous fittings) may suggest that some of the material derives from later occupation in the vicinity or brought in from elsewhere. Other unstratified finds included a mason's pick, tool handle tang, a modern spanner, broken horseshoes and a musket ball.

6 objects found unstratified in Trench 2 can be independently dated to the medieval or early post medieval period, and are listed below:

- 2 fiddlekey horseshoe nails (11th-12th century),
- 1 cuboid-headed horseshoe nail (14th-15th century)
- Socket possibly broken from a small arrowhead (medieval)
- Small rotary key and timber nail with faceted head (medieval/early post medieval)

Potential for analysis, suggested further work and costing
A basic record of the material accompanies this assessment and the majority of the finds will require no further work. It is suggested that the material from stratified deposits be summarised along with relevant independently datable items from unstratified deposits, to inform those writing the site narrative and for inclusion in any published site report as necessary. The detailed description and discussion of the copper alloy objects already selected (see below) will be incorporated into the summary text.

Investigative Conservation: Five items have previously undergone conservation (by Phil Parkes Cardiff Conservation Services). One further item would benefit from conservation the complete iron knife SF55 (2077) X-ray J376. The tip of the blade of this knife (SF55) is fractured but held in place within an iron corrosion blister. Conservation would allow it to be more easily illustrated (in consultation with X-radiograph J376).

X-radiography: A horseshoe nail (SF63) and two strip fragments (SF155.1, 155.2) were recovered from amongst metal-working debris during post-excavation processing. These items require X-radiography to confirm identification and provide a permanent record.

17.3. Summary of the portable metal finds from Hen Gastell

Quita Mould, freelance finds specialist

The majority of the objects were recovered from topsoil [001] in the metal detector survey (38 items) in the evaluation trench excavated in 2013 (Trench 1) and unstratified deposits in the main excavation (24 items) undertaken in 2014 (Trench 2). These finds comprised principally of coins and small personal items (buckles, buttons, badge, thimble, silver ferrule, modern key, heel irons) of chiefly 19th and 20th century date; all apparently the result of casual loss. A smaller quantity of household items (furniture knob, window catch, miscellaneous fittings of copper alloy, window lead) and tools (mason's pick, tool tang handle, spanner) were present deriving from early modern and recent occupation in the vicinity. Amongst this material was a small number of independently datable items of significantly earlier date relating to the medieval activity and these are described in the discussion below.

The building postholes

A single nail shank (SF43) was found in a packing deposit (2069) in posthole [2068], presumed to be associated with the use of the building and probably incorporated in the deposit when rubbish accumulated in the corners. Two fiddlekey horseshoe nails were found in post pipes, one (SF38) in the upper fill (2072) in posthole [2005] and the other (SF 39) in fill (20710) of post hole [2052]. Points from two fine, round-sectioned iron stems (SF103), from needles or pins were found in the fill (2015) of [2108], another posthole. These small items are likely to derive from backfilling of the postholes after the posts had been removed. As the backfill included burnt stones it is thought that it derives from the burnt stone deposit nearby and likely to be associated with the use of the building.

Smithing activity inside the building

Pit 2078: a small timber nail (SF145) was found in a lower fill (2099) and a small knife (SF55*) was found in the upper fill (2077) of pit [2078], thought as the base of a smithing hearth.

Hollows 2067 and 2081: The slag-rich fill (2066) of a hollow [2067] contained two fragments of rectangular-sectioned strip (SF155.1, 155.2) likely to be bar iron, as defined by Ottaway (1992, 492-3), and related to the smithing activity. A rectangular-shaped, iron-rich concretion (SF40) came from a shallow hollow [2081], located immediately adjacent. Tim Young (GeoArch) has suggested it 'may have been formed by accretion of iron-rich deposits in the corner of an organic container' (Kenney with McKenna 2015, 8) and this seems a likely explanation for its formation. It is discussed along with the slag in the metallographic analysis of the metalworking debris. The pointed tip broken from a triangular-sectioned stem of gilded copper alloy (SF64) came from the same deposit. The presence of gilding (Parkes 2015, UWC 6323/05) indicates it was broken from a prestigious decorative item.

Burnt stone deposits

Iron fiddlekey horseshoe nails (SF28.1, 63), the blade from a small iron knife (SF28.2), a decorated copper alloy strap end (SF20*[2]) and a small copper alloy mount (SF32*) came from the extensive deposits of burnt stone (2003 and 2023) found against the inner bank in Trench 2. A second decorative mount (SF34*), of the same type, came from a relict soil (2054) that lay directly below the burnt stone layer (2023) containing the other (SF32*), and they will be considered together below. A similar deposit of burnt stone (017) within a slot [018] in the inner bank contained the tip of a rivet made of copper alloy sheet (SF18). These deposits, containing domestic refuse and a small amount of smithing waste, and may be the result of the dumping of heat-fractured stone from cooking activities outside the building.

Dress accessories

A simple folded strap end of copper alloy sheet (SF20*) was found in a burnt soil deposit (2003) against the inner bank in Trench 2. Strap ends of folded sheet are a common type being the simplest form to produce, this example (SF20*) is relatively wide and has simple incised decoration. Of the examples from the City of London none came from contexts earlier than the late 13th century (Egan and Pritchard 1991, 129). The impression of woven textile present on both the interior and exterior surface may suggest that the strap end had been attached to a textile girdle, rather than a leather strap, but the large rivet holes would appear excessive if intended to rivet to anything other than a very coarse material. It may be that the fibres and textile impression are the result of post-depositional proximity to textile.

Two cast copper alloy mounts (SF32, 34) were found. One of the mounts (SF32) came from the burnt stone deposit

2 Objects marked with a star have been illustrated.

(2023) over the inner bank [2018] containing the strap end (SF20), the other (SF34) came from relict ploughsoil (2054) directly below. The mounts are of the same design and construction and are likely to have come from the same item. The mounts were essentially square-headed with decorative scalloped and nicked edges producing a four-armed or cruciform appearance but were heavily worn and the edges of the arms are now broken. They had been used to decorate a leather belt or other personal accessory.

Small pieces broken from the fixings of other decorative or personal items were also recovered. The pointed, triangular-sectioned tip from a pin stem or rivet shank of gilded copper alloy (SF64) came from fill (2080) of a hollow [2081]. Mercury and gold were present suggesting that the item had been fire-gilded (Parkes 2015, Lab No 6323/05) indicating that the item had been decorative and expensive. Another tip from a rivet cut from copper alloy sheet (SF18) came from a burnt stone deposit (017) in the inner bank in Trench 1. In addition, two pointed tips (SF103) broken from fine stems from iron mounts or possibly needles or pins were recovered from fill (2105) of post void [2106] in post hole [2108].

Small decorative mounts such as these were commonly used to decorate a range of personal dress accessories and leather fittings for horses, dogs and hawks in the later medieval and early post-medieval periods across north Western Europe (Egan and Pritchard 1991; Willemsen and Ernst 2012). In general it can be said that small decorative metal mounts were at their most popular in the late 14th, 15th and 16th centuries (Willemsen and Ernst 2012, 14). These items being small, worn and often fragmentary, may suggest that the deposits in which they were found had been subject to re-working.

Horseshoe related items
Four fiddlekey horseshoe nails of a type used with horseshoes of Clark's Type 2 (Clark 1995) and datable to the 11th-12th centuries were found in stratified deposits: two (SF28.1* and SF156) found in a burnt stone deposits (2003, 2023) and two (SF38, 39) in post pipes of post holes [2005, 2052] in the building. Two further examples (SF25.4, 25.5) and a cuboid-headed example (SF25.6), dating slightly later to the 14th-15th century were found unstratified in Trench 2. The right branch broken from a small horseshoe (SF68.2) was found during the metal detector survey of topsoil (001).

Knives
Two small knives were found; a complete example (SF55*) came from the upper fill (2077) of the base of a smithing hearth [2078], the blade of a second (SF28.2), broken before the tang, came from a burnt stone deposit (2003) found against the inner bank in Trench 2.

Other items from the main excavation
Iron objects found unstratified in Trench 2 may come from later medieval or early post-medieval activity. A small conical, iron socket may be broken from a small arrowhead (SF154) and is potentially of medieval date. A small iron rotary key (SF25.3) with a round bow with a simple collar moulding beneath is likely to be of medieval or early post medieval date but, being broken across the bit, now lacks the diagnostic features that would allow more accurate dating. Similarly, a timber nail with a faceted, rectangular head (SF25.12) is of a type with the same time span; a relatively common form, nails of this type were found at Berry Pomeroy Castle Devon for example, built in the 15th century and abandoned at the end of the 17th (type 3 Mould 1996, 252 and figure 74, no 19).

Dating
Radiocarbon dating indicates that use of the inner platform lasted no more than three or four generations sometime in the 11th and 12th centuries (Kenney 2016, 5). The fiddlekey horseshoe nails are contemporary with this, however, other items of metalwork found would suggest some later activity, see above. These include the dress accessories and the cuboid-headed horseshoe nail. Other items such as the key (SF23.5) and the potential arrowhead socket (SF154 formerly 25.8) might also fall into this category.

Catalogue of illustrated items
Iron knife. Small knife with straight back and edge tapering to a pointed tip. Complete. Encrusted with corrosion blister at the tip. Length 73mm, blade length c. 42mm, width 14mm, back thickness c 6mm. G2246 SF55 Context 2077 pit 2078 (X-ray J376).

Iron horseshoe nail. Fiddlekey nail with crescentic head of rectangular section and short, straight shank. Length 32mm, head 17x5mm. G2246 SF28.1 Context 2003 (X-ray J376).

Copper alloy strap end SF20
Broad strap end of folded sheet 0.5mm thick, folded widthways, one side survives largely intact with a pair of large rivet holes, 3mm in diameter, at the open end and broken across a third. The second side has been broken off close to the fold but a small triangular fragment of it survives. The upper face has crudely incised decoration comprising two triangles infilled with cross hatching; similar decoration is present on the fragment. The impression of woven textile is visible on the inner face and fibres are present on both the outer and inner faces. Incomplete, fractured. Mechanically cleaned and consolidated. Length 30mm, width 23mm. Fragment 13x8mm. G2246 SF20 Lab No UWC 6323/02 Trench 2 context 2003 (x-ray J377).

Copper alloy mount SF32
Small cast mount with cruciform head and integral round-sectioned rivet. The shank is flat ended. The flat head has four arms each springing from a concave, curving side into a broad, pointed tip flanked by a pair of small projections at the base. None of the four arms are now complete as the edges have been lost through wear. The head has a gently curved profile and is undecorated. Almost complete. Head 13x13mm, shank length 9mm, diameter 3mm. Mechanically cleaned. G2246 SF32 Lab No UWC6323/03 Trench 2 context 2023 (X-ray J377).

Copper alloy mount SF34
Small cast mount with cruciform head and integral round-sectioned shank, slightly bent over and flattened at the end from hammering. The flat head has a slightly curved profile with concave curving sides with the remains of four arms with paired projections at their base at each corner. Almost complete. Head 13x13mm, 1mm thick. Shank length 8mm. G2246 SF34 Lab No UWC 6323/04 Trench 2 context 2054 (X-ray J377).

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17.4. Table VIII.1. Basic record of metal objects

Find No	Context No	Material	Name	Description	Condition	Completeness	Length (mm)	width (mm)	thickness (mm)	diameter (mm)	X-ray No	Metal detected	Lab No	Comment
01	001	Iron	buckle frame	Square frame of square section	encrusted, fissured	complete	36	6	6		J376	MD		post medieval
02	001	Copper alloy	button	Discoidal button with plain, flat head with no surface decoration visible, broke loop shank broken set into low cone seating	good	almost complete				22		MD		probably 18th century
03	001	Copper alloy	coin	Half penny 1951 George VI	good	complete						MD		20th century
04	001	Copper alloy	fitting	T-shaped fitting of sheet c 2mm thick with T-shaped head of dished section with a strap projecting at a right angle with its end pierced by a large central rivet/nail hole	good	complete	head 56, arm 48	head 12, arm 13	2			MD		20th century
05	001	Copper alloy	coin	Penny 1935 George V	good	complete						MD		20th century
06	001	Copper alloy	badge	discoidal badge with flat round head with traces of yellow and red enamelled surface and recessed border. Integral shank with crescentic head stamped BRAM MEDAL BD Co LTD ALBION BIRMINGHAM	good	complete				19		MD		probably 20th century
07	001	Copper alloy	coin	Penny 1948 George VI		complete						MD		20th century
08	001	Copper alloy	key	Yale lock key with pierced disc head and stem now bent at a right angle, head stamped UNION made in England		complete	47 (bent)	head 24				MD		20th century
09	001	Copper alloy	coin	comparable size to a Georgian half penny, little surface detail visible, very heavily worn		complete						MD		probably late 18th/19th century
10	001	Copper alloy	coin	Three penny piece 1944 George VI		complete						MD		20th century
11	001	Copper alloy	coin	Penny 1910 Edward VII		complete						MD		20th century
12	001	Copper alloy	coin	Penny 1991 Elizabeth II		complete						MD		20th century
13	001	Iron	nail, timber	fractured timber nail with rectangular sectioned faceted head and rectangular shank with the tip broken	encrusted, fissured, fractured	almost complete	56+	13	7		J376	MD		late med/post medieval
15.1	001	Copper alloy	coin	Half penny 1920 George IV		complete						MD		20th century

Find No	Context No	Material	Name	Description	Condition	Completeness	Length (mm)	width (mm)	thickness (mm)	diameter (mm)	X-ray No	Metal detected	Lab No	Comment
15.2	001	Copper alloy	thimble	thimble of thin sheet with machine made indentations, now broken and distorted		incomplete	height 21+			head 11		MD		probably 19th century
18	17	Copper alloy	rivet, sheet	slightly tapering narrow strip broken at each end and slightly curving in profile, tip of a rivet/shank made sheet metal		incomplete	8+	3	1		J377		UWC 6323/ 01	
20	2003	Copper alloy	strap end	Broad strap end of folded sheet, upper face decorated with two opposing incised triangles with cross hatching. Impression of textile on interior, fibres present adhering to exterior	conserved	incomplete	30	23	0.5		J377		UWC 6323/ 02	
23.1	U/S Tr 2	Copper alloy	coin	no surface detail visible, of comparable size to a 20th century farthing	good	complete				21		MD		post medieval
23.2	U/S Tr 2	Copper alloy	button	small discoidal button with gilded head with narrow border, no other surface decoration visible, and alph-type loop shank. Back stamped TREBLE GILT STD COLMS & JD	good	complete				16		MD		19th/20th century
25.1	U/S Tr 2	Iron	spanner	spanner with square head of rectangular section with straight, slightly expanded and round ended handle with central tapering tear-drop shaped cut out	encrusted	complete	100	handle 17, head 21x21			J375	MD		20th century
25.2	U/S Tr 2	Iron	handle	round sectioned rod-like handle flattened at one end, now broken, the other end turns at a right angle and is broken across a bifurcated end.	encrusted, slightly flak-ing, corrosion blister	incomplete	107+			stem 9	J375	MD		
25.3	U/S Tr 2	Iron	key	small rotary key with remains of broken round bow with simple collar beneath and stem broken across the bit	encrusted, cor-rosion	incomplete	35+		bow 14		J375	MD		med/post medieval
25.4	U/S Tr 2	Iron	nail, horseshoe	fiddlekey nail with straight shank, tip now missing	encrusted, fis-sured	almost complete	22+	17	8		J375	MD		11th-12th century
25.5	U/S Tr 2	Iron	nail, horseshoe	fiddlekey nail with gently curved shank, tip now missing	encrusted, flaking	almost complete	33+	15	7		J375	MD		11th-12th century
25.6	U/S Tr 2	Iron	nail, horseshoe	cuboid headed nail with broken shank	encrusted, fis-sured	almost complete	21+	15	12		J375	MD		late medieval (14th-15th century)

Find No	Context No	Material	Name	Description	Condition	Completeness	Length (mm)	width (mm)	thickness (mm)	diameter (mm)	X-ray No	Metal detected	Lab No	Comment
25.7	U/S Tr 2	Iron	stem	round sectioned stem tapering to a point, other end broken	encrusted, flaking	incomplete	50+			7	J375	MD		
25.9	U/S Tr 2	Iron	heel iron	left branch of heel iron with plano-convex section, straight ended with two long rectangular nail holes visible in radiograph	encrusted	incomplete	56	12			J375	MD		post medieval
25.10	U/S Tr 2	Iron	nail, timber	medium nail with flat round head and square sectioned gently curving broken shank	encrusted	incomplete	112+			head 16	J375	MD		
25.11	U/S Tr 2	Iron	nail, timber	medium nail with round flat head and rectangular sectioned curving shank with straight tip	encrusted, flaking	complete	72			head 17	J375	MD		
25.12	U/S Tr 2	Iron	nail, timber	medium nail with slightly bent rectangular shank broken before the tip and faceted rectangular head flattened from being hit	slightly encrusted, flaking	almost complete	67+	head 12	head 8		J375	MD		
25.13	U/S Tr 2	Iron	nail, timber	nail with round flat head and rectangular sectioned straight shank	encrusted, slightly flaking	complete	54	head 12			J375	MD		
25.14	U/S Tr 2	Iron	nail, timber	nail with clenched broken shank and small probably rectangular faceted head	encrusted	almost complete	34+	head 10	head 6		J375	MD		late med/post medieval
25.15	U/S Tr 2	Iron	nail shanks	4 straight nail shank fragments from timber nails ranging from 30-43 mm in length	encrusted, flaking	incomplete					J375	MD		
25.16	U/S Tr 2	Iron	fragment	fragment of thick triangular section, little metal visible in radiograph, no diagnostic features	encrusted	incomplete	35	17	12		J375	MD		
27	U/S Tr 2	Lead	spillage	solidified droplet with circular impressed channel in upper surface resulting in a slightly raised disc shaped area. Wt 16g			32	25	3			MD		
28.1	2003	Iron	nail, horseshoe	fiddlekey horseshoe nail with crescentic head of rectangular section and straight rectangular sectioned shank	encrusted	complete	32	head 17	5		J376			11-12th century
28.2	2003	Iron	blade	fragment of small blade with triangular section with straight back dropping to the straight edge at a blunt tip, broken before the tang	encrusted, corrosion blisters	incomplete	35+	13	back 4		J376			

Find No	Context No	Material	Name	Description	Condition	Completeness	Length (mm)	width (mm)	thickness (mm)	diameter (mm)	X-ray No	Metal detected	Lab No	Comment
32	2023	Copper alloy	mount	cast decorative mount with flat cruciform head and integral round sectioned, flat-ended rivet. Head is gently curved in profile	conserved	almost complete	head 13	head 13			J377		UWC 6323/ 03	
34	2054	Copper alloy	mount	cast decorative mount with flat cruciform head, arms now broken, and integral round sectioned, flat-ended rivet. Head is gently curved in profile.	conserved	almost complete	head 13	head 13			J377		UWC 6323/ 04	
35	2023	Iron	nail, timber	rectangular sectioned nail shank with pointed tip	encrusted	incomplete	22+				J376			
38	2072	Iron	nail, horseshoe	fiddlekey horseshoe nail with crescentic head of rectangular section and straight rectangular sectioned shank with tip broken	encrusted	almost complete	23	17	8		J376			11th-12th century
39	2071	iron	nail, horseshoe	fiddlekey horseshoe nail with crescentic head of rectangular section and straight rectangular sectioned shank	encrusted	complete	37	19	7		J376			11-12th century
40	2080	Iron	concretion	rectangular block with straight sides, base has an irregular depression, irregular upper face apparently with a broken upstanding flange around two of the sides and an irregular vertical slot or deep groove in one of the shorter sides. Sooty/charcoal rich deposit on the surface. Probably an iron-rich concretion collected in a rectangular man-made hole. Wt 439g not encrusted			84	58	47		J377			
43	2069	Iron	nail, timber	clenched shank tapering to a pointed tip	encrusted	incomplete	50		10		J376			
55	2077	Iron	knife	small knife with centrally placed tang and blade with straight back and edge tapering to a pointed tip	encrusted, corrosion blister	complete	73, blade 42	blade 14	back 6		J376			medieval
59	2002	Lead	sheet	small piece folded sheet Wt 4g	soil adhering	incomplete	23+	11+	1					
60	001	Silver	ferrule, collar	small collar ferrule of thin sheet from tip of walking cane (remains present within), made in Birmingham 1895	good	complete		13		12		MD		19th century

Find No	Context No	Material	Name	Description	Condition	Completeness	Length (mm)	width (mm)	thickness (mm)	diameter (mm)	X-ray No	Metal detected	Lab No	Comment
64	2080	Copper alloy	rivet shank	pointed tip broken from a small shank or rivet of triangular section, other end broken. Gold detected suggesting originally gilded	conserved	incomplete	7	4			J377		UWC 6323/ 05	
68.1	001	Iron	pick	heavy square-sectioned shank tapering to a rectangular sectioned relatively narrow blade, the flat head is burred. Probably a mason's pick	slightly en-crusted, surface flaking	complete	175	head 27, shank 20	head 25, shank 20		J377	MD		19th/20th century
68.2	001	Iron	horseshoe	right branch of horseshoe broken across the arch with straight-ended flat heel, 4 small rectangular nail holes each 5x4mm, no fuller	encrusted, flaking	incomplete	110	30			J376	MD		post medieval
68.3	001	Iron	heel iron	left branch of heel iron with plano-convex section tapering slightly to a blunt tip, with 3 rectangular nail holes 2 with shanks in situ	encrusted, flaking	incomplete	80	13			J376	MD		post medieval
68.4	001	Iron	buckle	square frame of round section with buckle pin (now bent) wrapped around the frame	slightly en-crusted, surface flaking	complete	36		5		J376	MD		post medieval
68.5	001	Iron	tang, tool	round sectioned tang handle, now broken, with a thickened shoulder and beginning of a round sectioned stem	slightly en-crusted, surface flaking	incomplete	76+	shoul-der 11, tang 7			J376	MD		post medieval
68.6	001	Iron	sheet	c 5 flat sectioned sheet fragments, 2 with a rolled rim, likely to come from a galvanised bucket or similar	poor	incomplete			0.5	rim 8	J376	MD		19th/20th century
69.1	001	Copper alloy	button	Discoidal button with alpha type loop shank, no surface detail visible on head	good	complete	shank 5			20		MD		19th century
69.2	001	Copper alloy	button	Discoidal button with edges of head broken in places and cone shank with loop missing. Upper face tinned	good	almost complete				30		MD		probably 18th century
69.3	001	Copper alloy	button	four hole button with dished centre and flat flange. Flat stamped with raised lettering NOT CUT THREAD LONDON	good	complete				16		MD		19th/20th century
69.4	001	Copper alloy	sheet	fragment all edges broken with 2 angular nail holes present, 1 with iron corrosion products within		incomplete	44+	32+	1			MD		

Find No	Context No	Material	Name	Description	Condition	Completeness	Length (mm)	width (mm)	thickness (mm)	diameter (mm)	X-ray No	Metal detected	Lab No	Comment
69.5	001	Copper alloy	knob, furniture	cast circular knob with recessed head to hold a separate decorative rondel, now missing, concave neck and small circular base with broken iron shank	good	almost complete	21+			head 26		MD		post medieval
69.6	001	Copper alloy	window catch	cast window catch with rectangular sec-tioned, right angled shank with spherical knop terminal with concentric decorative mouldings	good	complete	59	height 41				MD		probably 19th century
69.7	001	Copper alloy	cartridge cap	sheet metal cap with central hole stamped ELEY BROS LONDON	poor	almost complete				21		MD		20th century
69.8	001	Copper alloy	sheet, folded	small fragment of folded sheet with rolled rim and corrugated profile		incomplete	33+ (fold-ed)	13+	>0.5			MD		
69.9	001	Copper alloy	fitting	cast fitting of plano-convex section expand-ing into a semi-circular straight ended termi-nal of differing size at each end connected by a short neck.	poor	complete	20	18				MD		post medieval
70.1	001	Lead	window lead junc-tion	2 flattened pieces lead, with all edges broken, and a piece of glass 3mm thick sandwiched between. Wt 5g		incomplete	22+	15+	>1			MD		post medieval
70.2	001	Lead	trimming	triangular sectioned trimming with slightly curved profile, likely to be cut from a win-dow lead. Wt 4g			38	8	4.5			MD		post medieval
70.3	001	Lead	sheet	small fragment of folded sheet Wt 2g		incomplete	15+	13+	1			MD		
70.4	001	White metal	spillage	thin white metal spillage Wt 1g			22	18	7			MD		20th century
71.1	001	Copper alloy	coin	Penny 1916 George V		complete						MD		20th century
71.2	001	Copper alloy	coin	Penny 1883 Victoria		complete						MD		19th century
72	001	Lead	musket ball	Wt 38g	good	complete				19		MD		post medieval

Find No	Context No	Material	Name	Description	Condition	Completeness	Length (mm)	width (mm)	thickness (mm)	diameter (mm)	X-ray No	Metal detected	Lab No	Comment
103	2105	Iron	stem/rivet	2 fine round sectioned stems each broken at one end and tapering to a pointed end at the other. Broken from needle/pin stems or fine rivets/shanks for metal mounts	encrusted	incomplete	11+			1.5		from soil sam-ple 42		
145	2099	Iron	nail, timber	small timber nail with flat round head and short shank with the tip now missing	encrusted	almost complete	21+			head 14		from soil sam-ple 33		
154	U/S Tr 2	Iron	socket ?arrow-head	small tapering round sectioned socket, potentially from a small arrowhead	encrusted, cor-rosion blister	incomplete	34+			9	J375	MD		medieval
155.1	2066	Iron	bar iron	fragment rectangular sectioned strap/strip with straight sides, one end broken, other appears rounded, slightly curved in profile. Found in metalworking debris likely to be offcut of bar iron	encrusted, fis-sured, flaking	complete	46+	20	5					
155.2	2066	Iron	bar iron	fragment of straight sided strap/strip of rect-angular section tapering in thickness at one end which is blunt, other end is straight and slightly burred over. Found in metalworking debris likely to be offcut of bar iron	encrusted, flak-ing, corrosion blister present	complete	46+	16	7					
156	2023	Iron	nail, horseshoe	fiddlekey horseshoe nail with crescentic head of rectangular section and curved shank	encrusted, flaked at head	complete	25	head 17	8					11-12th century

18. APPENDIX IX: Archaeometallurgical residues

18.1. Assessment of archaeometallurgical residues

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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 examined materials are listed in Table IX.1.

Results

Description of residues

The submitted materials amounted to an overall total of approximately 7.9kg. The macroscopic collection comprised approximately 900 counted items, with a total weight of 6.1kg, of which approximately 4kg proved to be archaeometallurgical residues in the strict sense (i.e. large after exclusion of concretions and a few pieces of natural rock).

Preservation of the residues was generally good.

Smithing slags

The smithing residues could broadly be divided into two categories – smithing hearth cakes (SHCs) and blebby slags containing much partially melted sandy and gravelly sediment.

The SHCs were generally well-formed, just slightly concavo-convex, dense slag cakes of small size. Included within this category are smaller slag masses, broadly plano- to concavo- convex, but which are too small to have fully developed the morphology of a typical SHC. These may be interpreted as incipient SHCs, limited in size by the amount of slag generated in the hearth. These have been loosely and informally termed proto-SHCs in this account. Taking these and the well-formed SHCs together, there were six reasonably complete examples, weighing 306g, 168g, 104g, 84g, 80g and 72g. The 306g example was a composite cake, including a moderately small SHC attached at its base to an inclined sheet of slag (either an earlier SHC, or perhaps a long-term build-up of slag on the wall/floor of the earth. In addition there was part of a much larger SHC, with a weight of 754g, that might be extrapolated to an original weight in the order of 1kg. This larger cake had a very porous internal structure, with a particularly large void just below the upper surface.

The blebby, gravelly, clinkery slags had clearly formed separately from the SHCs, but they too are assigned to the smithing process. Similar slags have been recorded from other sites with low-level hearths on gravelly substrates, both of medieval (e.g. Exminster, Young 2014b) and Roman (e.g. Neath, Young 2013, 2014b) age. Although a small amount of coal was recorded from the site, there was none from the main forge area 9it occurred mainly in isolated pit [2035] and the clinkery appearance of the slags is attributed to the partial melting of a slightly aluminous substrate.

The SHCs comprised approximately 49% of the macro-residue assemblage by weight and the clinkery slags 39%.

Indeterminate residues

There was a variety of slag that was not easily attributable to the classes of slag described above. This indeterminate material comprised approximately 10% of the macroscopic assemblage by weight. Most of the material referred to this class was in the form of fragments too small to be attributed to the other classes, but a small proportion was of small slag blebs and prills. The use of 'y' in Tables IX.2 and IX.3 indicates the presence of indeterminate comminuted slag in the sieved resides samples.

Hearth lining
There were only a few fragments of hearth lining present (2% of the macro-residue assemblage by weight). The only significant piece was part of a blowhole or tuyère from deposit (2003). This piece showed part of the curving margin of the bore, which suggested a diameter of approximately 35-40mm. The presence of tiny blebs, apparently of slag spatter, on the inside of the bore suggest it was open, but the diameter is unusually large for a smithing hearth (more typically the diameter is in the range of 15-30mm) and the possibility that the ceramic was packed around a metal tuyère cannot be discounted.

Glazed stone
The assemblage included numerous examples of small particles of rock, mainly of gravel grade, that have been glazed by heating in the hearth under the fluxing influence of the fuel ash, but which have not undergone partial melting and incorporation into clinkery slag.

Micro-residues
The true micro-residues included, dominantly, flake hammerscale, with lesser quantities of spheroidal hammerscale. The coarser micro-residues included examples of slag spheroids, slag blisters and slag flats.

Hammerscale is associated with the superficial oxidation of iron at high temperature (Young 2014), with spheroidal hammerscale typically indicative of the process of forge (or fire) welding. Slag spheroids are droplets of smithing slag that cooled within the fuel bed of the hearth, without amalgamating into a large mass. Slag blisters are probably mostly formed as flake hammerscale, but are lifted off the surface of the underlying metal by build-ups of gas. Slag flats are thin skins of slag that, in this case, can be attributed to two distinct origins. Firstly they form as veneers of slag on boulders or cobbles that extend into the hearth pit. This type is characterised by a concave basal fracture. The second type forms by the adherence of slag to either the work piece or to the smith's tools. In the latter case, the presence of slag films with a right angle bend are common – having formed in contact with the tips of the smith's tongs or poker.

The true micro-residues are accompanied in almost all case by finely comminuted slag debris, derived by the fragmentation of the macroscopic slags.

'Smithing floor'
The term 'smithing floor 'is applied to concretionary material dominantly or entirely formed by the cementation of fine debris from the smithing process (hammerscale, fine slag fragments and droplets, charcoal…). Most commonly, this material was cemented by the corrosion of small included iron particles, and this appears to be the case with the present material. Although a characteristic material of the floor of a smithy (hence the name), the material may also form in other accumulations of fine-grained smithing debris, such as waste pits.

Iron
Three iron artefacts were recorded, two fragments of this iron bar and one small nail. Corrosion products from the weathering of iron were also common in the micro-residue collections, but are not always indicated unless certain on the data tables, because of the similarity with iron oxide crusts formed by the weathering of natural rocks.

Other
The macroscopic collections included, in addition to the material described above, small pieces of coal, concretions formed by iron oxides binding the natural gravel (potentially formed by the weathering of iron objects or debris), and also a number of natural materials.

Distribution of residues
The distribution of the residues is illustrated in Table IX.2 by context and Table IX.3 sorted by type of feature.

Samples from deposits below the bank (layers (2079) and (2082)) produced tiny amounts of hammerscale and fine slag particles. The quantities were very small and the possibility of intrusion of material from later residue-rich contexts must be considered, although they may genuinely indicate a degree of pre-bank metalworking.

The majority of the residues recovered derived from the cluster of metallurgical features, which bore both the largest assemblages of micro-residues and almost all of the macro-residues. Circular pit [2076] contained a broad spectrum of residues in small quantities, but with a rich hammerscale assemblage. Hollow [2067] produced approximately 70% (2.8kg) of the total true macro-residue from the site (4.0kg). In addition there was over 1kg of ‘smithing floor’ and 0.9kg of fine-grained metallurgical residues. The upper fills of pit [2078] contained a similar assemblage to that of hollow [2067], but the lower fills lacked macro-residues although they were rich in micro-residues.

Other pits also yielded residues, with pit [2089] near the southern wall yielding a moderately rich micro-residues assemblage. Pits [2035] and [2056] yielded only trace levels of hammerscale, with pit [2035] also yielding coal and coke.

The postholes of the structure produced assemblages of micro-residues and comminuted slag debris from almost all the post-pipe fills and many of the packing fills.

The late-stage burnt stone deposits overlying the bank (layer (2003)/(2023)) contained rich hammerscale assemblages accompanied by small quantities of a wide range of macro-residues.

Interpretation

The nature of both macro- and micro- residues clearly indicates that the metallurgical activity undertaken was ironworking. The small size of the smithing hearth cakes and the abundance of flake hammerscale indicates that the work being undertaken was mostly, if not entirely, associated with the end use of iron – in other words blacksmithing.

The macroscopic residues were mainly of two kinds – a clinkery slag formed of glassy slag binding partially melted sand and gravel in blebby, amorphous masses and denser, typically plano- or concavo- convex masses (SHCs). Several of these masses were so small they could not display the typical form of SHCs, so the term proto-SHC has been employed here. These small cakes are interpreted as the early stages of accumulation of a true SHC, and that they would have grown larger given sufficient slag supply. The weight range of the five small SHCs and their incipient equivalents was from 72g to 168g, with a larger piece (306g) being a composite mass of an SHC lying on an earlier denser slag sheet. The exception to these small, dense SHCs, was a partial fragmented SHC weighing 754g (probably originally approximately 1kg). This large SHC had a low density, rather frothy, slag forming much of its upper part.

A total assemblage of just seven SHCs does not permit rigorous comparison with SHC assemblages from other sites, but the assemblage is certainly comparable with others from early smithies. With a range of SHC weights of 72-1000g and a mean weight of approximately 260g for this assemblage, comparative medieval assemblages would include those from:

- Exminster, ‘medieval’; SHCs range from 32-482g with a mean of 127g.(Young 2014b)
- Worcester, Mill Street, 12th century; SHCs range from 74-782g, with a mean of 233g.(Young 2009a)
- Worcester, Willow Street, 12th century; SHCs range from 86-770g with a mean of 327g. (Young 2007)
- Garryleagh, Co. Cork, 13th-14th century; SHCs range from 84-802g with a mean of 316g. (Young 2009b)
- Coolamurry (Co. Wexford), of 12th-13th century date; SHCs range from 62-3588g with a mean of 386g. (Young 2008)

It has been argued (Young 2008b) that in Ireland, the presence of a small proportion of larger SHCs in the assemblages of otherwise small SHCs up until the 13th/14th centuries, is due to the need for the smith to undertake some of the final processing of the iron, because iron was traded or moved in an incompletely refined state. The high temperature processing of the iron is a process involving a greater loss of iron, so the slag cakes produced may tend to be larger. That appears, on present evidence, not usually to have been the case in medieval Britain, and fully processed iron may have been the normal form of trade iron. Unusually-sized SHCs that do not fit the main size-frequency distribution for a site, may also indicate another process, such as hearth steel-making.

Another factor that may result in the presence of very small SHCs is the potential use of an iron tuyère, instead of a ceramic tuyère or a simple blowhole. The use of an iron tuyère reduces the degree to which the hot-zone impinges on the hearth wall, and therefore reduces the flow of silicate melt into the hearth. The evidence for Hen Gastell was discussed above and it seems likely that a simple clay blowhole was used, but the only surviving blowhole is sufficiently large that it might have held an iron tuyère.

The introduction of iron tuyères was progressive, and by the early post-medieval period seems almost universal in

England, but ceramic tuyères continued in use well into the post-medieval period in Ireland,. The development of the smithy in this period in Wales is entirely unknown; it is not known whether medieval-style floor level hearths remained in use into the post-medieval period, as it is clear they did, at least locally, in Ireland.

In summary, the SHCs from Hen Gastell are small, which may reflect one of a number of contributing factors – including the tasks undertaken, the nature of the hearth/tuyère and the nature of the iron employed. The hearth technology is certainly compatible with a medieval age, but whether such technology continued in use in N Wales into the post-medieval is not known.

The amount of archaeometallurgical waste recovered from the site is relatively low; it is likely that the point(s) of waste disposal from the smithy lay outside the excavated area. This means it is impossible to provide any estimate of the scale or longevity of the activity. None-the-less, the presence of hammerscale in so many of the sampled contexts indicates that a significant quantity must have been distributed across the site.

The focus of the activity within the excavated area was the cluster of pits towards the northern side of the structure. Most of the residues (70% of the macro-residues from the site) derive from irregular hollow [2067]. The field description implies this feature had no in-situ burning. This may, therefore, be a worn 'working hollow', that became filled with debris. Close to this lay circular pit [2076] contained a broad spectrum of residues in small quantities, but with a rich hammerscale assemblage. It is possible this circular pit held a wooden anvil block (into the top of which a small metal anvil could be placed). The unusual 'iron' find SF40 came from a shallow scoop to the north of [2076] and requires further investigation. Furthest east of the features was the probable hearth [2078]. This pit was 0.47 x 0.40m and 0.20m deep. This is unusually small for a medieval forge hearth, but not impossibly so (particularly if the hearth was only intended for the working of small objects). The primary fills of this accumulated on micro-residues, but floor material accumulated in the hearth on its abandonment – giving an upper fill somewhat similar to the fill of [2067]. It has been suggested that the red clay within this hearth might be from its superstructure (perhaps particularly a wall between the hearth and the bellows). However, an alternative possibility is that the clay was an attempt to stabilise the pit, for much of the gravelly component observed in the slag may have been derived from the pit sides.

The presence of archaeometallurgical residues in the apparently late deposits overlying the bank may indicate late ironworking, but might also indicate movement of waste materials away from the interior of the enclosure long after abandonment of the smithy.

Discussion

The material is indicative of a blacksmithy undertaking light forge work (evidenced by the small SHCs and by the very small hearth). The residue assemblage is similar to those from other medieval forges where general purpose smithy work appears to have been undertaken. The characteristics of the assemblage are not indicative of date, since late medieval and early post-medieval smithies are almost unknown in Wales.

Medieval higher status sites typically yield evidence for at least some working of copper alloy – but such evidence is entirely lacking in the present material. The closest comparative assemblages are from a variety of site types, including open rural settings (Exminster, Coolamurry) and an urban setting (Worcester).

The scale of the activity cannot be estimated on the basis of the limited material (it is assumed there must have been some off-site dumping of waste), but the permeation of hammerscale into almost all of the adjacent cut features would suggest the activity was not inconsiderable.

Further work

The assemblage provides a very complete assemblage of macro-and micro-residues produced by what may have been a rather limited set of processes. Some detailed analysis and characterisation of these materials would assist in the understanding of the technology employed, aiding both the interpretation of the site and of similar materials when encountered elsewhere. A programme of analysis is therefore recommended and a costed proposal will be supplied separately.

Irrespective of the commissioning of any further work, it is strongly recommended that all the residues are retained for deposition as part of the site archive, as there are so few such assemblages on a national basis.

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Appendix IX.1 Tables

Table IX..1.1: summary catalogue. Assm = assemblage, FHS = flake hammerscale, SHS = spheroidal hammerscale, SHC = smithing hearth cake

Context	Find no	Sample no.	Label	sample wt	Item wt	Item no	Notes
T2 u/s	26		slag	96	96	1	fragment of small SHC, original size not known. Well-formed lower crust with fuel-dimpled base, top largely obscured by concretion
2002	66		cleaning over bank (2018)	88	88	4	irregular rounded nubs of black glassy clinkery slag with locally maroon surface and abundant variably melted clasts.
2003	21		furnace lining	38	38	1	oxidised and slagged lining with blowhole preserved on protrusion. Interior of blowhole is slightly vitrified with fine spatter. Blowhole appears to be 35-40mm diameter
2003	58		Fe slag	20	20	1	fragment of irregularly-lobed slag nub with glassy surface, apparently has corroded iron inclusion
2003	112	4	fine - metalworking	9		assm	mainly stone, but some maroon slag, slag spheroids, moderate FHS, some SHS, some fired clay
2003	113	5	fine - metalworking	<1		6	variety of slag types, spheroids, lining, dense, and vesicular
2003	113	5	fine - metalworking magnet	<1		assm	small but rich assemblage of FHS, flats, slag fragments, slag spheroid and some stone
2003	114	6	fine - metalworking magnet	<1		assm	stone, trace of FHS and SHS, with iron fragment
2003	116	8	fine - metalworking magnet	<1		assm	slag fragments and blebs with some FHS in v small assemblage
2008	124	18	fine - metalworking	2		assm	large pieces of lining slag, with trace of FHS amongst finer stones
2012	117	9	fine - metalworking magnet	<1		assm	stone, trace of FHS and SHS
2014	122	15	fine - metalworking magnet	2		assm	stone with some FHS and slag - the latter curiously finely crystalline
2014	122	15	fine - coal	<1		5	coal fragments
2015	142	7	coarse - slag	10	10	1	black glassy slag binding variously vitrified, bloated and partially melted lithic clasts
2015	115	7	fine - metalworking	<1		assm	stone, trace of FHS and SHS
2023	121	14	fine - metalworking magnet	<1		assm	small sample rich in FHS, slag flats and trace of SHS
2023	123	16	fine - metalworking magnet	<1		assm	concretion, stone, slag, FHS, slag spheroids, some SHS

Context	Find no	Sample no.	Label	sample wt	Item wt	Item no	Notes
2023	143	16	coarse - slag	4	4	1	glassy bound lining slag
2023	61		furnace lining	14	14	2	vitrified oxidised fired lining, black glassy vesicular slag. Ceramic has probable leaf impressions
2023	63		Fe slag	78	6	1	rusted Fe object - small nail?
2023	63				50	1	dimpled lobate slag nub, possibly part of SHC or incipient SHC, very dense; one end has rusty accretion (probably from iron in slag)
2023	63				18	2	blebs of lining slag, pale, glassy
2036	118	10	cinder? Slag?	4		22	coal and coke
2036	118	10	fine - coal	<1		3	coal
2036	118	10	fine - metalworking magnet	<1		assm	stone, trace of FHS and SHS
2042	119	12	fine - metalworking magnet	3		assm	mainly stone, but some FHS and slag flats
2048	120	13	fine - metalworking magnet	<1		assm	slag, FHS and SHS
2053	129	24	fine magnetic material	<1		assm	stone with trace FHS
2056	125	19	fine - metalworking magnet	<1		assm	mainly stone, trace slag and trace FHS
2066	104	21	coarse metalworking debris/ slag	670	4	3	vitrified/glazed gravel
2066	104	21			40	12	gravel with adhering slag, in many case glazed also
2066	104	21			4	3	gravel - natural
2066	104	21			226	91	blebby lining influenced slags, mostly with white granule clasts, most maroon surfaced,
2066	104	21			14	9	vitrified slagged lining
2066	104	21			42	13	rough, granular, dense slags
2066	104	21			84	22	dense flowed slag, varying from small good flow slag to more blebby material
2066	104	21			30	16	flats, tool casts etc. only a few show right-angled re-entrants
2066	104	21			226	135	concretionary fragments, mainly rusty, with variably clasts of slag, FHS, charcoal and iron

Context	Find no	Sample no.	Label	sample wt	Item wt	Item no	Notes
2066	106	21	fine metalworking debris (magnet)	524		assm	very rich assemblage, dominated by FHS, but with slag flats, slag fragments, slag blebs, slag spheroids, SHS and some concretionary material (lower proportion than in 2099)
2066	105	21	fine metalworking debris	384		assm	assemblage dominated by fine version of maroon, gravel-rich slagged substrate, other material include abundant vesicular to frothy flats, some FS, slag spheroids and prills, vitrified stones ,stones attached to slag, concretions and some laminated rusty spalls (unclear if the latter are from rocks or iron)
2066	148	21	abraded orange ware	<1		1	oxidised fired clay
2066	46		slag 1/2	2412	168	1	90x60x30, small SHC, just slightly concavo-convex, top locally smooth, slightly reddened and with charcoal inclusions, base microdimpled/microprilly, dense
2066	46				72	1	70x50x25, small proto-SHC, prilly base (coated with rusted organics), smooth top with slightly lobate margin
2066	46				306	1	double SHC, lower sheet of dense slag, overlain by lining rich SHC, 70x95x60 overall, upper SHC 30mm thick
2066	46				148	1	dense stone
2066	46				104	1	75x65x35, low density SHC, thick gravelly glassy top with stone extending above planar top, lower slag rich in charcoal
2066	46				84	1	proto SHC, lobate top with raised centre, strongly prilly base, 60x50x35mm, very gravelly, locally maroon surface
2066	46				260	1	block of quartz vein with adhering smithing floor type material - abundant FHS, charcoal and slag
2066	46				80	1	50x75x40mm, irregular blebby proto-SHC, strongly maroon, gravelly, very irregular, upper face was crescentic
2066	46				158	16	fragments of very dense cemented smithing floor - rich in FS, slag, charcoal etc.
2066	46				22	1	iron = 40x20x4mm
2066	46				372	35	rounded nubs of low density gravelly lining slag, mostly with slightly maroon surface
2066	46				304	7	ferruginous concretions in very coarse gravel some probably associated with iron
2066	46				40	13	fragments of gravelly lining slag
2066	46				16	1	angular fragment of glass bearing gravel, dense not vesicular

Context	Find no	Sample no.	Label	sample wt	Item wt	Item no	Notes
2066	46				70	1	fragment from centre of dense concavo-convex SHC with dimpled base and very smooth even top
2066	46				162	5	prilly dense slag pieces, probably proto-SHC material
2066	46				38	1	lip of SHC with extremely porous interior
2066	46				8	1	stone fragment
2066	46		slag 2/2	1815	92	20	small spiky fragments of clinkery lining slag
2066	46				122	10	nubs of clinkery lining slag, each low density so possibly coatings on individual clasts
2066	46				426	20	multi-lobed clinkery lining slags, some with inclusions of gravel
2066	46				280	7	denser slag lumps, one sheet like, but otherwise these do not resemble SHC fragments
2066	46				14	1	rounded strip of iron with turned up end, 45x15x3-4mm with end turned up by c4mm
2066	46				648	75	coarse concretions with lots of slag, flats and scale, along with charcoal, straw moulds etc.
2066	46				40	3	glazed stones
2066	46				38	7	natural gravel
2066	46				2	1	unusual fired clay with convex iron oxide contact surface one side, one end curves over like blowhole margin - unclear how this could be interpreted – as a plug?
2066	62		furnace lining	16	16	3	oxidised and slightly slagged ceramic
2070	126	20	fine slag	1		3	lining slag, one very porous, the other two dense and clinkery
2070	126	20	fine - metalworking magnet	<1		assm	mainly stone and FHS, with some slag flats
2071	128	23	fine magnetic material	<1		assm	stone with slag, some FHS and SHS
2072	127	22	fine magnetic material	<1		assm	stone with trace of slag and FHS
2075	107	25	metalworking debris	80	<2	1	vitrified/glazed gravel
2075	107	25			16	14	blebby lining influenced slags, mostly with white granule clasts, most maroon surfaced
2075	107	25			6	32	spiky to flowed dense slags

Context	Find no	Sample no.	Label	sample wt	Item wt	Item no	Notes
2075	107	25			6	42	flats, tool casts etc.
2075	107	25			44	132	concretionary fragments, mainly rusty, with variably clasts of slag, FHS, charcoal and iron (weight includes some dust)
2075	107	25			<2	8	slag spheroids
2075	107	25			2	1	lining slag with a planar re-entrant face probably picked by tongs/poker
2075	108	25	fine metalworking debris (magnet)	306		assm	assemblage dominated by FHS, with some SHS, also spheroids, slag flats (including re-entrant examples) and other slag debris. Maroon slag and concretions present but in lesser proportion.
2075	57		slag	44	6	1	fired clay
2075	57				14	2	dense clinkery slag nubs, maroon surfaced
2075	57				26	4	concretions, at least two probably associated with thin sheet of iron
2077	110	29	fine metalworking debris (magnet)	74		assm	assemblage dominated by FHS, some larger flats, maroon spheroids, slag fragments, droplets, lining-rich slag blebs
2077	109	29	metalworking debris	42		assm	mainly blebs of clinkery slags, concretions (several lager ones are probably on iron), FHS, slag spheroids, slag fragments, slag flats and blisters
2077	65		slag	852	754	5	fragmented large piece of SHC. Bowl filled by vesicular dense slag, base with much adhering gravel (must have formed against sediment not fuel), upper part highly vesicular and frothy, top deeply dimpled with fuel, 115x100v70 fragment, bowl 50mm deep, cannot be more than 80% of original, frothy layer effectively single large void underlies most of the top. top pale and plastic/resinous appearing around fuel dimples
2077	65				86	1	irregular mass of glassy gravelly slag, rather dense glass, maroon surface
2077	65				12	3	small lining slag fragments
2079	130	26	fine - metalworking magnet	<1		assm	stone with trace of slag and SHS
2082	131	28	fine - metalworking magnet	<1		assm	stone with trace of slag and FHS
2082	139	41	porous stone? Slag?	24		38	porous igneous rock
2082	138	41	fine magnetic material	<1		assm	stone with 1 frag of FHS
2090	134	35	fine - metalworking magnet	<1		assm	one large piece of lining slag, moderate amount of FHS, some SHS and some fine slag debris, rest stone

Context	Find no	Sample no.	Label	sample wt	Item wt	Item no	Notes
2093	133	34	fine - metalworking magnet	<1		assm	stone with sparse assemblage of slag, FHS and SHS
2097	136	38	fine -slag	<1		1	bleb of clinkery lining slag
2098	132	32	fine - metalworking magnet	8		assm	dominated by FHS, but lots of maroon slag debris and plenty of SHS and slag spheroids. Some flats and large blisters
2098	149	32	ceramic	2		7	oxidised fired clay
2099	111	33	fine metalworking debris (magnet)	196		assm	very rich assemblage of FHS, slag flats, slag spheroids, SHS, maroon slag blebs and lots of ashy concretionary material with HS and charcoal
2099	144	33	mw debris/slag/concretions/ iron?	14	6	5	large slag flats with curved concave attachment areas
2099	144	33			2	2	maroon slag fragments
2099	144	33			2	2	concretions
2099	144	33			2	1	vitrified pebble
2099	144	33			<1	1	laminar iron oxides- unclear if spall of rust or from rock
2101	135	36	fine magnetic material	<1		assm.	mainly fine stone, one large piece of clinkery lining slag
2105	140	42	fine - metalworking	4		assm	mainly maroon slag, some stone, one carbonised nut (?),
2105	140	42	fine - metalworking magnet	5		assm	mainly stone, some lining slag, moderate FHS, slag spheroid, charcoal
2105	150	42	burnt clay	<1		1	oxidised fired clay
2105	150	42				1	concretion?
2105	141	42	coarse - slag	8	8	2	dark glassy slag binding partially- melted gravel, some charcoal
2120	137	40	fine - metalworking magnet	<1		assm	stone with some FHS

Table IX.1.2: summary of residues by context. For the micro-residue assemblages mod = moderate, tr = trace, y = present.

context	notes	macro-residues				micro-residues			other				
		SHC	clinkery slags	indet slag	hearth lining	scale	spheroid	flats	glazed stone	smithing floor	iron	coal	conc
T2 u/s	unstratified	96											
2002	cleaning over bank		88										
2003	burnt stone deposit		20	y	38	rich	y	y			y		
2008	packing fill in p/h [2007]				y	tr							
2012	possible post-pipe fill in p/h [2011]					tr							
2014	fill of post-pipe in p/h [2009]					tr						y	
2015	fill of post-pipe in p/h [2007]		10	y		tr							
2023	burnt stone deposit over bank 2018	50	22	y	14	rich	y	y			6		
2036	fill of pit [2035]					tr						4	
2042	fill of post-pipe in p/h [2118]					tr		y					
2048	packing fill in p/h [2011]			y		tr							
2053	packing fill in p/h [2052]					tr							
2056	fill of cut [2055]			tr		tr							
2066	Charcoal and slag rich fill of hollow [2067] 1.60 x 1.10m x 0.15m	1084	1294	406	32	rich		30	84	1032	36		304
2070	fill of post-pipe in p/h [2068]		y			tr		y					
2071	fill of post-pipe in p/h [2052]			y		tr							
2072	fill of post-pipe in p/h [2005]			y		tr							
2075	Charcoal rich fill of small pit [2076], 0.60m diameter, 0.30m deep		32	6	6	rich	y	6	1	44			26
2079	Buried soil ‘A’ horizon, under bank 2018					tr							
2077	Upper fill of pit [2078]	754	98	y		rich	y	y					
2082	Layer containing burnt bone and charcoal that underlies bank 2116					tr							

context	notes	macro-residues				micro-residues			other				
		SHC	clinkery slags	indet slag	hearth lining	scale	spheroid	flats	glazed stone	smithing floor	iron	coal	conc
2090	Relatively charcoal rich fill of pit [2089], 0.35 x 0.33m, 0.11m deep			y	yes	mod							
2093	packing fill in p/h [2092]			y		tr							
2097	fill of post-pipe in p/h [2092]		y										
2098	heat reddened clay in the base of pit [2078]		y		y	mod	y						
2099	Thin, dark, silty charcoal rich fill in the base of pit [2078]		2			rich	y	6	2				2
2101	Fill of a possible post void at NW end of posthole [2083]		y										
2105	Fill of post void [2106] in posthole [2108]		8		y	mod	y						y
2120	Disturbed packing fill of posthole [2119]					tr							
	Total weighed	*1984*	*1574*	*412*	*90*			*42*	*87*	*1076*	*42*	*4*	*332*

Table IX.1.3: summary of stratified residues by type of feature and context. For the micro-residue assemblages mod = moderate, tr = trace, y = present.

Context	notes	SHC	clinkery slags	indet slag	hearth lining	scale	spheroids	flats	glazed stone	smith-ing floor	iron	coal
	Deposits below bank											
2079	Buried soil 'A' horizon, under bank 2018					tr						
2082	Layer containing burnt bone and charcoal, underlies bank 2116					tr						
	Burnt stone deposits over bank											
2003	burnt stone deposit over bank 2018		20	y	38	rich	y	y			y	
2023	burnt stone deposit over bank 2018	50	22	y	14	rich	y	y			6	
	Packing fills of postholes											
2008	packing fill in p/h [2007]				y	tr						

Context	notes	SHC	clinkery slags	indet slag	hearth lining	scale	spheroids	flats	glazed stone	smith-ing floor	iron	coal
2048	packing fill in p/h [2011]			y		tr						
2053	packing fill in p/h [2052]					tr						
2093	packing fill in p/h [2092]			y		tr						
2120	Disturbed packing fill of posthole [2119]					tr						
	Post-pipe fills of postholes											
2012	possible post-pipe fill in p/h [2011]					tr						
2014	fill of post-pipe in p/h [2009]			y		tr						y
2015	fill of post-pipe in p/h [2007]		10			tr						
2042	fill of post-pipe in p/h [2118]					tr		y				
2070	fill of post-pipe in p/h [2068]		y			y		y				
2071	fill of post-pipe in p/h [2052]			y		y						
2072	fill of post-pipe in p/h [2005]					tr						
2097	fill of post-pipe in p/h [2092]		y									
2101	Fill of a possible post void at NW end of posthole [2083]		y									
2105	Fill of post void [2106] in posthole [2108]		8		y	mod	y					
	Minor pits											
2036	fill of pit [2035]			y		tr						4
2056	fill of cut [2055]			tr		tr						
2090	Relatively charcoal rich fill of pit [2089], 0.35 x 0.33m, 0.11m deep			y	y	mod						
	Metallurgical group											
2066	Charcoal and slag rich fill of hollow [2067] 1.60 x 1.10m x 0.15m	1084	1294	406	32	rich		30	84	1032	36	
2075	Charcoal rich fill of small pit [2076], 0.60m diameter, 0.30m deep		32	6	6	rich	y	6	1	44		

Context	notes	SHC	clinkery slags	indet slag	hearth lining	scale	spheroids	flats	glazed stone	smith-ing floor	iron	coal
2077	Upper fill of pit [2078]	754	98	y		rich	y	y				
2098	Heat-reddened clay in the base of pit [2078]		y		y	mod	y					
2099	Thin, dark, silty charcoal rich fill in the base of pit [2078]		2			rich	rich	6	2			

18.2. **Archaeometallurgical residues from Hen Gastell, Llanwnda**

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Abstract
Iron working residues were recovered from many of the cut features associated with the timber structure at Hen Gastell, as well as from the metallurgical features close to its northern side. The smithy included a small hearth (less than 0.5m diameter), a probable anvil block, and a hollow probably representing where the smith was positioned. A hammerscale-rich concretion may have formed in the void in the top of the anvil block below the anvil's basal spike.

The archaeometallurgical residue assemblage was small, probably because of the limited opportunity for deposition or accumulation. The limited smithing hearth cake (SHC) assemblage was consistent with assemblages from medieval blacksmithing.

The detailed archaeometallurgical investigations entailed analysis of samples of both flake and spheroidal hammerscale, of a slag film, of examples of large and one small smithing hearth cake (SHC) and of one small lump of gravelly slag.

The macroscopic slag samples were chosen to illustrate the slags produced in a range of work periods ranging from a very low level of iron-loss, up to a period in which approximately 0.5kg of iron had been lost. The bulk compositions of the three smithing slags showed varying proportions of iron, but when the analytical data were recast on an iron-free basis, the remaining material showed very similar compositions. This suggests that the composition of the hearth wall lost into the hearth through melting and incorporation into the slag was similar during the quite different work periods. This interpretation was also supported by the rare earth element (REE) profiles of the analyses of samples of macroscopic slags, which were all close to being parallel indicating a common origin. This argues against any of the sampled residues having been produced during the working of raw iron, in which case the smelting slag carried by the raw iron (bloom that had not been fully processed) would be likely to contribute significantly to the slag chemistry.

The assemblage included numerous examples of slag films from the surface of the workpiece, or more likely the smith's tools. Analysis of one of these showed an iron-poor composition, compatible with the slag being primary melt from the hearth wall. This may suggest the films were produced when the smith cleared slag away from the blowhole.

The microscopic residues show more variable chemical properties, reflecting the complex influences on their formation (slag, slag inclusions in the iron, the iron itself and any welding flux). The complexity of modelling the chemical composition of the microresidues means than unambiguous interpretation is difficult, but a variable degree of enrichment in phosphorus, probably suggests that a proportion of the iron being worked was phosphoric, and together with an enrichment in manganese in some particles provides tentative evidence for a bog iron source for at least some of the iron being worked.

Methods
The assemblage was visually inspected as part of the assessment (Young 2015c). The catalogue from the assessment is included in the appendix to this report (IX.3 appA, Table A1). Following the assessment of the assemblage, samples were selected for further laboratory analysis (Table IX.2.2). These were chosen to represent the variety of material of material present in the overall assemblage, but drawn from just a small number of contexts to increase the likelihood of a direct relationship, or at similarity between the materials involved in their production.

Selected macroscopic samples were slabbed on a diamond saw and subsamples used firstly for preparing a polished block for use on the SEM and secondly for crushing for preparation of a whole-sample chemical analysis.

Bulk chemical analysis was undertaken using two techniques. The major elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, and P) were determined by X-Ray Fluorescence using a fused bead on the Wavelength- Dispersive X-Ray Fluorescence (WD-XRF) system in the Department of Geology, Leicester University (this also generated analyses for S, V, Cr, Sr, Zr, Ba, Ni, Cu, Zn, Pb and Hf). Whole-specimen chemical analysis for thirty six minor and trace elements (Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Sn, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Pb, Th, U) were undertaken using a sample in solution on the ThermoScientific ICAP-

Qc quadrupole ICP mass spectrometer (ICP-MS) in the Department of Geology, Leicester University (this also generates lower quality results for Fe, Mn, Ti, P that are used mainly for QA purposes). The raw results of the chemical analyses are presented in full in the archive appendix (IX.3 appB), with the key adjusted data presented as Tables IX.2.3 and IX.2.4. Adjustment has assumed all iron was originally present as FeO and all manganese as MnO. The assistance of Dr Tom Knott (XRF) and Dr Tiffany Barry (ICP-MS) is gratefully acknowledged.

Polished blocks for investigation on the SEM were prepared in the Earth Science Department, The Open University. Electron microscopy was undertaken on the *Zeiss Sigma HD Field Emission Gun Analytical Scanning Electron Microscope* in the School of Earth and Ocean Sciences, Cardiff University. Microanalysis was undertaken using the system's energy-dispersive x-ray analysis system (EDS) controlled by Aztec software. The assistance of Dr Duncan Muir is gratefully acknowledged.

The site code used for the samples is HGA. Locations of EDS analyses are presented as sample-area-spectrum (e.g. HGA1 area2 spectrum3). The microanalytical data are presented in IX.3 appC. Images of all areas including analyses are included in IX.3 appD, including, where appropriate, details of the analysed points/areas.

All EDS analyses were collected with all elements analysed (including oxygen, but not carbon; all samples were carbon-coated). Area analytical totals were frequently far from 100%, because the analytical system is designed to provide totals of 100% from spot analyses in the centre of the field. The area analyses required for this project are not standardised in the same way and will diverge from a total of 100% (either above or below, depending on the location of the area with respect to the centre of the field).In order to make the microanalytical results simply comparable across materials (and also sites), no attempt has been made to adjust for the oxidation state of elements with variable valency. The figures employed in the report have therefore been constructed with elements expressed as oxides in weight% calculated stoichiometrically, except for mineral structure calculations, where the measured oxygen has been used.

Analyses of olivine have been quoted using the following convention: the proportions of iron and magnesium have been used to first define the relative proportions of forsterite (Fo; Mg_2SiO_4) and fayalite (Fa; Fe_2SiO_4) in the form Fa_nFo_m, where n+m = 100. The proportions of calcium and manganese have then been taken to calculate percentage substitutions into the olivine. Finally, the substitution of phosphorus for silicon has been expressed as atoms per formula unit (APFU), based on four oxygens and where the formula unit ideally has a single silicon atom. Values of more than 0.015 APFU phosphorus are defined as phosphoran fayalite (Boesenberg & Hewins 2010).

Throughout this report standard mineral terminology is applied to both natural and anthropogenic materials – although artificial phases are no longer strictly considered to be minerals.

The residues

Distribution of the residues

The distribution of the residues is illustrated in Table IX.2.1.

Samples from deposits below the bank (layers (2079) and (2082)) produced tiny amounts of hammerscale and fine slag particles. The quantities were very small and the possibility of intrusion of material (e.g. by worm action) from later residue-rich contexts must be considered, although they may genuinely indicate a degree of pre-bank metalworking.

The majority of the residues recovered derived from the cluster of metallurgical features, which bore both the largest assemblages of microresidues and almost all of the macroresidues. Circular pit [2076] contained a broad spectrum of residues in small quantities, but with a rich hammerscale assemblage. Hollow [2067] produced approximately 70% (2.8kg) of the total true macroresidues from the site (4.0kg). In addition, there was over 1kg of 'smithing floor' and 0.9kg of fine-grained metallurgical residues. The upper fills of pit [2078] contained a similar assemblage to that of hollow [2067], but the lower fills lacked macroresidues although they were rich in microresidues.

Other pits also yielded residues, with pit [2089] near the southern wall yielding a moderately rich microresidues assemblage. Pits [2035] and [2056] yielded only trace levels of hammerscale, with pit [2035] also yielding coal and coke (this was probably unrelated to the metalworking).

The postholes of the structure produced assemblages of microresidues and comminuted slag debris from almost all the post-pipe fills and many of the packing fills.

The late-stage burnt stone deposits overlying the bank (layer (2003)/(2023)) contained rich hammerscale assemblages accompanied by small quantities of a wide range of macroresidues.

Description: iron smithing macro-residues
The macroscopic smithing residues from the site were divisible into three broad classes: smithing hearth cakes (SHCs), hearth slags and hearth lining. The SHCs comprised approximately 49% of the macro-residue assemblage by weight and the clinkery slags 39%. The hearth lining comprised just 2% of the assemblage, just 2% by weight, of which the only significant piece was a blowhole fragment (see below). This meant that it was not practical to analyse the bulk composition of the hearth ceramic.

Smithing hearth cakes (SHCs): SHCs are the slag cakes that form just below the air input, from a mixture of iron (or iron oxide) last from the workpiece and melted hearth lining, with lesser contributions from the fuel ash and, where appropriate, from any welding flux employed by the smith. SHCs are typically approximately plano-convex in shape, with a rounded base and a sub-triangular to sub-oval shape in plane.

The SHCs at Hen Gastell were generally well-formed, just slightly concavo-convex, dense slag cakes of small size. Included within this category are smaller slag masses, broadly plano- to concavo- convex, but which are too small to have fully developed the morphology of a typical SHC. These may be interpreted as incipient SHCs, limited in size by the amount of slag generated in the hearth. These have been loosely and informally termed proto-SHCs in this account. Taking these and the well-formed SHCs together, there were six reasonably complete examples, weighing 306g, 168g, 104g, 84g, 80g and 72g. The 306g example was a composite cake, including a moderately small SHC attached at its base to an inclined sheet of slag (either an earlier SHC, or perhaps a long-term build-up of slag on the wall/floor of the earth. In addition there was part of a much larger SHC, with a weight of 754g that might be extrapolated to an original weight in the order of 1kg. This larger cake had a very porous internal structure, with a particularly large void just below the upper surface.

The SHCs were sampled as:

- **HGA4** (upper frothy dense layer; chemical analysis only) and **HGA5** (lower dense layer; both chemical analysis and polished block) from a 754g fragment of SHC (estimated at an original weight of approximately 1kg, from upper fill (2077) of pit [2078]. This SHC had its bowl filled by vesicular dense slag, with its base having much adhering gravel (and so must have formed against the hearth base not a fuel bed). The upper part is highly vesicular and frothy, with the top deeply dimpled with fuel. The fragment measured 115mm x 100mm x 70mm thick, of which the bowl was 50mm deep. A single large void underlies much of the upper surface, which is pale and of resinous lustre around the fuel dimples.

- **HGA6** from a small, well preserved SHC (weight 168g) from fill (2066) of hollow [2067]. This piece was sampled for both chemical analysis and a polished block. Both samples extended across the entire thickness of the SHC. This SHC was neatly formed, oval in shape and slightly plano-convex. It measured 90mm x 60mm x 30mm. The top was locally smooth, slightly reddened and has deeply impressed charcoal pieces. The base was microdimpled.

Smithing hearth slags: the assemblage contained a large proportion of nubs and fragments of gravelly slag. These clinkery slags had clearly formed separately from the SHCs, but they too are assigned to the smithing process. Similar slags have been recorded from other sites with low-level hearths on gravelly substrates. The clinkery appearance of the slags is attributed to the partial melting of a slightly aluminous substrate. This material was sampled with a single sample:

- **HGA7** was a rounded slag nub from fill (2066) of hollow [2067]. This piece was sampled for chemical analysis only.

Hearth lining: the site yielded very little hearth lining, apart from part of a blowhole or tuyère from deposit (2003). This piece showed part of the curving margin of the bore, which suggested a diameter of approximately

35-40mm. The presence of tiny blebs, apparently of slag spatter, on the inside of the bore suggest it was open, but the diameter is unusually large for a smithing hearth (more typically the diameter is in the range of 15-30mm) and the possibility that the ceramic was packed around a metal tuyère cannot be discounted. Because this item was a significant find, no further analysis was made of the earth lining.

Description: iron smithing micro-residues
The true microresidues included, dominantly, flake hammerscale, with lesser quantities of spheroidal hammerscale. The coarser microresidues (passing up strictly into macroresidues) included examples of slag spheroids, slag blisters and slag flats.

Hammerscale is associated with the superficial oxidation of iron at high temperature (Young 2014), with spheroidal hammerscale typically indicative of the process of forge (or fire) welding. Slag spheroids are droplets of smithing slag that cooled within the fuel bed of the hearth, without amalgamating into a large mass. Slag blisters are probably mostly formed as flake hammerscale, but are lifted off the surface of the underlying metal by build-ups of gas. Slag flats are thin skins of slag that, in this case, can be attributed to two distinct origins. Firstly they form as veneers of slag on boulders or cobbles that extend into the hearth pit. This type is characterised by a concave basal fracture. The second type forms by the adherence of slag to either the work piece or to the smith's tools, and commonly shows a right angle bend, or re-entrant from contact with the metal substrate.

The true microresidues are accompanied in almost all cases by finely comminuted slag debris, derived by the fragmentation of the macroscopic slags.

The term 'smithing floor' is applied to concretionary material dominantly or entirely formed by the cementation of fine debris from the smithing process (hammerscale, fine slag fragments and droplets, charcoal…). Most commonly, this material was cemented by the corrosion of small included iron particles, and this appears to be the case with the present material. Although a characteristic material of the floor of a smithy (hence the name), the material may also form in other accumulations of fine-grained smithing debris, such as waste pits.

A very unusual dense block of concretionary material (SF40) containing hammerscale was recovered from a shallow scoop to the north of [2076]. This piece is cuboidal, 90mm by 55m and up to 52mm deep. The sides taper slightly inwards towards the base. On one narrow side (and just possibly on two other sides also, although less well-preserved) a narrow 'V'-profile void (40mm wide, 6mm across and 20mm deep) penetrates downwards, defining one side of an inner zone, 74mm by 54mm. This void shows traces of wood impressions on its sides. The piece is interpreted as a concretion generated in a void, into which an object was wedged by narrow wooden wedges. Replacement of rotting wood by hammerscale-rich ('smithing floor') concretions has been observed in material from the Viking site at Woodstown (Young 2006), and similar mechanism is at least partly possible here. The size of the object being wedged in place is entirely compatible with the basal spike on medieval anvils (see Goodall 2011, figure 2.1) and it seems quite likely that was the origin of this piece.

These materials were investigated through three samples:

- **HGA1**: tabular microresidue particles (coarse flake hammerscale and slag flats) derived from the handpicking of the magnetically separated fraction of sample #21 (<106>) from fill (2066) of hollow [2067], were made into a strew mount for microscopic investigation.

This sample included grains which showed a range of microstructures from wustite with polygonal grain boundaries, through wustite with rounded grain boundaries (typically with a silicate glass matrix), sometimes present as isolated 'clots', to stout rounded wustite dendrites or pseudo-dendrites with a glass or olivine-rich matrix, through to silicate-dominated microstructures with olivine dominant and just delicate dendrites of wustite. Three of the particles were of olivine/glass-dominated slag (#T1, #T5, #T7), two were flake hammerscale (#T2, #T3), one was a concretion containing fine-grained hammerscale (#T4) and one was a flake of rust (#T6).

- **HGA2**: spheroidal microresidue particles (coarse spheroidal hammerscale and slag droplets) derived from the handpicking of the magnetically separated fraction of sample #21 (<106>) from fill (2066) of hollow [2067], were made into a strew mount for microscopic investigation.

The spheroidal particles were larger than typical spheroidal hammerscale, because the originating sample had been made with a coarse mesh. The particles were dominantly of vesicular slag, most with a central cavity equivalent in size to at least 70% of the diameter of the particle (8 out of 11 particles), which suggests that despite their coarse grain size, these particles were spheroidal hammerscale rather than slag droplets.

The spheroidal particles showed a similar range of microtextures to the tabular particles. One of the grains showed a microstructure of coarse wustite, marginally oxidised to magnetite, that was very similar to that of classic flake hammerscale (#S8; it is possible this was an extreme slag blister, rather than a spheroidal particle), six of the grains were formed of slag in which the iron oxides were more prevalent than the olivine/glass (#S2, #S3, #S5, #S7, #S10, #S11) and four grains were dominated by the silicates, with subordinate iron oxide minerals (#S1. #S4, #S6, #S9).

- **HGA3**: a selected piece of slag film with morphological evidence for having been formed in contact with a piece of metalwork (either tool or workpiece) >) from sample #21 (<104>) from fill (2066) of hollow [2067], was mounted for preparation of a polished block. The piece showed a maroon surface colour over grey vesicular slag, particularly on the metal contact surface, which was reflective and bore tiny pores.

Mineralogy and Microstructure

Iron smithing macro-residues (Figure 1)

The microstructure and mineralogy of the two samples both show a restricted range of mineralogy and microstructure, but differ markedly in texture. Sample HGA5, the lower part of a large SHC, shows a microstructure with equant (0.3-1.0mm) olivine as the main phase (Figure IX.2.1a,b), whereas the small SHC HGA6 (which has a very similar bulk chemical composition) has a main phase of extremely long (5mm) elongate olivine crystals (Figure IX.2.1c), becoming small towards the base of the cake. In both cases the olivine is largely clear of cotectic phases. The olivine is seen to overlie small wustite dendrites in both samples (Figure IX.2.1 b,e,f) and where the elements of the wustite dendrites occur in areas interstitial to the main olivine they are coated in a thin layer of olivine. In both cases the typical textures show interstitial areas with minor late olivine (slightly more calcic than the main phase). In HGA5 there may also be tiny late hercynite dendrites in the interstitial areas (Figure IX.2.1b) and in HGA6, interstitial areas close to vesicles show complicated textures involving a leucite-wustite cotectic and a minor olivine-hercynite cotectic (Figure IX.2.1d).

This mineralogy has been strongly influenced the rather simple chemical composition. This composition is moderately silicic and is dominated by alumina, silica and ferrous oxide, with all other ‘major’ elements in low concentrations.

Wustite (ideally FeO) is present in low proportions in both samples, forming small primary dendrites that are overlain by the margins of the main phase olivine and by minor late stage interstitial olivine. The wustite has a slightly ambiguous relationship with the olivine; both may have grown at the same time despite, unusually, not having formed as a cotectic and some olivine growth clearly post-dates the wustite formation. The slag compositions plot well within the olivine field, so it is likely that olivine would be the primary phase if the material formed in an equilibrium.

Olivine is typically very variable in its morphology in these samples, because they have differing chemical compositions and cooling histories.

The olivine composition is generally close to that of the iron end-member fayalite (ideally Fe_2SiO_4), but may show significant substitution. The most forsterite-rich (i.e. magnesium-rich) olivine in the core of crystals attained only 5% forsterite (i.e. $Fa_{95}Fo_5$). Calcium substitution was very low throughout but rising towards the margins: 0.3% to 0.5% in HGA5 and 0.3% to 1% in the main olivine of HGA6, rising to 2% in the minor late-stage interstitial olivine. Manganese substitution was just 0.25% to 0.3%, declining slightly towards the outside of the crystals.

Hercynite is widely present only as a minor late phase. It occurs as minute interstitial dendrites locally in HGA5 and as cotectic with olivine in interstitial areas close to vesicles in HGA6. For hercynite present as tiny dendrites in HGA5, analysis suggests a magnetite content of up to 20%, with just minor titanium substitution. For the hercynite forming as a cotectic phase with the late olivine in HGA6, there is about 60% hercynite end-member, with the magnetite more titanium-rich (overall titanium provides approximately 0.1 atoms per formula unit).

Leucite (ideally $KAlSi_2O_6$) is a minor component of HGA6, occurring both on its own and in a cotectic with wustite in areas close to vesicles. Analysis suggests an approximately 7% atomic substitution of sodium for potassium.

Iron occurs in tiny prills in both HGA5 and 6.

Iron smithing micro-residues (Figure IX.2.2)
The fine grain size of component materials within the micro-residues makes the acquisition of high-quality mineralogical data difficult.

The exterior of many particles shows the development of **magnetite** (ideally Fe_3O_4), mainly apparently through the in-situ oxidation of wustite. The textures involved are very similar to those well documented elsewhere in hammerscale (Young 2011). In spheroidal particles the crust (skin) of the spheroid was commonly of magnetite, and inward growing magnetite dendrites were observable inside the crust on several particles. In tabular particle #T3 there was a vesicle fill formed of stubby dendritic magnetite. This new-formed magnetite, as with the oxidised wustite, showed a composition very close to end-member magnetite, with very low levels of aluminium and magnesium substitution.

Wustite (ideally FeO) is present in low proportions in both samples, forming small primary dendrites that are overlain by the margins of the main phase olivine and by minor late stage interstitial olivine. The wustite has a slightly ambiguous relationship with the olivine; both may have grown at the same time despite, unusually, not having formed as a cotectic.

The wustite is overlain and replaced by **iscorite** (ideally $Fe^{2+}_5Fe^{3+}_2SiO_{10}$) in narrow zones just inside the crust of some spheroidal particles in HGA2. No examples were sufficiently coarse to provide good quality analyses. Iscorite can be an indicator of oxidation of a slag during solidification. It has been observed widely in both flake and spheroidal hammerscale (e.g. Young 2011c, Figure 6a; Young 2011a, Figure 18f,g).

Olivine is typically very fine-grained in the hammerscale samples, so high quality analyses were very difficult. In general, the olivine shows a similar range of magnesium substitution to those of the macroscopic slags, with most analyses in the range of Fa98Fo2 to Fa100. Some examples, notably those in the glassy siliceous material of particle #T2 show more magnesian compositions of Fa87Fo13, a ferro-hortonolite.

Another key difference between the olivine in the two groups is the substitution by manganese: in the tabular particles it was typically around 0.5% and as much as 1% in the ferro-hortonolite, and varied from 0.1% to 0.8% in the spheroidal particles. These values give much higher (albeit still low) values for substitution of manganese in the hammerscale than the macro-residues.

Analyses of fine-grained olivine in some spheroidal particles show levels of phosphorus apparently in excess of the 0.03 APFU that forms the definition of phosphoran fayalite (Boesenberg & Hewins 2010). However, in each of these occurrences there is considerable doubt that the phosphorus may actually be present dominantly in the admixed glass phase. It appears most likely that none of fayalite is phosphoran in these samples.

The olivine in the slag film, HGA3, more closely resembles that of the smithing hearth cakes, with a narrow range of composition from Fa98Fo2 to Fa100, with 0.2 to 0.45% calcium substitution and 0.15% to 0.3% manganese substitution.

Details of sampled materials

Tabular microresidues, sample HGA1:
[Figure IX.2.2a-c; Plates IX.3 appD A1-A10; IX.3 appC Table C1]

Particle #T1 [Plates IX.3 appD A2-A3] – this particle is formed of slag with variably 5-15% iron oxide minerals. The majority of the slag comprises slight dendrites of wustite, angular fayalite and some glass. The slag has a rounded shape, with a 10µm external crust. In the centre of the fragment there are multiple internal arcuate crust, in the process of dissolution and with some associated iscorite on their concave side. This piece is interpreted as a slag flat.

Particle #T2 [Figure IX.2.*2a; Plate* IX.3 appD *A4]* – this particle is a coarse scale fragment. Much of the fragment comprises dense, locally highly vesicular iron oxide scale. Away from the dense surface the material becomes more layered, including a layer of sand inclusions formed of angular quartz and feldspar grains. This layer is continued by a dense line within the slag, upon which lies a layer of glass, containing small prills of iron and stout angular crystals, just slightly dendritic, of olivine of a composition equivalent to ferro-hortonolite.

Particle #T3 [Figure IX.2.*2b-c; Plates IX.3 appD A5-A6]* – a dense scale fragment, with a neat external magnetite-rich surface and coarse internal pores. Towards the original external surface, the scale shows areas with polygonal boundaries within the wustite, which also bears a coarse magnetite exsolution. In one area there is a round vesicle bearing a coarse dendritic fill of magnetite.

Particle #T4 [Plate IX.3 appD A7] – this was a piece of 'smithing floor' concretion, bearing numerous inclusions of fine hammerscale.

Particle #T5 [Plate IX.3 appD A8] – this piece also appears to be a fragment of concretion, but is mainly compose of two pieces of slag with rounded outlines (just possibly parts of a single piece). Textures include disrupted and fragmented wustite dendrites set in glass, which also bears iron droplets.

Particle #T6 – a spall of rust; not investigated further.

Particle #T7 [Plates IX.3 appD.A9-A10] – this particle possessed a straight contact with brecciated by substantial oxide scale, attached to which was a silicate-rich slag with a rounded outline. The slag bore a thin outer crust, and had a marginal zone containing small wustite clots. Internally, the particle showed concentric zones of decreasing proportion of wustite, from 20-30% on the outside near the crust, down to 5-10% internally.

Spheroidal microresidues, sample HGA2:
[Figure IX.2.2 d-h; Plates IX.3 appD A11-A23; IX.3appC Table C2]

Particle #S1 [Plate IX.3 appD A12] – this particle was approximately 2.6mm in diameter, with a central void occupying 78% of the diameter. The material was silicate-dominated (approximately 40% iron oxide minerals), with wustite and fayalite. The particle showed a very thin external crust.

Particle #S2 [Figure IX.2.*2g; Plate IX.3 appD A13]* – an oxide-dominated particle with around 70% iron oxide minerals, formed of stout, blebby, wustite pseudo-dendrites in glass. It bears a magnetite crust, inside which is a zone of stout magnetite dendrites. The piece is 1.5mm across, irregularly trilobate in section, with 40% of the diameter occupied by the principal void.

Particle #S3 [Plate IX.3 appD A14] – this is oxide-dominated (probably 80% wustite), with dense rounded wustite with blebby 'clots', plus fayalite. There was no crust. The particle was 5x4.6mm, with the void occupying 80-85% of the diameter.

Particle #S4 [Plate IX.3 appD A15-A16] – this is a silicate-dominated particle, formed of wustite and fayalite with 40-60% wustite. There is a thin crust. The particle was 4mm in diameter with a void occupying 60% of the diameter.

Particle #S5 [Figure IX.2.*2e; Plate IX.3 appD A17]* – an oxide-dominated particle, 5.4 x 4.4mm and with a void occupying 75-90% of the diameter. The material showed dense rounded wustite set in some glass (<10%), but with many clots of rounded wustite particles and also relict piece of scale with polygonal wustite. There was no crust.

Particle #S6 [Figure IX.2.*2h; Plate IX.3 appD A18]* – a silicate-dominated particle with primary wustite comprising up to approximately 25%, followed by olivine. There is no crust. The particle is 4.6mmx5mm with a central void equivalent to 75-90% of the diameter.

Particle #S7 [Figure IX.2.*2d; Plate IX.3 appD A19]* – an oxide-dominated particle with no visible olivine or glass. It is irregularly 'D'-shaped, 1.7mm x 2mm, possibly suggesting either impact, or an irregular detachment from its original substrate. The central void occupies 70-78% of the diameter. The wall shows polygonal wustite as the major part of a texture which, notwithstanding the rounded shape, resembles that of flake hammerscale.

Particle #S8 *[Figure* IX.2*.2f; Plate IX.3 appD A20]* – an oxide-dominated grain of dense rounded wustite with clots, plus glass, in which the wustite comprises 75% – 90% of the texture. There is a thin crust. The grain is a 2.5-2.7mm in size with a multicuspate central void occupying 65-75% of the diameter.

Particle #S9: *[Plate IX.3 appD A21]* - a silicate-dominated grain, with 15% wustite in delicate large dendrites followed by fayalite. The grain measures 2.8mm x 3.1mm with a central void occupying just 25% of the diameter (there was a more even spread of vesicularity rather than simply a central void). There was a very thin crust.

Particle #S10 [Plate IX.3 appD A22] – an oxide-dominated grain with stout rounded wustite dendrites with some 'clots', plus glass. The grain was 4.7mm in diameter, with the central void constituting 80% of the diameter. There was a thin crust.

Particle #S11 [Plate IX.3 appD A23] -an oxide-dominated grain, with marginal hammerscale flakes (associated with euhedral magnetite in glass with iscorite), and a body of wustite dendrites/ pseudo-dendrites (up to 85%) in glass, with significant iscorite towards the outside.

Slag film, sample HGA3:
[Figure IX.2.3 a-c; Plates IX.3 appD.A24-A27; IX.3 appC Table C3]

A piece of the material interpreted as a slag veneer from the surface of a tool or workpiece was sectioned. It showed that the internal faces formed a 'V'-shaped notch, approximately 11mm deep and 4.5mm wide at the opening, the surfaces of which included fragments of flake hammerscale (Figure IX.2.3a,b). It is interpreted that this scale detached from iron substrate when the slag was removed.

The slag shows a degree of zonation parallel to this inner margin, with a zone adjacent to the scale that was very low in iron oxide minerals (Figure IX.2.3b), a central zone showing dominantly olivine in glass, with only traces of wustite, then a denser zone in which the early clear olivine was followed by olivine with a cotectic of wustite (Figure 3c), and finally the outer layers tended to be poor in iron oxide minerals again. The has a narrow range of composition from Fa98Fo2 to Fa100, with 0.2 to 0.45% calcium substitution and 0.15% to 0.3% manganese substitution.

Smithing hearth slags, samples HGA4-7:
Sample HGA4
This sample contains an area within the upper section of a large SHC (see also HGA5). This sample was investigated through its bulk chemistry alone.

Sample HGA5 [Figure IX.2*.1a-b; Plates IX.3 appD.A28-A31; IX.3 appC Table C4]*
This sample contains an area within the lower section of a large SHC (see also HGA4). The texture is fairly homogeneous (Figure IX.2.1a), with olivine of a granular appearance as the major phase (Figure IX.2.1b). The olivine appears to form mainly euhedral equant, to very slightly elongate crystals, of up to 300µm, but in some cases at least these are sub-divisions of larger complex equant olivine crystals of approximately 1mm across. The olivine shows a very narrow range of composition from Fa95Fo5 to Fa100, with a rise in calcium substitution across the same range of approximately 0.3% to 0.5%, and a fairly constant amount of manganese substitution of approximately 0.25%.

The main phase olivine locally overgrows wustite near its margin, but most wustite occurs on areas interstitial to the olivine (where it is often overgrown y a thin layer of olivine). The wustite typically occurs on small, but well-formed dendrites, and makes up a very small proportion of the slag.

The interstitial areas show the wustite dendrites (coated in olivine), fine olivine dendrites and locally tiny hercynite dendrites, all set in glass.

The porosity is represented by a fairly even distribution of variable and irregular vesicles.

Sample HGA6 [Figure IX.2*.1c-f; Plates IX.3 appD.A32-A37; IX.3 appC Table C5]*
This sample shows a complete section through the SHC that is 18mm thick (Figure IX.2.1c). The section shows an overall variation in the olivine crystals, from a basal crust (approximately 1mm thick) formed of equant olivine

crystals of less than 1mm, into a central section of approximately 9mm thickness, in which the olivine is elongate, increasing upwards in grain size from approximately 1mm to 5mm, followed by an upper section 8mm thick in which the elongate olivine (5mm in length) commonly has a lack of any interstitial material. The top is marked by inclusions of charcoal.

The vesicularity includes a few upwardly elongate large vesicles (‘tubular vesicles’), some sub-spherical vesicularity throughout, but coarser towards the base, and the porosity created by the olivine framework in the upper part.

The coarse grain size of the upper part suggests slow cooling of a melt of close to olivine composition promoted a rapid growth of the olivine, with a draw-down of the residual melt, leaving the exposed olivine framework.

The olivine composition in the sample shows a narrow range of variation from Fa93Fo7 to Fa100, over which range the calcium substitution rises from 0.3% to 1% and the manganese substitution falls from 0.3% to 0.25%. The main-phase olivine does not typically bear any cotectic phases. The olivine locally overgrows wustite near its margin, but most wustite occurs on areas interstitial to the olivine (Figure IX.2.1e). The wustite typically occurs on small, but well-formed dendrites, and makes up a very small proportion of the slag.

The interstitial volumes may be glass with fine olivine, or may show coarser mineral development including a leucite-wustite cotectic and olivine (Fa100 with up to 2% calcium substitution) – hercynite cotectic (Figure IX.2.1d). These coarse, leucite-bearing interstices are more common on, and close to, vesicle margins, but also occur widely in a zone just above the base (Figure IX.2.1f)

Sample HGA7
This sample was taken from a nub of gravelly slag; it was investigated through its bulk chemistry alone.

Chemical composition of residues
Bulk major element composition
The major elemental compositions of the residues are provided in Table IX.2.3. The illustrations (Figures IX.2.4 and IX.2.6) also include EDS area data from both macro- and microresidues.
The major element composition of the residues may conveniently be considered within the system SiO_2-Al_2O_3-FeO (Figure IX.2.4; after Schairer and Yagi 1952, fig 6) because these three oxides together comprise a very high proportion of the total. The low concentrations of all the other ‘major’ elements is noteworthy.

When these analyses are recast on an iron-free basis the compositions of the analysed samples are remarkably similar (Table IX.2.5).

Trace elements
The trace elemental compositions of the residues are provided in Table IX.2.4. The contents of most trace elements in the slags is relatively low, and show approximately linear correlation, suggesting a dominant origin in the hearth ceramic and a dilution of that material by iron.

The rare earth elements (REE) show inclined upper crust-normalised profiles (normalisation after Taylor & McLennan 1981; Figure IX.2.5a). In detail, the profiles show slightly different gradients, with those of HGAHGA4 and HGA5 (the upper and lower parts of the same large SHC) being slightly more inclined than those of HGA6 and HGA7. The difference is very small, perhaps reflecting slightly different compositions of hearth ceramic. When the data are recast on an iron-free basis (Figure IX.2.5b) the four profiles are very closely coincident, reinforcing the evidence for the common origin of these samples.

Interpretation
Interpretation of the microresidues
The samples available for investigation of the microresidues were relatively coarse-grained because of the original sample processing technique, but nonetheless contained examples of both flake and spheroidal hammerscale, as well as slag flats.

The particles show a wide range of composition (Figure IX.2.4b). There are examples of fine flake hammerscale within concretionary fragments (particles #T4 and #T5) and large flake hammerscale (#T3). These are essentially wustite (with exsolved magnetite) and magnetite superficial layers, as typical flake hammerscale (Young 2014). Flake hammerscale clasts also occur within both the slag flats and spheroidal hammerscale. The clasts show similar microstructures to the isolated scale fragments, and are characterised by polygonal grain boundaries in the wustite.

The slag flats and spheroidal scale show microstructures more generally indicative of formation from melts, notwithstanding the presence of these relict flake scale inclusion. The most wustite-rich particles show 'clots' of coarse blebby wustite with rounded grain boundaries. Lower proportions of wustite produce irregular rounded 'pseudo-dendrites', stout stubby dendrites and eventually delicate extended dendrites at the lowest iron contents. The primary wustite is followed either by elongate fine fayalite or by glass.

This range of microstructures may be compared with those observed in the assemblage from Coolamurry, a 12^{th} – 13^{th} century site in Co. Wexford, Ireland (Young 2008). A wider range of particle sizes was examined at Coolamurry which may account or some of the differences, but nonetheless even within the coarser grain sizes there are some marked differences between the assemblages. The two assemblages have very similar proportions of spheroids that are dominated by iron oxides (62% at Coolamurry, 67% at Hen Gastell), but the Coolamurry assemblages comprised only 40% hollow spheroids (60% vesicular), whereas 82% of the Hen Gastell assemblage were hollow. The small sample size may reduce the reliability of this differentiation, but nonetheless it is a striking figure. The most likely explanation would be that the development of a large central cavity, as opposed to distributed vesicularity, is favoured by a slightly lower viscosity. Modelling the viscosity of typical compositions for a wustite-rich (80% FeO) particle suggests that the viscosity is 10-15% higher for the more aluminous compositions seen at Coolamurry (data modelled using the Algoness slag viscosity utility).

The bulk analyses of small areas of these grains is shown in Figure 4b. The flake hammerscale and the relict inclusions thereof plot very close to the FeO pole. The composition of the analyses of the fully-melted textures form an array extending away from the FeO pole. The most iron-rich examples lie in a location corresponding approximately to the 1300C isotherm on the liquidus. This gives some indication of the minimum temperature of formation.

The variation in the major elements of the particles is illustrated in Figure 6, in which the concentration of other elemental oxides is plotted against silica. Although broadly suggesting a mixing trend between iron oxide and a ceramic (hearth lining) inputs, these diagrams illustrate considerable variability within the microresidues, in part probably reflecting both local inhomogeneity within the particles, but mostly differences between particles. An important illustration of this is the high level of magnesium report for particle #T2 (1.05-1.83 wt% MgO), affecting both the oxide-rich layers and the glassy area. The bulk composition of the glassy layer was reflected also in the relatively magnesian olivine (Fa88Fo2; ferro-hortonolite) present within the glass. This particle also preserved a layer of sand grade grains of quartz and feldspar. The precise significance of this unusual composition is unclear; both the elevated magnesium content and the quartz/feldspar inclusions might be the result of interaction with a melt derived from the hearth wall or they may be associated with a material employed as a welding flux. The elevated magnesium level might also, potentially, be associated with the redistribution of magnesium from slag inclusions with the iron. Unfortunately this ambiguity cannot be resolved using the current data.

Notwithstanding the variability of the analyses of the particles, many of the microresidue particles show an elevated content of phosphorus. Both the scale and gravelly slag analyses show low phosphorus, but at intermediate silica contents, the phosphorus is strongly elevated in some particles (including tabular particles #T1, #T2 and #T5, and spheroidal particles #S6 and #S9). Similar elevated levels were also recorded in an area of the slag veneer (HGA3) close to the marginal scale inclusions. This increase in phosphorus in the melt that generated these micro-residues cannot be explained by consideration of a simple iron-ceramic mixture and so suggests that the phosphorus originated in the iron itself, indicating in turn that the iron being worked was likely to have been phosphoric.

The olivine present in the microresidues shows an elevated level of substitution of manganese. This is significant for the composition of the microresidues will be strongly influenced by composition of the slag inclusions in the original metal. The microresidues are probably, therefore, providing evidence for elevated levels of manganese in those inclusions.

Taken together, the tentative evidence for the working of phosphoric iron and of iron with manganese-rich inclusions, points to the site having worked iron produced from bog iron ores.

Analyses of the slag veneer (HGA3) plot just on the tridymite side of the fayalite-tridymite divide (Figure 4a, open circles), close to the 1200C isotherm on the liquidus. This is significant, because it suggests that the slag veneers are not simply slag from the SHC that has been caught up on tools or workpiece, nor are they directly related to the slag flats. Instead, this composition represents a composition of a melt produced by reaction of iron and the wall ceramic. The analyses plot on the tie-line between the bulk composition of the 'gravelly slag' (HGA7) and iron. The gravelly slag composition does not equate to a melt composition (such a composition would not be molten until it had reached a temperature of approximately 1500C, outside the range of a smithing hearth), but to a mixture of melt and unmelted residual material (the composition of the unmelted residual material would be further along the tie-line, close to the SiO_2 axis of Figure IX.2.4a). The iron involved in that reaction would probably be small particles of iron or iron oxide lost from the workpiece and falling onto the hearth wall above the blowhole. Some indication of the nature of the iron input is shown by the glass film on tabular particle #T2 (Figure IX.2.2a), which shows inclusions of droplets (prills) of iron, as well as fragments of hammerscale.

The interpretation of the film is most likely to be sought in the removal of blebs of melted wall by the smith, perhaps when they started to impinge on the blowhole itself. The substantial layer of scale present in the re-entrant angle of the film indicates not only the contact surface with the tool, but also suggests that the tool had developed scale through use in the hearth, but the chilled contact of the slag with the scale might suggest that the tool surface was relatively cool at the actual moment when the smith used it to clear this slag bleb.

Interpretation of the macroresidues

A total assemblage of just seven SHCs does not permit rigorous comparison with SHC assemblages from other sites, but the assemblage is certainly comparable with others from early smithies, particularly those from the earlier part of the medieval period (Table 6). With a range of SHC weights of 72-1000g and a mean weight of approximately 260g for this assemblage, comparative medieval assemblages would include those from Worcester, Mill Street (12th century; Young 2009a), Worcester, Willow Street (12th century; Young 2007) and Tidworth (Saxo-Norman; Young 2016). There are also comparable assemblages from SE Ireland, including Garryleagh, Co. Cork (13th-14th century; SHCs range from 84-802g with a mean of 316g; Young 2009b) and Coolamurry, Co. Wexford (12th-13th century date; SHCs range from 62-3588g with a mean of 386g; Young 2008). The larger maximum size of SHC recorded on some Irish sites has been attributed to the distribution of iron in a less than fully-processed state (Young 2009b), whereas the lack of such large outliers in the British examples suggests that iron was being distributed already worked down to stock iron. There is no evidence from the chemical analysis of the Hen Gastell material of transfer of large amounts of smelting residue into the smithing slag, as would occur when incompletely processed bloom was worked. Transfer of small quantities of slag, from the slag inclusions that had been present in the iron lost to the smithing hearth, would have occurred, but was a minor influence on slag chemistry compared with the influx of molten silicate from the hearth wall.

The interpretation of task, or even the size of the task, from the SHC produced remains understood rather poorly. One recent investigation into smithing wastes (Soulignac & Serneels 2014) documented the loss in iron from the metal and the amount of slag produced for a variety of tasks undertaken by Malian smiths. They determined that the loss of metal was between 7% and 60% depending on the complexity of the task, the number of welds, the shape of the starting stock and skill of the smiths. From extrapolation of their Figure 8, a slag cake of 1kg would be generated by the loss of 850g of iron (the difference between the loss and the amount of iron in the SHC being mainly due to the loss of iron in microresidues outside the hearth). Thus, using the same figures, a loss of 850g would represent the loss from processing between 1.4kg and 12.1kg of iron, depending on the complexity of the task, for the work period producing that large SHC.

Interpretation of the distribution

The focus of the activity within the excavated area was the cluster of pits towards the northern side of the structure. Most of the residues (70% of the macro-residues from the site) derive from irregular hollow [2067]. The field description implies this feature had no in-situ burning. This may, therefore, be a worn 'working hollow', that became filled with debris. Close to this lay circular pit [2076] contained a broad spectrum of residues in small quantities, but with a rich hammerscale assemblage. It is possible this circular pit held a wooden anvil bock (into the top of which a small metal anvil could be placed. Furthest east of the features was the probable hearth [2078]. This pit was 0.47 x 0.40m and 0.20m deep. This is unusually small for a medieval forge hearth, but not impossibly so (particularly if the hearth was only intended for the working of small objects).

There have been few earlier medieval floor-level smithing hearths properly identified and recorded; later medieval hearths appear to have been mostly-waist level structures. In the early medieval, smithing hearths are known from South Wales at Gelligaer (7th century; Young 2015a) and Pontarddulais (5th-7th century; Ward 1978). Both of these examples were approximately figure-of-eight shaped pits, with a hearth at one end and a possible anvil base at the other. The hearths of these structures (1.25x1.1m at Pontarddulais and 0.66x0.62m at Gelligaer) are rather equant (ratio of long to short axes approximately 1.1). The probable smithing hearths at Porth Trafadog (Longley 1991), of similar age to the Hen Gastell metalworking, were variably of 0.30m up to 1.0m.

In contrast, smithing hearths of this period in Ireland tend to be rather larger and, although some are equant, others are elongate (e.g. Cornamucklagh: 11th-13th century, 0.82m by 0.54m and 0.99m by 0.21m, Young 2014; Coolamurry, 12th-13th century, 1.0m by 0.9m, 0.92m by 0.82m and 1.2m by 0.8m, Young 2008; Garryleagh: 13th – 14th century, 0.90m by 0.87m, Young 2009b).

Summary

The analysis presented above suggests that blacksmithing was probably undertaken in a small hearth in the northern side of the building at Hen Gastell. The hearth was a small, floor level, hearth less than 0.5m in diameter. A slightly larger pit just 0.25m south of the hearth may have been for a wooden anvil block. The size is appropriate for a block to hold an anvil of the type suggested by find #40 (see Goodall 2011, cover and figure 2.1, for illustrations of blocks and anvils).The relative size and positioning of these two features is reminiscent of early medieval paired smithing hearths and anvil blocks on sites at Gelligaer and Pontardulais in S Wales (Young 2015a; Ward 1978). Such an arrangement would allow a smith sitting or squatting in the area of the worn hollow, to remove the metal from the hearth with the tongs in the left hand and rotate slightly right to use a hammer on the anvil with the right hand.

The small size of the hearth and the small size of the majority of the recovered SHCs suggests that rather smaller items/batches of work were the norm. The presence of at least one large SHC suggests that the smith undertook some heavy work that was capable of entailing the loss of 0.5kg of iron into the hearth during just one work period. This pattern resembles that indicated by the residues found at several other blacksmithies of the period, in both rural and urban settings.

The chemical composition of the SHCs provides no evidence that they (including the large example) were produced during the refining of raw blooms down to bar iron. Rather, the evidence suggests that the forge was supplied with finished iron.

The microresidues produced during the working of iron at the anvil included both flake and spheroidal hammerscale. Feldspathic sand trapped in one example of slag-rich flake hammerscale (or ‘slag flat’) may possibly be remnants of a smithing flux, although derivation from the hearth wall cannot be excluded.

An example of a ‘slag flat’ that had apparently formed on the smith’s tools had a composition indicative of freshly-melted hearth wall (fluxed by the addition of iron). It can be speculated that the slag may represent a lobe of melt that had interfered with the air blast and had required removal with the tongs.

Evidence for the air delivery system was limited to a single fragment of hearth ceramic containing a part of the blowhole margin. This was of unusually large diameter for such a blowhole (35-40mm; more typically the diameter is in the range of 15-30mm). The presence of tiny blebs, apparently of slag spatter, on the inside of the bore suggest it was indeed an open blowhole, but there is a possibility that it actually held an iron tuyère (which are only recorded from rather later in the medieval period).

Only a very small population of spheroidal hammerscale particles were analysed, so determination of certain chemical trends is difficult, but it would appear that some spheroids had enhanced contents of phosphorus, whereas others showed enhanced levels of manganese. These two elements would be concentrated in the metal (phosphorus) and the slag inclusions (phosphorus and manganese) of iron produced from bog iron ores. Such sources were probably utilised for the production of iron in the earlier medieval period at Cefn Graianog (Young 2015b), just 8km to the south of Hen Gastell (although there were presumably many other, as yet undiscovered, similar smelting operations).

The scale of the smithing at Hen Gastell is not known. The relatively small assemblage of residues may reflect the limited opportunity for incorporation of slag into the archaeological record within the footprint of what might be a fairly high-status building. The residue-rich deposits were probably formed on the abandonment of the smithing operation, with residues being left in the hearth, the anvil block pit and in the hollows worn in the floor by the feet of the blacksmith. The normal waste disposal from the forge is likely to have been outside the immediate setting. The occurrence of hammerscale within almost all the excavated postholes of the structure indicates that these fine scale residues became well-distributed around the structure during its lifetime, suggesting a significant amount of activity.

In summary, the evidence points to the use of the forge by a smith undertaking a variety of tasks, similar to those undertaken in contemporary smithies in both rural manors (e.g. Tidworth) and urban centres (e.g. Worcester). Although the scale of the activity cannot be determined, it was not ephemeral. The smith probably had access to a relatively local source of phosphoric iron (although it would be likely that other forms of iron and steel would also have been worked). Some of the work undertaken must have been fairly large-scale, as the largest SHC represents the loss of 0.5kg of iron to the hearth, perhaps a loss of 0.85kg in total, probably during a single work session.

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Figures

Figure 1

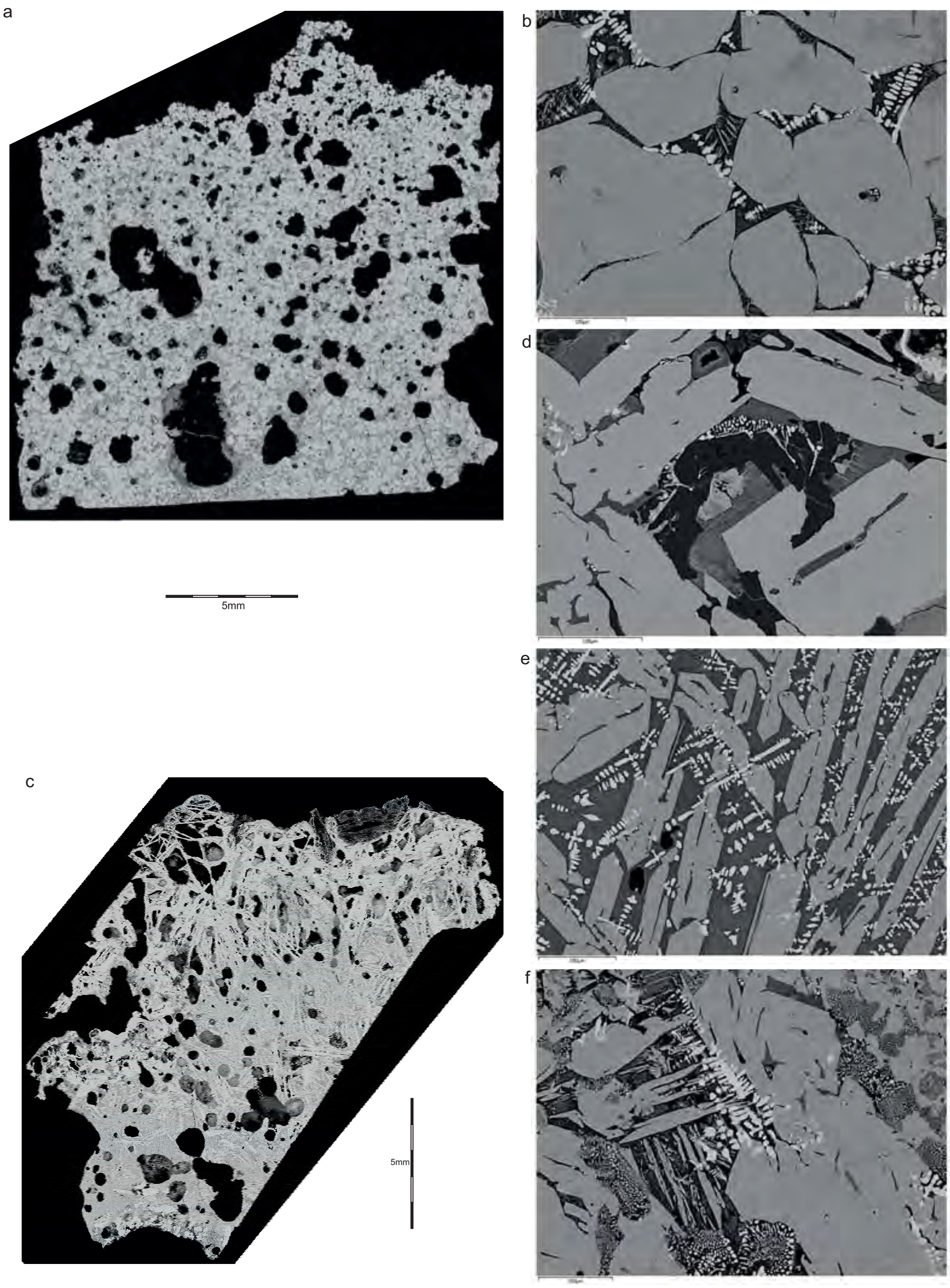


Figure IX.2.1: backscattered electron images of smithing slags.
a. Sample HGA5, whole mount. Shows granular texture of olivine (pale grey) and the large vesicles (black).
b. Sample HGA5, site 1337. Detail showing equant olivine (mid-grey), with interstitial areas bearing wustite (white), together with very fine olivine and hercynite (mid-grey) in glass (dark).
c. Sample HGA6, whole mount. Note cavernous texture to elongate olivine (pale) near upper surface and vertically-oriented vesicles
d. Sample HGA6, site 1342. Coarse olivine in upper part of SHC. Interstitial areas are partly weathered (voids surround by iron oxides with a gradational tone), but also show complex relationships of leucite (dark), leucite-wustite cotectic (speckled) and a hercynite-olivine cotectic (centre), together with glass bearing fine olivine dendrites.
e. Sample HGA6, site 1344. Texture in mid-section of SHC with wustite dendrites (white), olivine (mid-grey) with interstitial glass (dark) bearing fine late olivine dendrites.
f. Sample HGA6, site 1345. Texture near base of cake, showing abundant development of leucite-wustite cotectic (black and white).

Figure 2

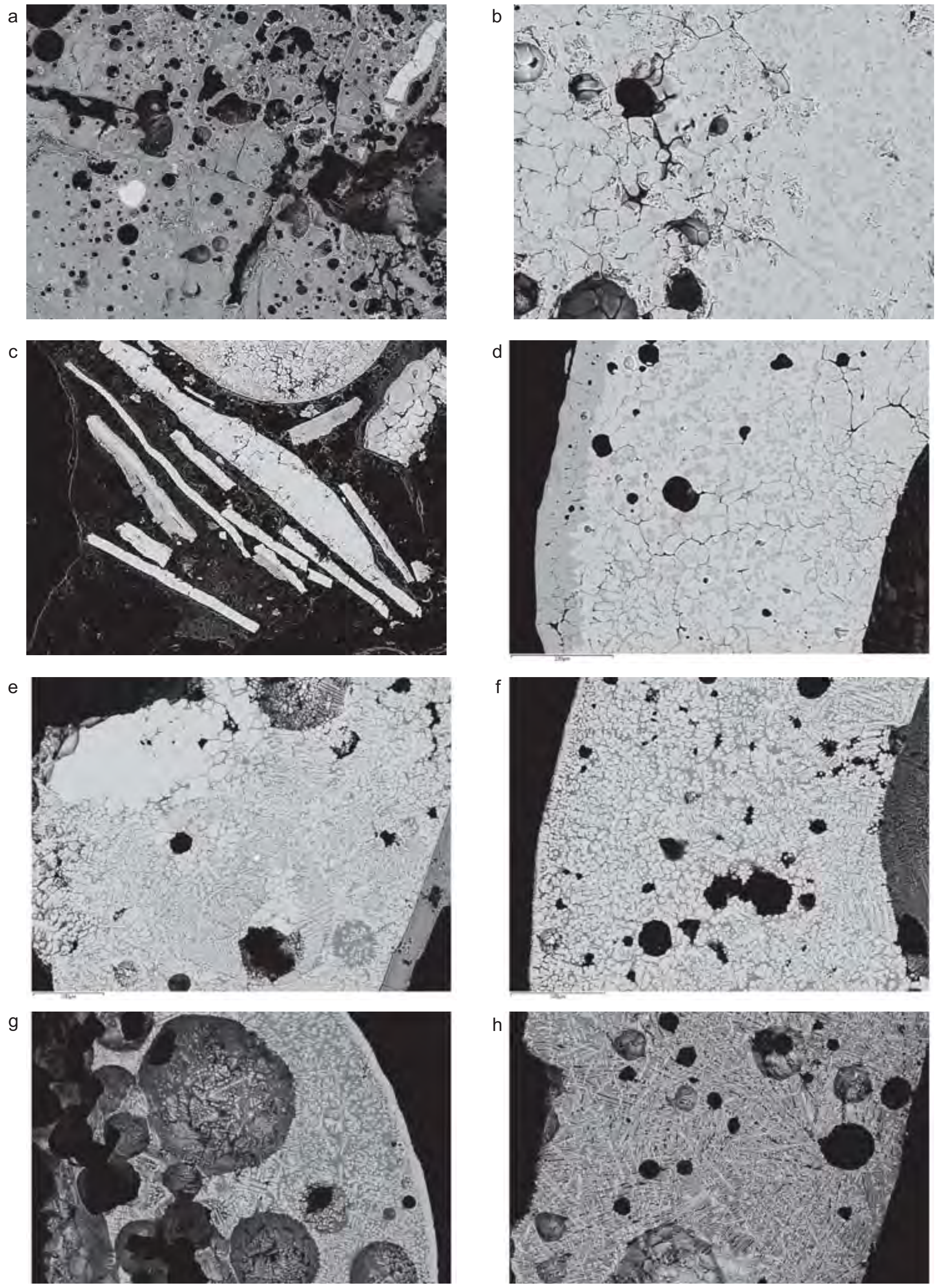


Figure IX.2.2: backscattered electron images of smithing microresidues.
a. Sample HGA1, particle #P2. Site 1111. Glass (mid grey) bearing blebs of iron (pale) and hammerscale (pale elongate). Crystals of olivine (ferro-hortonolite) are just slightly darker than the glass.
b. Sample HGA1, particle #P3. Site 1113. Area showing polygonal grain boundaries in wustite (probably inherited from the oxidised iron) to the left, and wustite with exsolved magnetite to the right.
c. Sample HGA1, particle #P3. Site 1116. 'Smithing floor' concretion fragment showing fine flake hammerscale and rounded particle in dark hydrated iron oxide matrix.
d. Sample HGA2, particle #S7. Site 1131. Texture of polygonal wustite relict in a wustite-rich spheroidal particle.
e. Sample HGA2, particle #S5. Site 1128. Relict wustite scale fragment (in upper left) in spheroidal particle largely formed of newly-formed wustite in various forms of dendrites and pseudo-dendritic 'clots'.
f. Sample HGA2, particle #S8. Site 1132. Slightly less iron rich spheroidal particle than in (d) and (e), showing greater development of glass between wustite dendrites.
g. Sample HGA2, particle #S2. Site 1121. More oxidised and silicate-rich spheroidal particle, showing well-developed magnetite crust (skin), inward-growing magnetite dendrites and internally wustite in glass.
h. Sample HGA2, particle #S6. Site 1129. Silicate rich spheroidal particle showing delicate wustite dendrites *white), followed by sheaves of elongate olivine crystals.

Figure 3

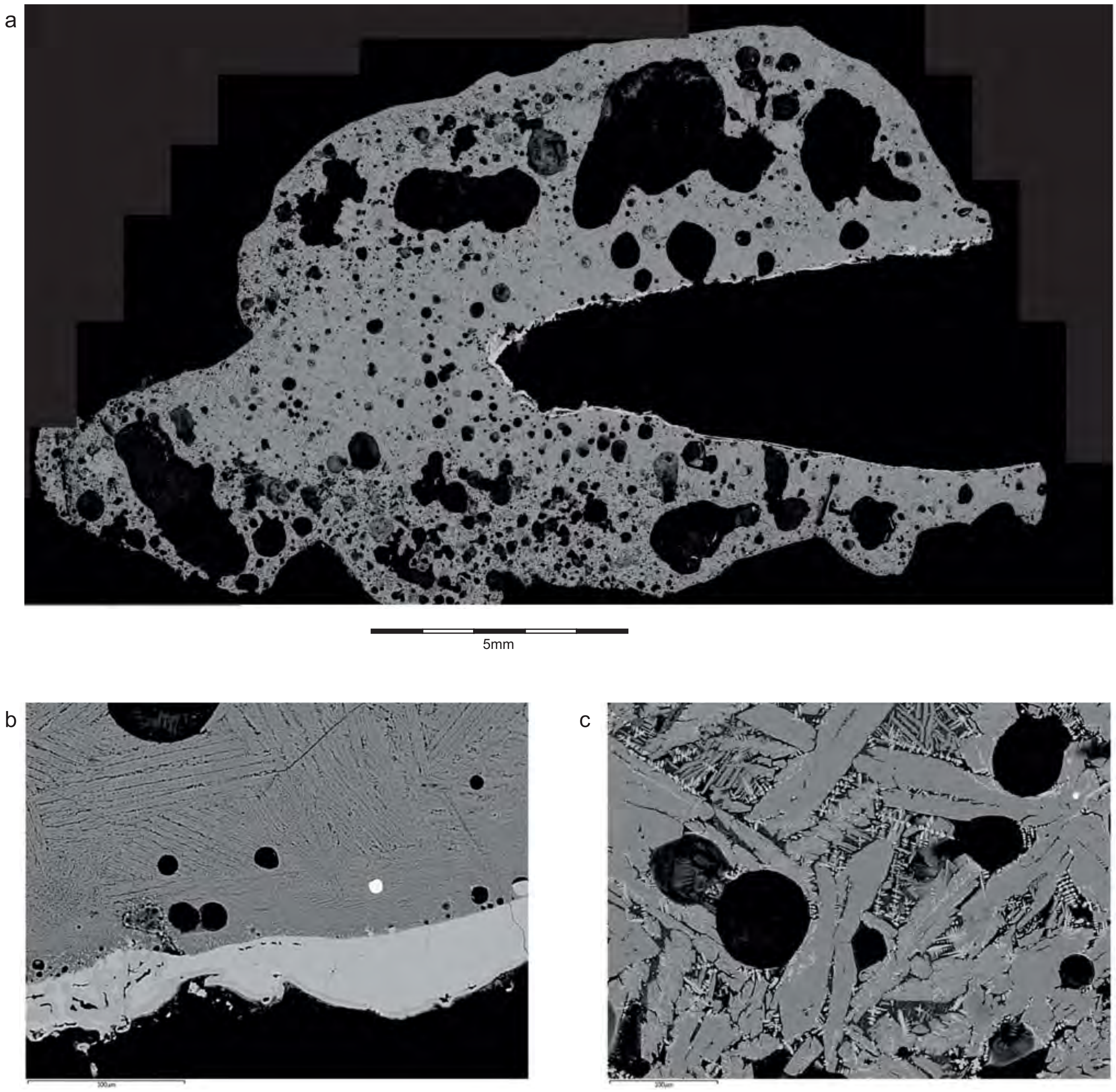


Figure IX.2.3: backscattered electron images of slag film HGA3

a. Sample HGA3, whole mount. The relict scale on the inside of the notch shows as a bright zone. The overlying slag is zoned, both compositionally and by style of vesicle development.

b. Sample HGA3, site 1330, Detail of scale on inner surface. Scale is of magnetite (slightly darker) and wustite (paler). Bright bleb is a prill of iron metal. Note the lack of wustite within the slag.

c. Sample HGA3, site 1332, area within the body of the slag showing early clear olivine followed by olivine with a wustite cotectic.

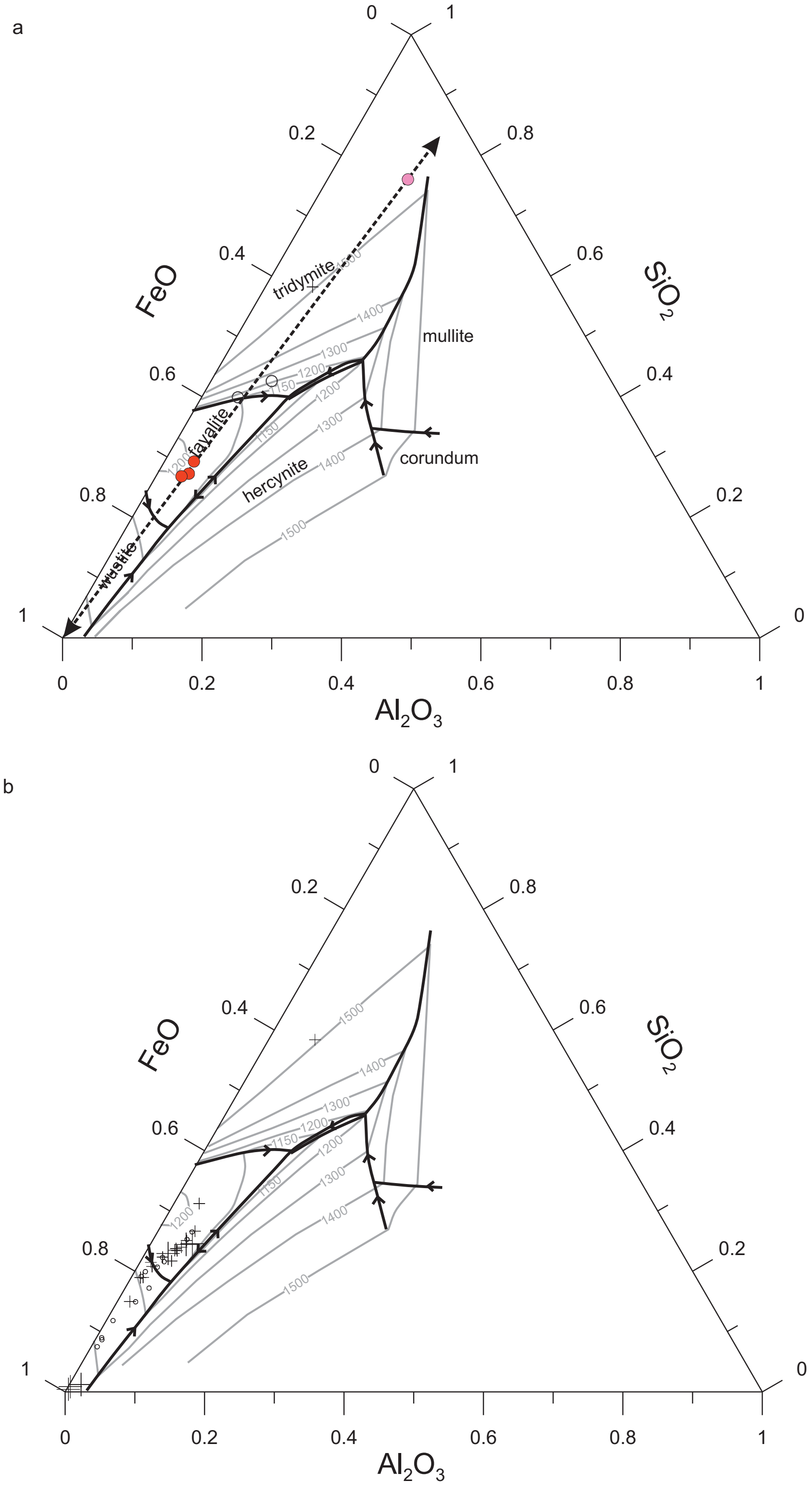


Figure IX.2.4: major element composition of bulk analyses of residues plotted within the ternary system SiO_2-Al_2O_3-FeO (fields after Schairer and Yagi 1952, fig 6).

a: analyses of residues from smithing. Filled red circles are analyses (by XRF) from the smithing hearth cakes (SHCs), HGA4-6, the pink-filled circle is the analysis (by XRF) of gravelly slag HGA7. The open circles are analyses (by EDS) of the slag film HGA3. The black cross is the analysis (by EDS) of the quartz/feldspar-bearing layer within sample HGA1, flake hammerscale particle 2.

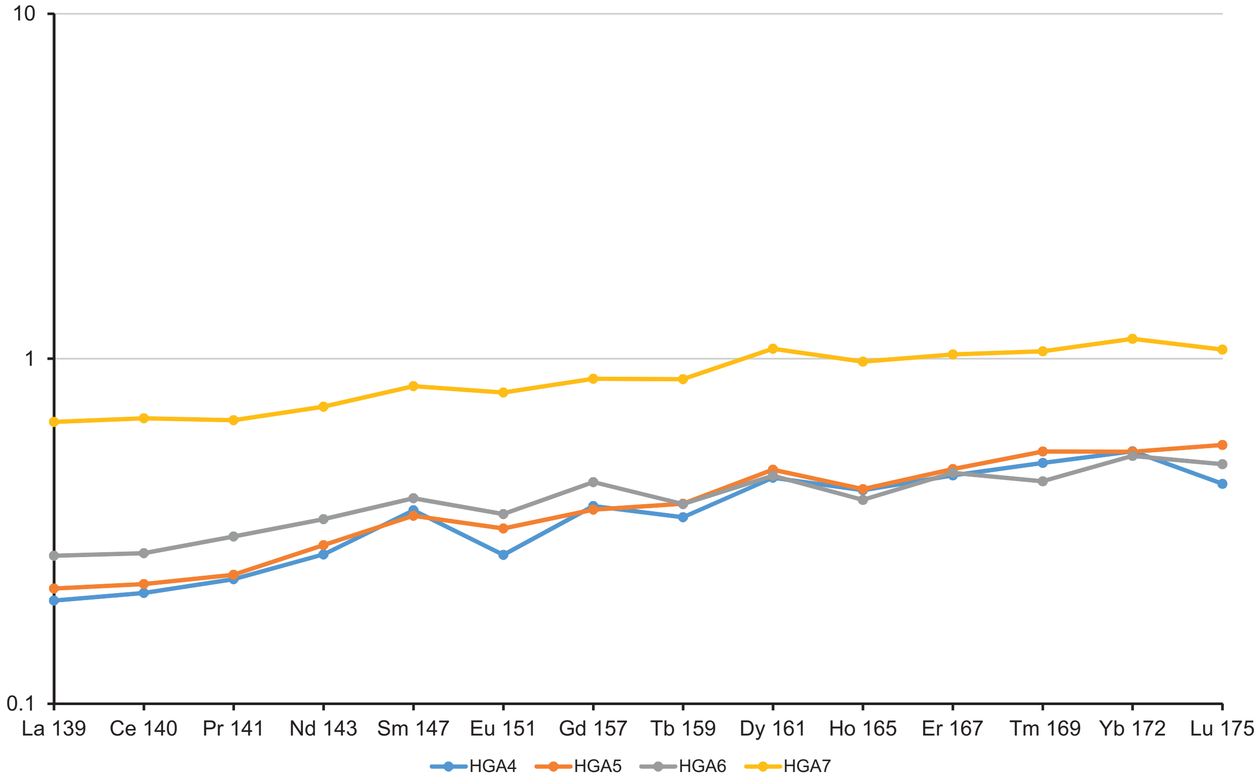
The dashed line indicates the hypothetical mixing tie-line between iron and hearth ceramic.

b: analyses of microresidues by EDS. Analyses of tabular residues indicated by crosses (large crosses indicate evidence for primary iron-oxidation textures, small crosses indicate melt textures), analyses of spheroidal residues indicated by open circles.

The array of points with an orientation slightly oblique to the main mixing trend may be the result of the influence of smithing flux, or alternatively may simply be produced by internal fractionation within solidifying particles.

Figure 5

a



b

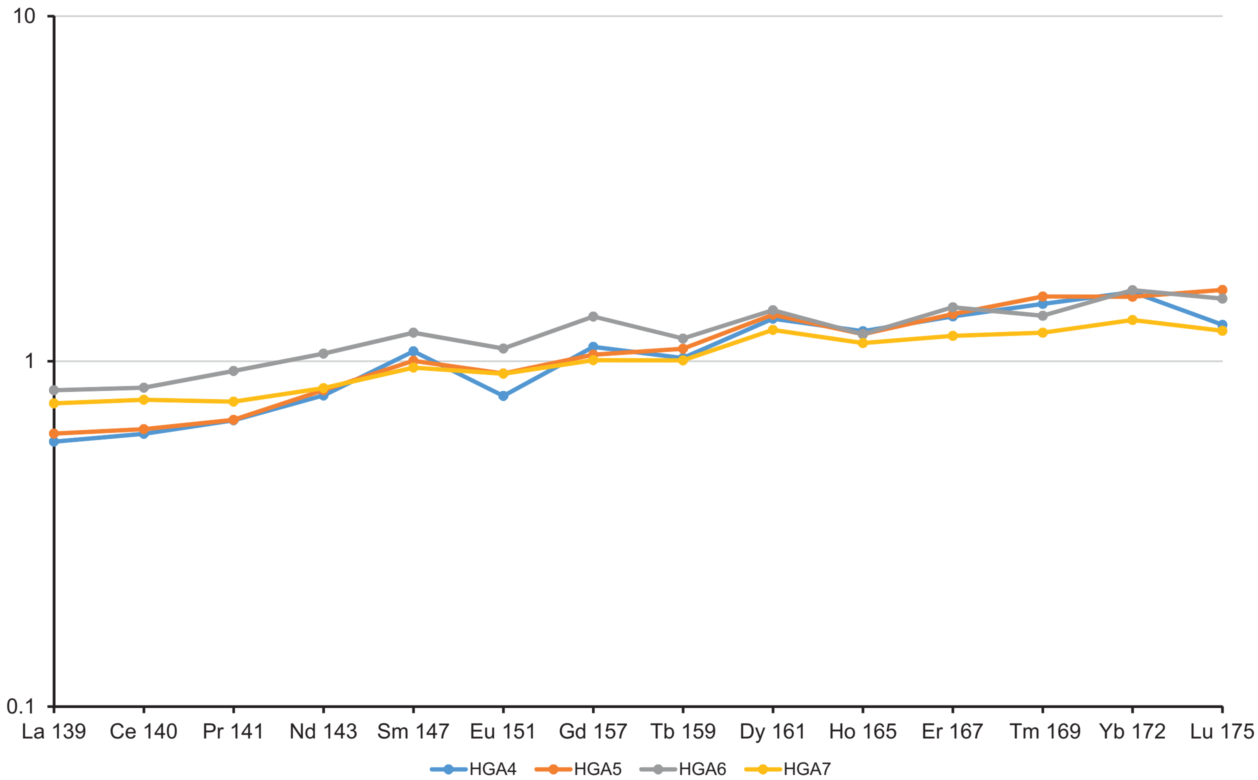


Figure IX.2.5: upper crust-normalised rare earth element (REE) profiles (normalisation after Taylor & McLennan 1981) for analyses of residue samples from Fleet Hill Farm.
a. as analysed.
b. analyses recast on an iron-free basis.

Figure 6

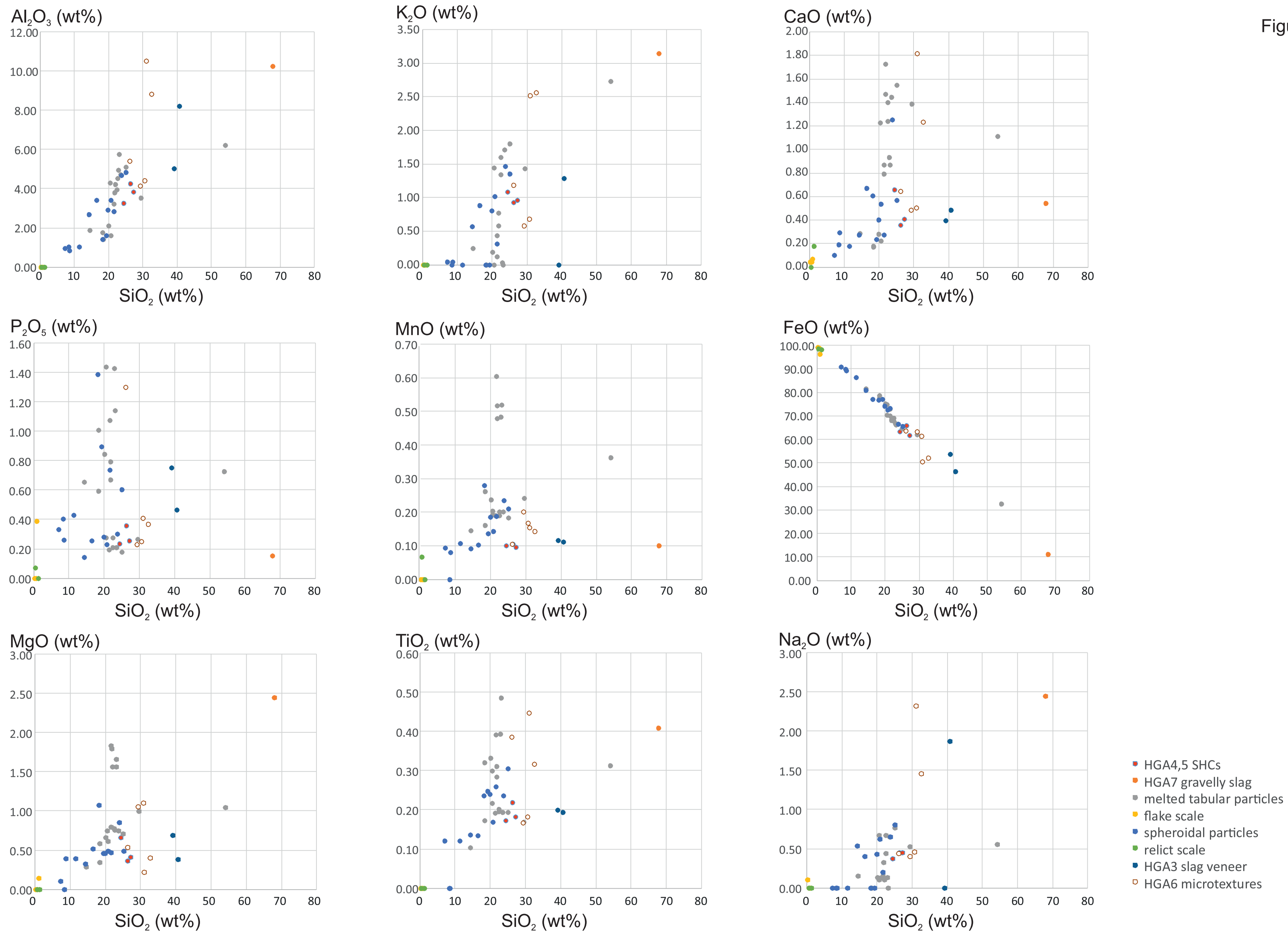


Figure IX.2.6: Binary plots of oxide concentrations (in wt%) from bulk chemical analyses (by XRF and ICP-MS)

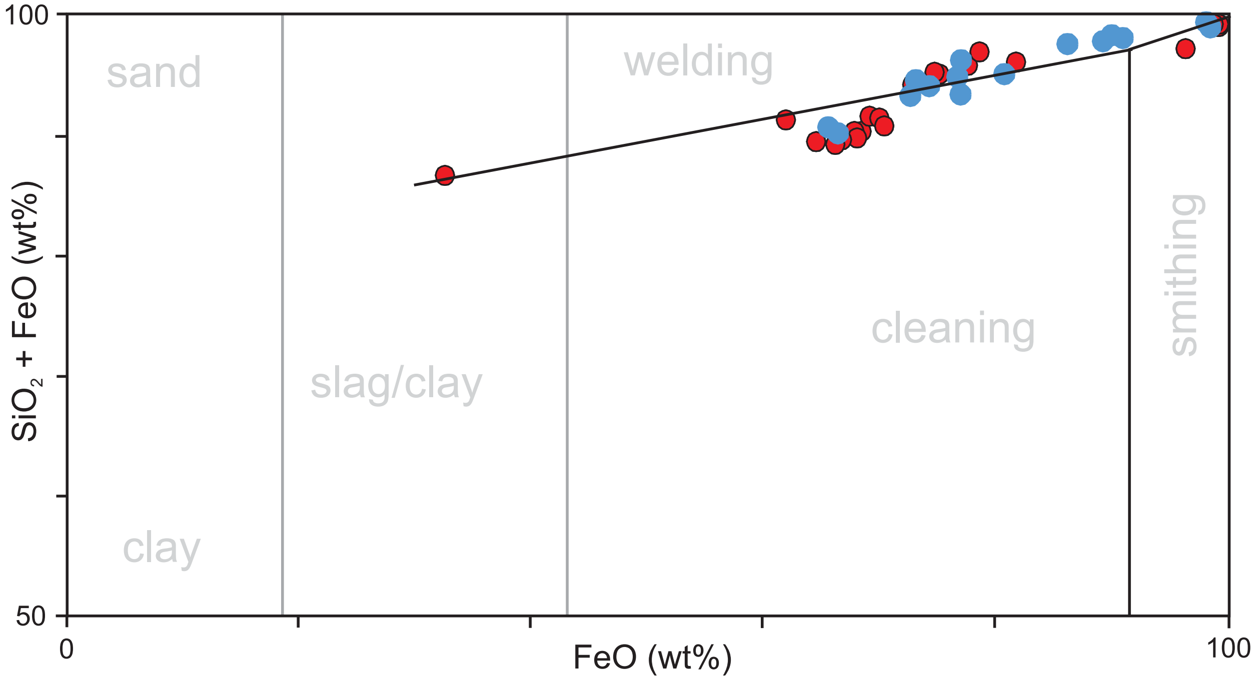


Figure IX.2.7: Analyses of tabular particles (HGA1; red) and spheroidal particles (HGA2; blue) of microresidue, plotted on the discriminant diagram of Jouttijärvi (2015).

Tables

Table IX.2.1: summary of stratified residues by type of feature and context. For the microresidue assemblages mod = moderate, tr = trace, y = present.

c	notes	SHC	clinkery slags	indet slag	hearth lining	scale	spheroids	flats	glazed stone	smithing floor	iron	coal
	Deposits below bank											
2079	Buried soil 'A' horizon, under bank 2018					tr						
2082	Layer containing burnt bone and charcoal, underlies bank 2116					tr						
	Burnt stone deposits over bank											
2003	burnt stone deposit over bank 2018		20	y	38	rich	y	y			y	
2023	burnt stone deposit over bank 2018	50	22	y	14	rich	y	y			6	
	Packing fills of postholes											
2008	packing fill in p/h [2007]				y	tr						
2048	packing fill in p/h [2011]			y		tr						
2053	packing fill in p/h [2052]					tr						
2093	packing fill in p/h [2092]			y		tr						
2120	Disturbed packing fill of posthole [2119]					tr						
	Post-pipe fills of postholes											
2012	possible post-pipe fill in p/h [2011]					tr						
2014	fill of post-pipe in p/h [2009]			y		tr						y
2015	fill of post-pipe in p/h [2007]		10			tr						
2042	fill of post-pipe in p/h [2118]					tr		y				
2070	fill of post-pipe in p/h [2068]		y			y		y				
2071	fill of post-pipe in p/h [2052]			y		y						
2072	fill of post-pipe in p/h [2005]					tr						
2097	fill of post-pipe in p/h [2092]		y									
2101	Fill of a possible post void at NW end of posthole [2083]		y									

c	notes	SHC	clinkery slags	indet slag	hearth lining	scale	spheroids	flats	glazed stone	smithing floor	iron	coal
2105	Fill of post void [2106] in posthole [2108]		8		y	mod	y					
	Minor pits											
2036	fill of pit [2035]			y		tr						4
2056	fill of cut [2055]			tr		tr						
2090	Relatively charcoal rich fill of pit [2089], 0.35 x 0.33m, 0.11m deep			y	y	mod						
	Metallurgical group											
2066	Charcoal and slag rich fill of hollow [2067] 1.60 x 1.10m x 0.15m	1084	1294	406	32	rich		30	84	1032	36	
2075	Charcoal rich fill of small pit [2076], 0.60m diameter, 0.30m deep		32	6	6	rich	y	6	1	44		
2077	Upper fill of pit [2078]	754	98	y		rich	y	y				
2098	Heat-reddened clay in the base of pit [2078]		y		y	mod	y					
2099	Thin, dark, silty charcoal rich fill in the base of pit [2078]		2			rich	rich	6	2			

Table IX.2.2: Sampled material

Sample	Facies/Type	Material notes	Context	Source notes	Chemical analysis?	SEM?
HGA1	micro	tabular microresidues	2066	Fill of hollow [2067]		yes
HGA2	micro	spheroidal microresidues	2066	Fill of hollow [2067]		yes
HGA3	adhesion	slag flats from tool/workpiece	2066	Fill of hollow [2067]		yes
HGA4	SHC	large SHC upper frothy dense layer	2077	U fill of pit [2078]	yes	
HGA5	SHC	large SHC lower dense layer	2077	U fill of pit [2078]	yes	yes
HGA6	SHC	small SHC bulk	2066	Fill of hollow [2067]	yes	yes
HGA7	smithing slag	gravelly slag	2066	Fill of hollow [2067]	yes	

Table IX.2.3: Major elements by XRF. < = below detection. All elements presented as wt% oxide. Adjusted to Mn^{2+} and Fe^{2+} and adjusted to exclude volatiles (LOI).

	SiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5
HGA4	26.84	4.34	67.05	0.11	0.36	0.36	0.46	0.94	0.22	0.36
HGA5	28.26	3.99	64.05	0.10	0.42	0.26	0.46	0.99	0.19	0.26
HGA6	25.79	3.43	66.72	0.11	0.69	0.54	0.39	1.14	0.18	0.25
HGA7	68.53	10.33	11.16	0.10	0.96	0.55	2.46	3.17	0.41	0.15

Table IX.2.4: trace elements by ICP-MS. < = below detection. All elements presented as ppm. Adjusted to Mn^{2+} and Fe^{2+} and adjusted to exclude volatiles (LOI).

	Co	**Cu**	**Ga**	**Ge**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Mo**	**Ru**	**Sn**	**Cs**	**Ba**	**La**	**Ce**	**Pr**
HGA4	13.19	11.46	8.16	20.69	18.62	39.51	8.89	76.93	8.87	7.12	0.01	0.30	0.70	221.03	5.97	13.41	1.63
HGA5	13.17	10.58	7.36	19.34	20.89	36.22	10.16	68.53	8.51	6.64	0.01	0.32	0.66	237.70	6.47	14.23	1.68
HGA6	9.67	84.93	21.10	19.55	24.23	50.26	10.50	57.75	5.38	5.79	0.01	8.12	0.58	198.44	8.06	17.48	2.17
HGA7	14.39	18.50	13.55	4.38	91.91	109.62	24.99	118.29	16.24	4.08	0.00	0.38	2.62	560.27	19.68	42.99	4.71

Table IX.2.4 (continued): Minor and trace elements by ICP-MS. < = below detection. All elements presented as ppm. Adjusted to Mn^{2+} and Fe^{2+} and adjusted to exclude volatiles (LOI).

	Nd	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Hf**	**Ta**	**W**	**Pb**	**Th**	**U**
HGA4	7.04	1.64	0.24	1.42	0.22	1.58	0.33	1.06	0.16	1.19	0.14	2.05	0.34	0.69	1.50	2.24	0.88
HGA5	7.49	1.58	0.28	1.39	0.24	1.67	0.34	1.10	0.18	1.18	0.18	1.90	0.31	0.65	1.10	2.51	0.80
HGA6	8.91	1.77	0.31	1.67	0.24	1.60	0.31	1.07	0.15	1.15	0.16	1.56	0.22	0.62	1.72	2.62	0.81
HGA7	18.88	3.75	0.70	3.32	0.56	3.74	0.78	2.37	0.35	2.51	0.34	3.18	0.72	1.09	6.16	7.49	1.52

Table IX.2.5: Major elements by XRF as Table 2, normalised to exclude iron.

	SiO_2	Al_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5
HGA4	78.93	12.76	0.31	1.07	1.05	1.34	2.76	0.65	1.07
HGA5	80.86	11.41	0.28	1.21	0.76	1.32	2.83	0.54	0.75
HGA6	79.21	10.53	0.33	2.13	1.67	1.21	3.50	0.56	0.76
HGA7	78.94	11.90	0.12	1.10	0.63	2.84	3.66	0.48	0.17

Table IX.2.6: Comparison of the SHC weight-frequency distribution with that of other assemblages from blacksmithing from medieval sites in Britain. Weights in gram.

Site:	Hen Gastell	Tidworth	Worcester	Worcester	Prior Park Cricklade	Worcester Deansway	Worcester Deansway	Burton Dassett
			35 Mill St	Willow St	total	(period 8)	(period 9)	
Reference:	this study	Young 2016a	Young 2009b	Young 2007	Young 2008b	McDonnell & Swiss 2004	McDonnell & Swiss 2004	McDonnell 1992
Age:	11th-12th	Saxo-Norman	12th	12th	11th-15th	11th – 13th	13th-15th	14th- 15th
fuel	charcoal	charcoal	charcoal	charcoal	charcoal			
SHC count	7	12	23	28	17	61	32	60
SHC min. wt	72	80	74	86	156	168	144	130
SHC max. wt	1000	680	782	770	794	1490	1800	1670
SHC mean wt	260	265	233	327	329	492	499	550
% <150g	57%	33%	39%	18%				
% <500g	86%	75%	91%	82%	82%			

18.3. Appendices to IX.2

IX.3 appA: Catalogues

Table A1: summary catalogue. Assm = assemblage, FHS = flake hammerscale, SHS = spheroidal hammerscale, SHC = smithing hearth cake

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
T2 u/s	26		slag	96	96	1	fragment of small SHC, original size not known. Well-formed lower crust with fuel-dimpled base, top largely obscured by concretion
2002	66		cleaning over bank (2018)	88	88	4	irregular rounded nubs of black glassy clinkery slag with locally maroon surface and abundant variably melted clasts.
2003	58		Fe slag	20	20	1	fragment of irregularly-lobed slag nub with glassy surface, apparently has corroded iron inclusion
2003	4	112	fine - metalworking	9		assm	mainly stone, but some maroon slag, slag spheroids, moderate FHS, some SHS, some fired clay
2003	5	113	fine - metalworking	<1		6	variety of slag types, spheroids, lining, dense, and vesicular
2003	5	113	fine - metalworking magnet	<1		assm	small but rich assemblage of FHS, flats, slag fragments, slag spheroid and some stone
2003	6	114	fine - metalworking magnet	<1		assm	stone, trace of FHS and SHS, with iron fragment
2003	8	116	fine - metalworking magnet	<1		assm	slag fragments and blebs with some FHS in v small assemblage

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
2003	21		furnace lining	38	38	1	oxidised and slagged lining with blowhole preserved on protrusion. Interior of blowhole is slightly vitrified with fine spatter. Blowhole appears to be 35-40mm diameter
2008	18	124	fine - metalworking	2		assm	large pieces of lining slag, with trace of FHS amongst finer stones
2012	9	117	fine - metalworking magnet	<1		assm	stone, trace of FHS and SHS
2014	15	122	fine - metalworking magnet	2		assm	stone with some FHS and slag - the latter curiously finely crystalline
2014	15	122	fine - coal	<1		5	coal fragments
2015	7	142	coarse - slag	10	10	1	black glassy slag binding variously vitrified, bloated and partially melted lithic clasts
2015	7	115	fine - metalworking	<1		assm	stone, trace of FHS and SHS
2023	14	121	fine - metalworking magnet	<1		assm	small sample rich in FHS, slag flats and trace of SHS
2023	16	123	fine - metalworking magnet	<1		assm	concretion, stone, slag, FHS, slag spheroids, some SHS
2023	16	143	coarse - slag	4	4	1	glassy bound lining slag
2023	61		furnace lining	14	14	2	vitrified oxidised fired lining, black glassy vesicular slag. Ceramic has probable leaf impressions

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
2023	63		Fe slag	78	6	1	rusted Fe object - small nail?
					50	1	dimpled lobate slag nub, possibly part of SHC or incipient SHC, very dense; one end has rusty accretion (probably from iron in slag)
					18	2	blebs of lining slag, pale, glassy
2036	10	118	cinder? Slag?	4		22	coal and coke
2036	10	118	fine - coal	<1		3	coal
2036	10	118	fine - metalworking magnet	<1		assm	stone, trace of FHS and SHS
2042	12	119	fine - metalworking magnet	3		assm	mainly stone, but some FHS and slag flats
2048	13	120	fine - metalworking magnet	<1		assm	slag, FHS and SHS
2053	24	129	fine magnetic material	<1		assm	stone with trace FHS
2056	19	125	fine - metalworking magnet	<1		assm	mainly stone, trace slag and trace FHS
2066	21	104	coarse metalworking debris/slag	670	4	3	vitrified/glazed gravel
					40	12	gravel with adhering slag, in many case glazed also

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
					4	3	gravel - natural
					226	91	blebby lining influenced slags, mostly with white granule clasts, most maroon surfaced,
					14	9	vitrified slagged lining
					42	13	rough, granular, dense slags
					84	22	dense flowed slag, varying from small good flow slag to more blebby material
					30	16	flats, tool casts etc. only a few show right-angled re-entrants
					226	135	concretionary fragments, mainly rusty, with variably clasts of slag, FHS, charcoal and iron
2066	21	106	fine metalworking debris (magnet)	524		assm	very rich assemblage, dominated by FHS, but with slag flats, slag fragments, slag blebs, slag spheroids, SHS and some concretionary material (lower proportion than in 2099)
2066	21	105	fine metalworking debris	384		assm	assemblage dominated by fine version of maroon, gravel-rich slagged substrate, other material include abundant vesicular to frothy flats, some FS, slag spheroids and prills, vitrified stones ,stones attached to slag, concretions and some laminated rusty spalls (unclear if the latter are from rocks or iron)
2066	21	148	abraded orange ware	<1		1	oxidised fired clay
2066	46		slag 1/2	2412	168	1	90x60x30, small SHC, just slightly concavo-convex, top locally smooth, slightly reddened and with charcoal inclusions, base microdimpled/microprilly, dense
					72	1	70x50x25, small proto-SHC, prilly base (coated with rusted organics), smooth top with slightly lobate margin
					306	1	double SHC, lower sheet of dense slag, overlain by lining rich SHC, 70x95x60 overall, upper SHC 30mm thick
					148	1	dense stone
					104	1	75x65x35, low density SHC, thick gravelly glassy top with stone extending above planar top, lower slag rich in charcoal
					84	1	proto SHC, lobate top with raised centre, strongly prilly base, 60x50x35mm, very gravelly, locally maroon surface

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
					260	1	block of quartz vein with adhering smithing floor type material - abundant FHS, charcoal and slag
					80	1	50x75x40mm, irregular blebby proto-SHC, strongly maroon, gravelly, very irregular, upper face was crescentic
					158	16	fragments of very dense cemented smithing floor - rich in FS, slag, charcoal etc.
					22	1	iron = 40x20x4mm
					372	35	rounded nubs of low density gravelly lining slag, mostly with slightly maroon surface
					304	7	ferruginous concretions in very coarse gravel some probably associated with iron
					40	13	fragments of gravelly lining slag
					16	1	angular fragment of glass bearing gravel, dense not vesicular
					70	1	fragment from centre of dense concavo-convex SHC with dimpled base and very smooth even top
					162	5	prilly dense slag pieces, probably proto-SHC material
					38	1	lip of SHC with extremely porous interior
					8	1	stone fragment
2066	46		slag 2/2	1815	92	20	small spiky fragments of clinkery lining slag
					122	10	nubs of clinkery lining slag, each low density so possibly coatings on individual clasts
					426	20	multi-lobed clinkery lining slags, some with inclusions of gravel
					280	7	denser slag lumps, one sheet like, but otherwise these do not resemble SHC fragments
					14	1	rounded strip of iron with turned up end, 45x15x3-4mm with end turned up by c4mm
					648	75	coarse concretions with lots of slag, flats and scale, along with charcoal, straw moulds etc.
					40	3	glazed stones
					38	7	natural gravel
					2	1	unusual fired clay with convex iron oxide contact surface one side, one end curves over like blowhole margin - unclear how this could be interpreted – as a plug?
2066	62		furnace lining	16	16	3	oxidised and slightly slagged ceramic

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
2070	20	126	fine slag	1		3	lining slag, one very porous, the other two dense and clinkery
2070	20	126	fine - metalworking magnet	<1		assm	mainly stone and FHS, with some slag flats
2071	23	128	fine magnetic material	<1		assm	stone with slag, some FHS and SHS
2072	22	127	fine magnetic material	<1		assm	stone with trace of slag and FHS
2075	25	107	metalworking debris	80	<2	1	vitrified/glazed gravel
					16	14	blebby lining influenced slags, mostly with white granule clasts, most maroon surfaced
					6	32	spiky to flowed dense slags
					6	42	flats, tool casts etc.
					44	132	concretionary fragments, mainly rusty, with variably clasts of slag, FHS, charcoal and iron (weight includes some dust)
					<2	8	slag spheroids
					2	1	lining slag with a planar re-entrant face probably picked by tongs/poker
2075	25	108	fine metalworking debris (magnet)	306		assm	assemblage dominated by FHS, with some SHS, also spheroids, slag flats (including re-entrant examples) and other slag debris. Maroon slag and concretions present but in lesser proportion.
2075	57		slag	44	6	1	fired clay
					14	2	dense clinkery slag nubs, maroon surfaced
					26	4	concretions, at least two probably associated with thin sheet of iron

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
2077	29	110	fine metalworking debris (magnet)	74		assm	assemblage dominated by FHS, some larger flats, maroon spheroids, slag fragments, droplets, lining-rich slag blebs
2077	29	109	metalworking debris	42		assm	mainly blebs of clinkery slags, concretions (several lager ones are probably on iron), FHS, slag spheroids, slag fragments, slag flats and blisters
2077	65		slag	852	754	5	fragmented large piece of SHC. Bowl filled by vesicular dense slag, base with much adhering gravel (must have formed against sediment not fuel), upper part highly vesicular and frothy, top deeply dimpled with fuel, 115x100v70 fragment, bowl 50mm deep, cannot be more than 80% of original, frothy layer effectively single large void underlies most of the top. top pale and plastic/resinous appearing around fuel dimples
					86	1	irregular mass of glassy gravelly slag, rather dense glass, maroon surface
					12	3	small lining slag fragments
2079	26	130	fine - metalworking magnet	<1		assm	stone with trace of slag and SHS
2082	28	131	fine - metalworking magnet	<1		assm	stone with trace of slag and FHS
2082	41	139	porous stone? Slag?	24		38	porous igneous rock
2082	41	138	fine magnetic material	<1		assm	stone with 1 frag of FHS
2090	35	134	fine - metalworking magnet	<1		assm	one large piece of lining slag, moderate amount of FHS, some SHS and some fine slag debris, rest stone

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
2093	34	133	fine - metalworking magnet	<1		assm	stone with sparse assemblage of slag, FHS and SHS
2097	38	136	fine -slag	<1		1	bleb of clinkery lining slag
2098	32	132	fine - metalworking magnet	8		assm	dominated by FHS, but lots of maroon slag debris and plenty of SHS and slag spheroids. Some flats and large blisters
2098	32	149	ceramic	2		7	oxidised fired clay
2099	33	111	fine metalworking debris (magnet)	196		assm	very rich assemblage of FHS, slag flats, slag spheroids, SHS, maroon slag blebs and lots of ashy concretionary material with HS and charcoal
2099	33	144	mw debris/slag/concretions/iron?	14	6	5	large slag flats with curved concave attachment areas
					2	2	maroon slag fragments
					2	2	concretions
					2	1	vitrified pebble
					<1	1	laminar iron oxides- unclear if spall of rust or from rock
2101	36	135	fine magnetic material	<1		assm.	mainly fine stone, one large piece of clinkery lining slag
2105	42	140	fine - metalworking	4		assm	mainly maroon slag, some stone, one carbonised nut (?),

C	S	Sf#	Label	sample wt	Item wt	Item no	Notes
2105	42	140	fine - metalworking magnet	5		assm	mainly stone, some lining slag, moderate FHS, slag spheroid, charcoal
2105	42	150	burnt clay	<1		1	oxidised fired clay
						1	concretion?
2105	42	141	coarse - slag	8	8	2	dark glassy slag binding partially- melted gravel, some charcoal
2120	40	137	fine - metalworking magnet	<1		assm	stone with some FHS

IX.3 appB: Bulk chemical analyses

Table B1: Major elements by XRF. < = below detection. All elements presented as wt% oxide. Raw data, Fe expressed as Fe_2O_3 and Mn as Mn_3O_4

	Bead	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**Mn_3O_4**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**LOI**	**total**
HGA4	LF41660	26.31	0.22	4.25	73.05	0.11	0.36	0.35	0.45	0.92	0.36	-5.35	101.03
HGA5	LF41661	27.21	0.18	3.84	68.55	0.10	0.41	0.25	0.44	0.95	0.25	-3.17	99.03
HGA6	LF41662	24.41	0.17	3.25	70.18	0.11	0.66	0.51	0.37	1.08	0.23	-1.69	99.31
HGA7	LF41663	67.89	0.41	10.24	12.29	0.11	0.95	0.54	2.44	3.14	0.15	-0.31	97.98

Table B2: Minor elements by XRF. < = below detection. All elements presented as wt% oxide. Raw data, Fe expressed as Fe_2O_3 and Mn as Mn_3O_4

	Bead	**SO_3**	**V_2O_5**	**Cr_2O_3**	**SrO**	**ZrO_2**	**BaO**	**NiO**	**CuO**	**ZnO**	**PbO**	**HfO_2**
HGA4	LF41660	<0.006	0.01	<0.005	<0.003	<0.003	<0.04	<0.004	<0.003	<0.002	0.004	<0.005
HGA5	LF41661	<0.006	<0.004	<0.005	<0.003	<0.003	<0.04	<0.004	<0.003	<0.002	0.003	<0.005
HGA6	LF41662	<0.006	0.01	<0.005	0.01	<0.003	<0.04	<0.004	0.007	<0.002	0.003	<0.005
HGA7	LF41663	<0.006	0.01	<0.005	0.01	0.02	0.08	<0.004	<0.003	0.003	0.002	<0.005

Table B3 (part 1): bulk chemical analyses by ICP-MS. All elements in ppm. bdl = below detection limit

		P	**Ca**	**Sc**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Cu**	**Ga**	**Ge**
HGA4	ICP045_01	1608.52	3437.39	3.50	1494.28	bdl	3.89	975.83	725888.74	12.93	11.23	8.00	20.28
HGA5	ICP045_2	1255.27	2895.53	4.11	1318.36	bdl	6.06	890.05	702194.56	12.68	10.19	7.09	18.62
HGA6	ICP045_3	1090.70	6231.54	6.42	1186.45	28.97	21.11	658.64	657137.38	9.15	80.39	19.97	18.51
HGA7	ICP045_4	817.26	6261.64	10.33	2799.65	19.16	20.01	1029.95	135045.10	14.25	18.33	13.43	4.34
BCR-1	ICP045_39	1222.93	65025.72	34.17	11304.58	407.60	bdl	1590.38	126456.13	36.40	13.85	23.77	3.73
BCR-1	recommended	3646.00	-	32.41	22420.00	410.00	13.50	1838.00	-	37.55	19.60	22.19	1.40

Table B3 (part 2): bulk chemical analyses by ICP-MS. All elements in ppm. bdl = below detection limit

		Rb	**Sr**	**Y**	**Zr**	**Nb**	**Mo**	**Ru**	**Sn**	**Cs**	**Ba**	**La**	**Ce**	**Pr**	**Nd**	**Sm**
HGA4	ICP045_01	18.25	38.73	8.72	75.41	8.70	6.98	0.01	0.30	0.69	216.67	5.85	13.15	1.60	6.90	1.60
HGA5	ICP045_2	20.11	34.88	9.79	65.99	8.20	6.39	0.01	0.31	0.64	228.89	6.23	13.71	1.62	7.21	1.52
HGA6	ICP045_3	22.94	47.57	9.93	54.66	5.09	5.48	0.01	7.69	0.55	187.83	7.63	16.54	2.05	8.43	1.68
HGA7	ICP045_4	91.06	108.61	24.76	117.20	16.09	4.04	0.00	0.37	2.59	555.07	19.50	42.59	4.66	18.70	3.71
BCR-1	ICP045_39	47.44	309.93	36.82	191.34	12.33	1.82	0.00	0.70	0.98	672.40	24.00	49.70	6.40	29.40	6.91
BCR-1	recommended	46.61	334.90	-	190.30	-	1.52	0.00	-	0.96	683.30	25.46	53.94	6.77	28.68	6.60

Table B3 (part 3): bulk chemical analyses by ICP-MS. All elements in ppm. bdl = below detection limit

		Eu	**Gd**	**Tb**	**Gd**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Hf**	**Ta**	**W**	**Pb**	**Th**	**U**
HGA4	ICP045_01	0.23	1.39	0.22	1.31	1.55	0.33	1.03	0.16	1.16	0.14	2.01	0.33	0.68	1.47	2.19	0.86
HGA5	ICP045_2	0.27	1.34	0.23	1.34	1.61	0.32	1.06	0.17	1.14	0.17	1.83	0.30	0.62	1.06	2.41	0.77
HGA6	ICP045_3	0.30	1.58	0.23	1.36	1.52	0.30	1.02	0.14	1.09	0.15	1.48	0.21	0.59	1.63	2.48	0.77
HGA7	ICP045_4	0.70	3.29	0.55	3.35	3.71	0.78	2.34	0.34	2.49	0.34	3.15	0.71	1.08	6.10	7.42	1.51
BCR-1	ICP045_39	1.87	6.68	0.92	6.50	5.97	1.20	3.60	0.47	3.46	0.49	4.37	0.57	0.48	12.77	5.33	1.61
BCR-1	recommended	1.96	6.73	1.06	6.73	6.39	1.27	3.66	0.54	3.38	0.50	4.92	0.79	0.43	13.44	5.79	1.68

IX.3 appC :EDS microanalyses

Table C1: EDS analyses for sample HGA1. All elements were measured. Presented as normalised atomic% with the analytical total in wt% in the right hand column. These analyses were made with the backscatter detector in the chamber, leading to low totals.

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 68	57.39	0	1.19	0.15	14.1	0.04	0	0	0	0.08	0	0	0	0.13	26.92	0	0	77.35
Spectrum 69	59.36	1.42	0	6.63	15.24	0.74	0.04	0	2.42	1.34	0.05	0	0	0.07	12.67	0.03	0	76.7
Spectrum 70	53.29	0	0	2.06	0.43	0	0	0	0	0	0.29	0	0	0.06	43.87	0	0	76.01
Spectrum 71	54.72	0.6	0	2.74	3.8	0.14	0	0	0.51	0.22	0.23	0	0	0.05	36.99	0	0	80.66
Spectrum 72	55.83	0.13	0.5	1.24	10.03	0.36	0	0	0.12	0.15	0.12	0	0	0.1	31.38	0.04	0	70.84
Spectrum 73	59.52	1.68	0.05	5.52	16.12	0.76	0.04	0	2.82	1.18	0	0	0	0.06	12.22	0	0.02	78.13
Spectrum 74	56.57	0	0.13	1.89	5.61	0.05	0	0	0.35	0.14	0.1	0	0	0.07	35.09	0	0	75.75
Spectrum 75	57.57	0	0.94	0.21	13.6	0.19	0	0	0.06	0.11	0	0	0	0.14	27.17	0	0	76.19
Spectrum 76	52.73	0	0.11	0.81	0.33	0	0	0	0	0	0.08	0	0	0.07	45.87	0	0	75.84
Spectrum 77	57.02	0	0.08	6.46	0.94	0	0	0	0.14	0.06	0.39	0	0	0.05	34.83	0.04	0	75.87
Spectrum 78	57.36	0	0	3.73	1.25	0	0	0	0.12	0.03	0.25	0	0	0.05	37.21	0	0	76.24
Spectrum 79	57.61	0	1.07	0.16	13.77	0.2	0	0	0	0.12	0	0	0	0.15	26.87	0.05	0	76.55
Spectrum 80	57.7	0	0.98	0.26	13.64	0.24	0	0	0	0.09	0.03	0	0	0.14	26.91	0	0	76.59
Spectrum 81	58.03	0	1.1	0.16	13.84	0.17	0	0	0.03	0.1	0	0	0	0.13	26.45	0	0	77.17
Spectrum 82	57.68	0	1.2	0.13	13.84	0.17	0	0	0	0.11	0	0	0	0.15	26.71	0	0	76.93
Spectrum 83	52.61	0	0.09	0.68	0.27	0	0	0	0.04	0	0.09	0	0	0.07	46.11	0.05	0	75.53
Spectrum 84	60.39	0	0	0.1	0.05	0	0	0	0	0	0	0	0	0.03	39.43	0	0	76.3
Spectrum 85	58.79	0	0.16	0.18	0	0	0	0	0	0.1	0	0	0	0.14	40.63	0	0	76.17
Spectrum 86	57.01	0	0.53	0.35	0.19	0	0	0	0.04	0.19	0.03	0	0	0.16	41.5	0	0	75.61
Spectrum 87	57.83	0.2	0.48	0.87	1.14	0	0	0	0.25	0.42	0.06	0	0	0.14	38.61	0	0	75.99
Spectrum 88	58.57	0.12	0.3	3.81	2.88	0.05	0	0	0.26	0.06	0.3	0	0	0.09	33.55	0	0	77.39
Spectrum 89	52.52	0	0.59	0.77	0.22	0	0	0	0	0.03	0.13	0.04	0	0.14	45.57	0	0	75.31
Spectrum 90	57.32	0	3.48	0.3	14.04	0	0	0	0	0.33	0.03	0	0	0.27	24.2	0.03	0	76.54
Spectrum 91	58.59	0.2	1.03	3.02	12.94	0.11	0.03	0	0.7	1.02	0.1	0	0	0.19	22.04	0.03	0	76.7
Spectrum 92	58.32	0.1	1.07	2.27	10.13	0.26	0	0.05	0.33	0.85	0.1	0	0	0.19	26.33	0	0	66.83

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 93	57.83	0	3.16	0.32	13.97	0	0	0	0	0.32	0	0	0	0.27	24.13	0	0	76.01
Spectrum 95	57.36	0	0	0.24	0.04	0	0	0	0	0.08	0	0	0	0	42.28	0	0	79.27
Spectrum 96	54.72	0	0	0.25	0.07	0	0	0	0	0.09	0	0	0	0	44.88	0	0	78.42
Spectrum 97	56.03	0	0.12	0.81	0.24	0	0	0	0	0	0	0	0	0	42.8	0	0	72.49
Spectrum 98	52.37	0	0	0.3	0.09	0	0	0	0	0.03	0.04	0	0	0	47.12	0.05	0	75.77
Spectrum 99	0.94	0	0.21	0.7	0.13	0	0	0	0	0	0	0	0	0.06	97.75	0.22	0	72.98
Spectrum 100	1.57	0.22	0.17	0.7	0	0	0	0	0	0	0	0	0	0	97.14	0.2	0	72.77
Spectrum 101	0	0	0.27	0.63	0.11	0	0	0	0	0	0	0	0	0.06	98.8	0.13	0	72.62
Spectrum 102	1.11	0	0.27	0.62	0.11	0	0	0	0	0	0	0	0	0	97.71	0.16	0	72.63
Spectrum 103	0	0.26	0.22	0.63	0.09	0	0	0	0	0	0	0	0	0	98.61	0.2	0	72.37
Spectrum 104	56.77	0.59	0.52	2.63	11.2	0.08	0	0	1.04	0.74	0.07	0	0	0.08	26.3	0	0	78.14
Spectrum 105	56.69	0.7	0.49	2.83	11.8	0.07	0	0	1.08	0.78	0.07	0	0	0.07	25.41	0	0	78.06
Spectrum 106	56.38	0.62	0.55	2.55	10.82	0.08	0	0	0.98	0.72	0.07	0	0	0.08	27.13	0.03	0	77.35
Spectrum 107	56.76	0.4	0.56	2.2	10.78	0.11	0	0	0.81	0.63	0.08	0	0	0.08	27.59	0	0	75.48
Spectrum 108	57.26	0.46	0.69	1.94	13.71	0.11	0	0.04	0.85	0.69	0.06	0	0	0.09	24.06	0.03	0	69.86
Spectrum 151	58.6	0.29	1.21	2.04	9.95	0.31	0.03	0.16	0.44	0.72	0.11	0	0	0.2	25.88	0.06	0	77.87
Spectrum 152	61.71	0.42	0.62	2.89	21.28	0.24	0.03	0.05	1.37	0.47	0.09	0	0	0.12	10.69	0.03	0	86.33
Spectrum 153	59.63	0.12	1.22	1.7	9.68	0.4	0.07	0.05	0.06	0.42	0.14	0	0	0.23	26.22	0.06	0	76.11

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 154	65.46	0.27	0	2.34	29.7	0.02	0	0.01	1.91	0.02	0	0	0	0	0.25	0.02	0	98.6
Spectrum 155	66.4	0	0	0.22	33.08	0	0	0	0.18	0	0	0	0	0	0.1	0.02	0	102.13
Spectrum 156	62.17	0.93	0.16	7.68	22.71	0	0	0	4.62	0.93	0	0	0	0.05	0.71	0.02	0.03	102.65
Spectrum 157	65.18	0.41	0.03	3.18	28.49	0	0	0.02	2.31	0.11	0	0	0	0.02	0.25	0	0	95.86
Spectrum 158	63.64	0.42	0.5	4.36	25.72	0.08	0.02	0.02	3.25	0.35	0.18	0.02	0	0.04	1.42	0	0	95.95
Spectrum 159	59.79	0.12	1.1	2.59	10.2	0.54	0.05	0.06	0.02	0.44	0.13	0	0.02	0.18	24.72	0.04	0	75.39
Spectrum 160	60.21	0	1.01	2.97	10.17	0.43	0.1	0.06	0	0.41	0.16	0	0	0.19	24.23	0.07	0	75.86
Spectrum 161	57.06	0	0.42	1	9	0.42	0	0.03	0	0.09	0.12	0	0	0.11	31.74		0	90.7
Spectrum 162	58.33	0	0.19	0.93	1.04	0	0	0	0.12	0.03	0.15	0	0	0.05	39.14		0	99.5
Spectrum 163	59.61	0.29	0.22	4.2	4.54	0.11	0	0	0.73	0.1	0.27	0	0	0.06	29.87		0	101.06
Spectrum 164	58.67	0.46	0.87	1.49	15.12	0.26	0	0	0.57	0.16	0	0.02	0	0.14	22.19	0.05	0	104.88
Spectrum 165	57.36	0	0.17	2.89	0.74	0	0	0	0.03	0	0.27	0	0	0	38.48	0.07	0	99.94
Spectrum 166	57.23	0.12	0	2.12	0.88	0.05	0	0	0.08	0.03	0.26	0	0	0.04	39.19	0	0	99.58
Spectrum 167	58.47	0	1.01	0.22	13.79	0.17	0	0	0	0.07	0	0	0	0.13	26.1	0.04	0	101.55
Spectrum 168	61.02	0	0.49	0.31	13.42	0.35	0	0	0	0.09	0	0	0	0.11	24.16	0.06	0	105.63
Spectrum 169	58.87	0	0.88	0.23	13.77	0.18	0	0	0	0.07	0	0	0	0.13	25.81	0.06	0	102.18

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 170	58.77	0	1.01	0.2	13.8	0.17	0	0	0	0.06	0	0	0	0.12	25.81	0.05	0	102.2
Spectrum 171	58.38	0	1.09	0.19	13.74	0.13	0	0	0	0.08	0.04	0	0	0.14	26.17	0.05	0	101.94
Spectrum 172	58.5	0	1.28	0.2	13.83	0.11	0	0	0	0.08	0.02	0	0	0.14	25.8	0.04	0	101.91
Spectrum 173	59.23	0	0.26	0.39	13.41	0.25	0	0	0	0.11	0.04	0	0	0.13	26.12	0.07	0	102.54
Spectrum 174	58.55	0	0.79	0.26	13.65	0.17	0	0	0	0.09	0.02	0	0	0.13	26.25	0.07	0	101.75
Spectrum 175	58.46	0.13	0	3.96	2.64	3.35	0.33	0.34	0.06	0.26	0.26	0	0	0.06	30.08	0.07	0	65.96
Spectrum 176	54.21	0	0	1.25	0.44	0	0	0	0	0	0.27	0	0	0.05	43.68	0.1	0	99.6
Spectrum 177	57.62	0.09	0.44	0.9	9.92	0.59	0.03	0.03	0	0.12	0.11	0	0	0.08	30	0.06	0	91.16
Spectrum 178	53.7	0	0	1.35	0.32	0.04	0	0	0	0	0.25	0	0	0.05	44.22	0.07	0	98.95
Spectrum 179	58.71	0.26	0.11	1.38	3.51	0	0	0	0.2	0.12	0.05	0	0	0.08	35.53	0.05	0	102.97
Spectrum 180	57.75	0	0.11	1.41	1.53	0	0	0	0.06	0.02	0.08	0	0	0.06	38.93	0.05	0	100.29
Spectrum 181	58.14	0	0	1.17	0.6	0	0	0	0.04	0.03	0.1	0	0	0.03	39.85	0.05	0	99.18
Spectrum 182	58.02	0	0	1.54	1.56	0	0	0	0.15	0.04	0.12	0	0	0.05	38.44	0.07	0	98.54
Spectrum 183	57.76	0	0.09	0.9	0.53	0	0	0	0.03	0	0.08	0	0	0.04	40.48	0.07	0	99.35
Spectrum 184	58.76	0.08	0.47	0.85	13.77	0.05	0	0	0.28	0.11	0.03	0	0	0.11	25.43	0.05	0	101.23
Spectrum 185	58.79	0	0.44	0.56	13.87	0.05	0	0.02	0.23	0.11	0.03	0	0	0.11	25.72	0.06	0	101.64

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 186	58.21	0	0.46	0.38	13.82	0.04	0	0.02	0	0.05	0.02	0	0	0.13	26.83	0.04	0	101.72
Spectrum 187	58.8	0	0.11	0.43	13.82	0.11	0	0	0.04	0.08	0.02	0	0	0.08	26.44	0.06	0	100.87
Spectrum 188	58.78	0.34	0.09	2.86	7.45	0.04	0	0	0.34	0.12	0.09	0	0	0.05	29.79	0.04	0	105.99
Spectrum 189	54.57	0	0	0.23	0	0.05	0	0	0	0	0	0	0	0.03	45.03	0.09	0	99.32
Spectrum 190	54.12	0	0	0.21	0	0.08	0	0	0	0	0	0	0	0	45.51	0.08	0	99.27
Spectrum 191	55.63	0	0	0.22	0.04	0.07	0	0	0	0	0	0	0	0	43.96	0.08	0	99.43
Spectrum 192	59.68	0.1	0	0.35	0.1	0.57	0	0	0	0	0	0	0	0	39.11	0.09	0	97.8
Spectrum 193	53.02	0	0	0.26	0	0.25	0	0	0	0	0	0	0	0	46.39	0.07	0	99.37
Spectrum 194	52.23	0	0	0.24	0.06	0	0	0	0	0	0	0	0	0	47.38	0.09	0	99.14
Spectrum 195	52.65	0	0	0.26	0	0.04	0	0	0	0	0	0	0	0	46.97	0.08	0	99.4
Spectrum 196	56	0	0	0.28	0.06	0.12	0	0	0	0	0	0	0	0	43.48	0.06	0	99.78
Spectrum 197	57.48	0	0	0.28	0.04	0.06	0	0	0	0	0	0	0	0	42.06	0.07	0	101.94
Spectrum 198	52.73	0	0	0.23	0	0	0	0	0	0	0	0	0	0	46.94	0.1	0	99.01
Spectrum 199	52.9	0	0	0.26	0	0.04	0	0	0	0	0	0	0	0	46.72	0.07	0	99.57
Spectrum 200	52.69	0	0	0.2	0	0	0	0.03	0.03	0	0	0	0	0.03	46.96	0.06	0	99.1
Spectrum 201	52.66	0	0.07	0.21	0	0	0	0	0	0	0	0	0	0	46.98	0.08	0	99.41

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 202	52.88	0	0	0.26	0	0	0	0	0	0	0	0	0	0	46.8	0.05	0	99.14
Spectrum 203	53.18	0.11	0	0.28	0	0	0	0	0	0	0	0	0	0	46.35	0.08	0	99.35
Spectrum 204	56.24	0.11	0	0.23	0	0	0	0	0	0	0	0	0	0.03	43.31	0.08	0	100.38
Spectrum 205	59.8	0	0	0.19	0.05	0.04	0	0	0	0	0	0	0	0	39.85	0.07	0	99.79
Spectrum 206	57.78	0	0	0.22	0	0.16	0	0	0	0	0	0	0	0	41.79	0.06	0	98.73
Spectrum 207	57.73	0	0	0.2	0.1	0.06	0	0	0	0	0	0	0	0.03	41.81	0.07	0	99.07
Spectrum 208	58.02	0.1	0	0.23	0.13	0.06	0	0	0	0	0	0	0	0.03	41.37	0.07	0	99.22
Spectrum 209	58.29	0.11	0	0.2	0.24	0.06	0	0	0	0	0	0	0	0	41.04	0.07	0	99.09
Spectrum 210	58.03	0	0	0.26	0.14	0.07	0	0	0	0	0	0	0	0	41.43	0.06	0	98.8
Spectrum 211	61.4	0	0	0.21	0.92	0.05	0.04	0	0	0	0	0.02	0	0	37.31	0.05	0	97.35
Spectrum 212	53.9	0	0	0.25	0	0	0	0	0	0	0	0	0	0	45.79	0.06	0	99.57
Spectrum 213	57.62	0	0	0.22	0	0	0	0.03	0	0	0	0	0	0.03	42.03	0.07	0	99.15
Spectrum 214	58.67	0	0	0.22	0.15	0.31	0	0	0	0	0	0	0	0	40.55	0.1	0	99.51
Spectrum 215	61.24	0.11	0	0.28	0.28	0.28	0	0	0	0	0	0	0	0	37.74	0.07	0	100.06
Spectrum 216	53.78	0.1	0	0.23	0.12	0	0	0	0	0.02	0	0	0	0	45.66	0.08	0	98.93
Spectrum 217	52.62	0	0	0.28	0.37	0	0	0	0	0.03	0	0	0	0.03	46.58	0.08	0	98.75

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 218	54.35	0	0.12	1.12	0.55	0.18	0	0.06	0	0.04	0.03	0	0	0.05	43.44	0.06	0	85.64
Spectrum 219	56.49	0	0.26	0.81	9.2	0.25	0	0	0	0.09	0.06	0	0	0.07	32.69	0.07	0	98.13
Spectrum 220	58.71	0	0.39	0.54	13.23	0.21	0	0	0	0.09	0.03	0	0	0.06	26.67	0.06	0	101.84
Spectrum 221	58.92	0	0.39	0.54	13.36	0.19	0	0	0.02	0.1	0.03	0	0	0.07	26.33	0.05	0	101.52
Spectrum 222	59.08	0	0.38	0.53	13.25	0.25	0	0	0	0.11	0.03	0	0	0.06	26.25	0.07	0	102.58
Spectrum 223	54.42	0	0	1.41	0.45	0	0	0	0	0	0.15	0	0	0	43.5	0.06	0	100.08
Spectrum 224	58.12	0.11	0.28	0.5	12.07	0.24	0	0	0	0.12	0.04	0	0	0.08	28.39	0.06	0	99.57
Spectrum 225	56.01	0.15	0.21	1.1	7.33	0.28	0	0	0.16	0.15	0.04	0	0	0.06	34.46	0.05	0	100.02
Spectrum 226	0	0	0.23	0.41	0	0	0	0	0	0	0	0	0	0	99.12	0.24	0	93.7
Spectrum 227	0	0.24	0.26	0.41	0.08	0	0	0	0	0	0	0	0	0.06	98.65	0.29	0	93.83
Spectrum 228	52.92	0	0	0.77	0.26	0	0	0	0	0	0.07	0	0	0.04	45.9	0.05	0	99.62
Spectrum 229	53.54	0	0.08	0.74	0.66	0.05	0	0	0	0.02	0.04	0	0	0.05	44.74	0.08	0	94.95
Spectrum 230	53.57	0	0	0.82	1.68	0.06	0	0	0	0.04	0.06	0	0	0.03	43.67	0.06	0	99.1
Spectrum 231	52.46	0	0.14	0.66	0.19	0	0	0	0	0.02	0.04	0	0	0.04	46.38	0.07	0	99.35
Spectrum 232	53.7	0	0.09	0.84	1.5	0	0	0	0.08	0.03	0.07	0	0	0.05	43.61	0.04	0	100.64
Spectrum 233	57.21	0.14	0.25	0.8	11.57	0.52	0	0	0.22	0.22	0.03	0	0	0.07	28.93	0.05	0	95.77

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	Total
Spectrum 234	56.1	0.63	0.54	2.44	9.94	0.11	0	0.03	0.89	0.64	0.08	0	0	0.08	28.5	0.04	0	101.45
Spectrum 235	58.72	0.42	1.05	1.75	13.98	0.1	0	0	0.75	0.44	0.04	0	0	0.11	22.62	0.03	0	102.13
Spectrum 236	59.05	1.7	0.12	6.29	14.21	0.18	0.09	0	2.85	2.49	0.07	0	0	0.04	12.86	0.03	0.02	97.34
Spectrum 237	58.78	0.58	0.79	2.1	14	0.1	0	0	0.93	0.69	0.03	0	0	0.08	21.92	0	0	101.73
Spectrum 238	57.08	0.12	0.57	1.6	10.37	0.08	0.03	0	0.26	0.4	0.07	0	0	0.08	29.28	0.07	0	97.39

Table C2: EDS analyses for sample HGA2. All elements were measured. Presented as normalised atomic% with the analytical total in wt% in the right hand column. These analyses were made with the backscatter detector in the chamber, leading to low totals.

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	W	Total
Spectrum 109	68	0	0	2.93	1.08	0.7	0.07	0.07	0	0.08	0	0	0	0	27	0.04	0		70.9
Spectrum 110	56.6	0.15	0.33	1.43	8.58	0.08	0	0	0.28	0.21	0	0	0	0	32.4	0	0		71.7
Spectrum 239	54.9	0	0.31	0.64	6.01	0.19	0	0	0	0.1	0.05	0	0	0.05	37.7	0.05	0		98.5
Spectrum 240	57.8	0	0.57	0.47	10.8	0.17	0	0	0	0.11	0.04	0	0	0.07	29.9	0.05	0		106
Spectrum 241	60.7	0	0.35	0.58	12.7	0.39	0	0	0	0.2	0.03	0	0	0.06	25	0.05	0		100
Spectrum 242	60	0.09	0.58	0.55	12.3	0.14	0	0	0.07	0.13	0.03	0	0	0.06	26	0.05	0		107
Spectrum 243	52.6	0	0.14	0.48	0.12	0	0	0	0	0	0.06	0	0	0.04	46.5	0.08	0		99
Spectrum 244	57.1	0.58	0.34	1.9	9.91	0.09	0	0	0.62	0.27	0.06	0	0	0.06	29	0.03	0		101
Spectrum 245	59.5	0.76	0.44	2.72	15.1	0.11	0	0	1.1	0.47	0.05	0	0	0.06	19.6	0.03	0		102
Spectrum 246	59.6	0.71	0.44	2.56	15	0.12	0	0	1.02	0.4	0.05	0	0	0.05	20.1	0.03	0		102
Spectrum 247	54.3	0	0.1	0.71	0.62	0	0	0	0.03	0	0.17	0	0	0.03	44	0.09	0		99
Spectrum 248	53	0	0.14	0.39	0.39	0	0	0	0	0	0.1	0	0	0.03	45.8	0.08	0		97.4
Spectrum 249	54.4	0	0.17	0.53	0.31	0	0	0	0	0.02	0.1	0	0	0.05	44.4	0.06	0		98.6

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	W	Total
Spectrum 250	57.5	0	0.2	1.28	1.99	0.05	0	0	0.12	0.05	0.12	0	0	0.04	38.6	0.05	0		101
Spectrum 251	57.9	0	0.14	0.84	0.89	0	0	0	0.04	0	0.11	0	0	0.03	40	0.07	0		98.8
Spectrum 252	57.7	0	0.22	0.43	0.76	0	0	0	0.05	0	0.05	0	0	0.06	40.7	0.05	0		99.3
Spectrum 253	59.4	0.19	0.24	1.73	4.5	0.03	0	0	0.34	0.14	0.04	0	0	0.05	33.3	0.06	0		102
Spectrum 254	55.9	0	0.21	0.86	0.67	0	0	0	0.03	0	0.17	0	0	0.03	42	0.09	0		100
Spectrum 255	54	0	0.31	0.53	4.66	0.12	0.03	0	0.03	0.17	0	0	0.02	0.04	40	0.06	0		98.3
Spectrum 256	0	0	0	0.18	0.08	0	0	0.18	0	0	0	0	0	0	99.4	0.2	0		89.7
Spectrum 257	52.6	0	0.18	0.44	0.09	0	0	0	0	0	0.04	0	0	0.03	46.5	0.06	0		98.7
Spectrum 258	52.5	0	0.27	0.4	0.13	0	0	0	0	0	0.04	0	0	0.05	46.5	0.07	0		98.7
Spectrum 259	57.5	0.08	0.45	0.6	12.3	0.26	0	0	0.12	0.4	0	0	0	0.06	28.2	0.05	0		97.1
Spectrum 260	58.8	0.11	0.46	0.77	13.5	0.32	0	0	0.16	0.44	0.04	0	0	0.06	25.4	0.05	0		99.1
Spectrum 261	58	0.4	0.32	1.6	9.4	0.11	0	0	0.49	0.2	0.08	0	0	0.07	29.3	0.07	0		101
Spectrum 262	62.7	0	0	0.13	0.43	0	0	0.14	0	0	0	0	0	0.03	36.5	0.06	0		86.8
Spectrum 263	58.3	0.15	0.3	0.21	0.13	0	0	0	0	0.06	0	0	0	0.07	40.8	0.06	0		97.5
Spectrum 264	57.8	0	0.25	0.76	0.15	0	0	0	0.03	0.03	0.03	0	0	0.05	40.8	0.06	0		98.2
Spectrum 265	57.4	0.13	0.27	1.68	0.45	0	0	0	0.06	0.07	0.08	0	0	0.07	39.7	0.06	0		98
Spectrum 266	58.5	0.15	0.18	1.49	0.98	0.04	0	0.03	0.12	0.03	0.08	0	0	0.06	38.3	0.06	0		100
Spectrum 267	57.5	0	0.17	1.14	0.85	0	0	0	0.09	0.05	0.06	0	0	0.08	39.9	0.09	0		97.7
Spectrum 268	58.3	0	0.19	1.66	0.99	0	0	0.03	0.1	0.04	0.1	0	0	0.03	38.5	0.06	0		98.1
Spectrum 269	58	0	0.15	1.5	0.76	0	0	0	0.03	0.02	0.09	0	0	0.03	39.4	0.07	0		99
Spectrum 270	57.8	0	0.19	0.67	0.51	0	0	0	0	0	0.07	0	0	0.04	40.7	0.08	0		98.9
Spectrum 271	59.9	0.1	0.18	2.16	4.83	0.04	0	0	0.26	0.13	0.11	0	0	0.06	32.1	0.07	0		101
Spectrum 272	55.5	0	0.31	0.54	0.47	0	0	0	0	0	0.04	0	0	0.05	43.1	0.06	0		99.1
Spectrum 273	57.1	0	0.17	2.6	1.09	0	0	0	0.09	0.04	0.18	0	0	0.05	38.7	0.07	0		97.5
Spectrum 274	58.2	0.2	0.23	1.36	3.83	0.05	0.03	0	0.2	0.09	0.11	0	0	0.04	35.6	0.06	0		100

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	W	Total
Spectrum 275	56	0	0.18	0.74	3.17	0.05	0	0	0.17	0.09	0.07	0	0	0.06	39.4	0.05	0		101
Spectrum 276	59.4	0.62	0.48	1.37	15.2	0.2	0	0	0.88	0.36	0.02	0	0	0.07	21.3	0.04	0		103
Spectrum 277	59.5	0.57	0.46	1.55	15.4	0.23	0	0	0.75	0.34	0	0	0	0.1	21	0.05	0		102
Spectrum 278	56.7	0.6	0.6	2.61	11.3	0.12	0	0	0.89	0.64	0.08	0	0	0.1	26.3	0.04	0		100
Spectrum 279	59.2	0.34	0.65	0.22	0.14	0	0	0.03	0	0.4	0	0	0	0.16	38.8	0.07	0		98.2
Spectrum 280	58.5	0	0.3	1.73	0.6	0	0	0	0	0.02	0.14	0	0	0.07	38.6	0.06	0		98.7
Spectrum 281	53.5	0	0.26	0.62	0.35	0.04	0	0	0	0	0.1	0	0	0.07	45	0.07	0		97.4
Spectrum 282	53.5	0	0.32	0.71	0.46	0	0	0	0.04	0.05	0.11	0	0	0.07	44.7	0.08	0		98.3
Spectrum 283	59	0.65	0.69	3.3	16.2	0.2	0.03	0	1.13	1.07	0.04	0	0	0.1	17.5	0.04	0		101
Spectrum 284	59.3	0.73	0.73	3.32	16.3	0.2	0	0	1.29	1	0.02	0	0	0.11	17	0.05	0		101
Spectrum 285	52.9	0	0.36	0.68	0.23	0	0	0	0.04	0.04	0.14	0	0	0.08	45.5	0.07	0		98.2
Spectrum 286	56.4	0	0.79	0.81	9.06	0.58	0	0	0	0.32	0.09	0	0	0.12	31.8	0.04	0		93.7
Spectrum 287	55.3	0	0.42	0.73	3.78	0.1	0	0	0	0.09	0.14	0	0	0.08	39.3	0.06	0		101
Spectrum 288	61.4	0	0.71	0.48	12.7	0.44	0	0	0	0.47	0.04	0	0	0.13	23.6	0.06	0		103
Spectrum 289	60.4	0.17	0.07	3.08	6.49	4.46	0.12	0	0.1	0.95	0.19	0	0	0.05	23.9	0	0		83.5
Spectrum 290	59.8	0	1.3	0.65	13	0.46	0	0	0	0.33	0.05	0	0	0.13	24.2	0.05	0		101
Spectrum 291	54.3	0	0.08	0.82	0.92	0.13	0	0	0	0.05	0.19	0	0	0.09	43.3	0.08	0		99.9
Spectrum 292	32	0	0.35	1.73	9.32	1.68	0	0.04	0	0.81	0.16	0	0	0.25	53.6	0.06	0		57
Spectrum 293	37.3	0.13	0.13	3.53	4.3	4.41	0.04	0.05	0.05	0.5	0.22	0	0	0.14	49.1	0.06	0		63
Spectrum 294	58.8	0	1.36	0.41	13.5	0.28	0	0	0	0.31	0.03	0	0	0.13	25.1	0.06	0		102
Spectrum 295	55.3			0.23	0.73					0.11					43.7				99.5
Spectrum 296	53.8			0.21											46				99.2
Spectrum 297	56.8			0.29											42.9			0	99.6
Spectrum 298	58.3			0.23	0.22										41.2				99.3
Spectrum 299	54.9			0.64	4.45	0.18				0.11					39.7				98.9

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	W	Total
Spectrum 300	56.7			0.75	11.1	0.55			0.04	0.24					30.6				97.8
Spectrum 301	58.2			0.56	12.9	0.54			0.04	0.27					27.5				99.6
Spectrum 302	53			0.51	0.12						0.03				46.3				99.2
Spectrum 303	55.5	0.4	0.38	2.02	8.28	0.1	0	0	0.56	0.36	0.05	0	0	0.05	32.3	0.07	0		101
Spectrum 304	59.1	0.66	0.44	3.28	15.2	0.21	0	0	1.11	0.71	0.02	0	0	0.06	19.3	0.04	0		101
Spectrum 305	59.2	0.64	0.5	3.09	15.2	0.21	0	0	1.14	0.71	0	0	0	0.05	19.2	0.04	0		101
Spectrum 306	52.3	0	0.27	0.7	0.2	0	0	0	0	0	0.09	0	0	0.07	46.3	0.06	0		97.4
Spectrum 307	56.8	0	0.33	0.93	9.54	0.37	0	0	0	0.13	0.09	0	0	0.05	31.7	0.05	0		96.3
Spectrum 308	57.6	0	0.54	0.64	13.3	0.31	0	0	0.02	0.1	0.04	0	0	0.08	27.3	0.04	0		99.8
Spectrum 309	58	0.1	0.43	0.74	12.8	0.38	0	0	0.03	0.13	0.04	0	0	0.08	27.2	0.05	0		101
Spectrum 310	57.3	0.18	0.33	1.6	10.4	0.3	0	0	0.19	0.14	0.09	0	0	0.08	29.4	0.03	0		98.2
Spectrum 311	58.4	0.71	0.33	2.58	11.5	0.23	0	0	0.79	0.28	0.1	0	0	0.08	25	0.05	0		101
Spectrum 312	56.4	0.22	0.18	1.76	2.79	0.07	0	0	0.29	0.07	0.18	0	0	0.06	38	0.07	0		97.1
Spectrum 313	60.1	0	0.32	0.45	0.41	0.11	0	0.03	0.04	0.16	0	0	0	0.09	38.2	0.07	0		96.4
Spectrum 314	58.6	0.41	0.8	0.7	1.68	0.04	0	0	0.22	0.24	0	0	0	0.19	37.1	0.06	0		98.9
Spectrum 315	60.1	0.22	0.28	0.59	0.76	0.14	0.03	0	0.08	0.18	0	0	0	0.1	37.5	0.05	0		97.8
Spectrum 316	58.8	0.99	0.29	1.59	5.28	0.08	0	0.03	0.78	0.19	0	0	0	0.09	31.9	0.05	0		99.2
Spectrum 317	58.7	0.21	0.18	3.13	4.86	0.13	0	0	0.35	0.17	0.28	0	0	0.04	31.9	0.05	0		102
Spectrum 318	57.8	0	0.14	1.59	1.69	0	0	0	0.1	0.06	0.19	0	0	0.03	38.4	0.06	0		99.4
Spectrum 319	57.9	0.16	0.15	3.29	3.78	0.08	0	0	0.33	0.17	0.3	0	0	0.04	33.7	0.06	0		97.9
Spectrum 320	57.8	0.1	0.3	1.59	9.22	0.26	0	0	0.17	0.12	0.08	0	0	0.07	30.2	0.06	0		99.3
Spectrum 321	59.1	0.37	0.47	1.68	13.9	0.35	0	0	0.64	0.21	0	0	0	0.08	23.1	0.05	0		101
Spectrum 322	58.4	0.55	0.37	2.34	13.8	0.26	0.04	0	0.84	0.3	0.07	0	0	0.09	23	0.04	0		103
Spectrum 323	55.1	0.53	0.24	1.6	7.36	0.06	0	0	0.37	0.15	0.05	0	0	0.04	34.4	0.06	0		99.6
Spectrum 324	56.4	0.67	0.32	2.32	14.6	0.09	0	0	0.8	0.25	0	0	0	0.05	24.5	0.04	0		99.6

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Ba	W	Total
Spectrum 325	55.8	0.76	0.29	2.49	14.4	0.09	0.03	0	0.82	0.31	0	0	0	0.04	24.9	0.05	0		98.8
Spectrum 326	53.3	1.1	0.24	3.1	12.2	0.11	0	0	0.8	0.3	0.04	0	0	0.04	28.7	0.03	0		101
Spectrum 327	56.9	0.61	0.37	1.91	13.4	0.1	0	0	0.55	0.23	0.03	0	0	0.06	25.8	0.05	0		101
Spectrum 328	53	0	0	0.4	0.32	0.04	0	0	0	0	0	0	0	0.03	46.2	0.09	0		98.9
Spectrum 329	54.6	0	0.08	0.6	3.85	0.14	0	0	0.02	0.06	0.05	0	0	0.04	40.5	0.05	0		99.7
Spectrum 330	57.6	0.1	0.15	0.37	12.3	0.37	0	0	0.03	0.29	0	0	0	0.04	28.7	0.07	0		99.4
Spectrum 331	58.8	0.21	0.12	0.62	13	0.9	0	0	0.08	0.27	0	0	0	0.06	25.9	0.03	0		98.9
Spectrum 332	51.8	0	0	0.38	0.38	0	0	0	0	0	0	0	0	0.04	47.3	0.07	0		98.5
Spectrum 333	52.9	0	0	0.36	0.12	0.04	0	0	0	0	0	0	0	0	46.5	0.06	0		98.9
Spectrum 334	53.4	0	0	0.37	0.27	0	0	0	0	0	0	0	0	0	45.9	0.09	0		99.5
Spectrum 335	52.9	0	0.08	0.45	0.24	0	0	0	0	0	0	0	0	0.03	46.2	0.07	0		98.9
Spectrum 336	54.6	0.13	0.15	0.5	5.01	0.14	0	0	0	0.13	0.03	0	0	0.03	39.2	0.08	0		102

Table C3: EDS analyses for sample HGA3. All elements were measured. Presented as normalised atomic% with the analytical total in wt% in the right hand column. These analyses were made with the backscatter detector in the chamber, leading to low totals.

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 25	56.95	0	0	0.17	0	0.06	0	0	0	0.02	0	0	0	0	42.8	0	96.71
Spectrum 26	52.05	0	0	0.14	0	0	0	0	0	0	0	0	0	0	47.8	0	96.38
Spectrum 27	52.25	0	0	0.21	0	0	0	0	0	0	0	0	0	0	47.54	0	96.49
Spectrum 28	52.14	0	0	0.23	0	0	0	0	0	0	0	0	0	0.04	47.59	0	96.46
Spectrum 29	52.28	0	0	0.33	0.13	0	0	0	0	0	0	0	0	0.03	47.23	0	96.47
Spectrum 30	2.21	0	0.15	0.23	0.08	0.11	0	0	0	0	0	0	0	0	97.21	0	89.51
Spectrum 31	57.06	0	0.28	1.78	12.29	0.22	0	0	0	0.19	0.08	0	0	0.06	28.04	0	97.53
Spectrum 32	57.94	0	0.38	0.88	13.06	0.16	0	0	0	0.14	0.07	0	0	0.06	27.3	0	99.69
Spectrum 33	1.77	0	0.19	0.22	0.08	0	0	0	0	0.04	0	0	0	0.05	97.64	0	89.3
Spectrum 34	57.62	0	0.56	0.4	14.17	0.06	0	0	0	0.08	0.03	0	0	0.07	27.02	0	100.32

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 35	57.34	0	0.5	0.28	14.38	0	0	0	0	0.08	0	0	0	0.07	27.36	0	99.48
Spectrum 36	57.24	0	0.51	0.4	14.27	0.08	0	0	0	0.08	0.03	0	0	0.07	27.31	0	99.5
Spectrum 37	57.61	0	0.3	0.37	14.13	0.09	0	0	0	0.08	0.03	0	0	0.07	27.33	0	100.01
Spectrum 38	57.53	0	0.26	0.29	14.32	0.07	0	0	0	0.08	0.03	0	0	0.05	27.37	0	99.67
Spectrum 39	57.48	0	0.3	0.34	14.04	0.09	0	0	0	0.09	0.04	0	0	0.06	27.56	0	101
Spectrum 40	56.72	0	0.3	2.68	11.8	0.07	0	0	0.04	0.1	0.08	0	0	0.05	28.16	0	98.49
Spectrum 41	57.53	0	0.51	0.26	14.14	0.06	0	0	0	0.06	0.03	0	0	0.06	27.34	0	99.08
Spectrum 42	57.74	0	0.55	0.35	14.13	0.06	0	0	0	0.08	0.02	0	0	0.06	27.02	0	99.55
Spectrum 43	57.26	0	0.57	0.28	14.22	0.07	0	0	0	0.06	0.04	0	0	0.07	27.43	0	99.35
Spectrum 44	57.58	0	0.55	0.32	14.16	0.07	0	0	0	0.07	0.03	0	0	0.08	27.13	0	99.63
Spectrum 45	57.27	0	0.56	0.29	14.32	0.06	0	0	0	0.06	0.02	0	0	0.05	27.36	0	98.85
Spectrum 46	57.02	0	0.36	1.25	12.48	0.08	0	0	0	0.11	0.06	0	0	0.07	28.57	0	98.56
Spectrum 47	57.34	0.09	0.09	0.71	14.25	0.16	0	0	0.07	0.12	0.03	0	0	0.06	27.09	0	100.14
Spectrum 48	57.31	0	0.26	0.21	14.3	0.11	0	0	0	0.07	0.02	0	0	0.07	27.65	0	98.85
Spectrum 49	57.24	0	0.57	0.22	14.36	0.06	0	0	0	0.07	0	0	0	0.06	27.41	0	98.7
Spectrum 50	57.4	0	0.7	0.2	14.26	0.07	0	0	0	0.06	0.02	0	0	0.08	27.2	0	98.96
Spectrum 51	57.34	0	0.38	0.36	14.16	0.07	0	0	0	0.07	0.04	0	0	0.07	27.52	0	99.2
Spectrum 52	57.63	0	0.12	0.52	13.91	0.1	0	0	0.02	0.09	0.06	0	0	0.06	27.5	0	99.55
Spectrum 53	57.3	0	0.45	0.26	14.13	0.09	0	0	0	0.08	0.03	0	0	0.07	27.6	0	98.89
Spectrum 54	57.22	0	0.38	0.25	14.33	0.1	0	0	0	0.06	0.02	0	0	0.07	27.56	0	98.75
Spectrum 55	57.42	0	0.16	0.27	14.23	0.11	0	0	0.03	0.09	0	0	0	0.04	27.65	0	98.91
Spectrum 56	57.72	0	0.12	0.51	14.32	0.11	0	0	0.21	0.16	0.05	0	0	0.04	26.76	0	98.92
Spectrum 57	57.94	0	0.15	0.46	14.3	0.14	0	0	0.06	0.11	0.03	0	0	0.06	26.75	0	101.15
Spectrum 58	58.59	3.6	0	10.55	15.56	0.28	0.07	0.02	3.87	1.2	0.06	0	0	0	6.13	0.07	98.65
Spectrum 59	59.12	3.49	0	10.43	15.51	0.28	0.07	0	3.88	1.2	0.06	0	0	0	5.89	0.05	97.54
Spectrum 60	57.61	0	0.44	0.23	14.32	0.06	0	0	0	0.07	0	0	0	0.08	27.19	0	98.29
Spectrum 61	57.68	0	0.37	0.21	14.39	0.03	0	0	0	0.08	0	0	0	0.06	27.17	0	98.34
Spectrum 62	57.74	0	0.32	0.24	14.35	0	0	0	0.02	0.07	0.03	0	0	0.07	27.15	0	98.5
Spectrum 63	57.83	0	0.22	0.5	14.17	0.1	0	0	0.09	0.1	0.05	0	0	0.07	26.87	0	98.77

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 64	57.73	0	0.2	0.31	14.26	0.08	0	0	0	0.09	0.02	0	0	0.07	27.24	0	98.06
Spectrum 65	57.72	0	0.33	0.38	14.13	0.08	0	0	0.02	0.09	0.04	0	0	0.06	27.14	0	98.47
Spectrum 66	57.51	0	0.31	0.23	14.33	0.09	0	0	0.02	0.09	0.03	0	0	0.07	27.32	0	98.74
Spectrum 67	55.89	3.73	0	10.77	15.79	0.31	0.07	0	2.88	0.91	0.05	0	0	0	9.57	0.04	102.58
Spectrum 68	51.47	0	0	0.54	0.33	0.05	0	0	0	0	0.18	0	0.02	0	47.41	0	95.46
Spectrum 69	56.42	0.96	0.16	3.02	13.19	0.14	0	0	0.74	0.24	0.08	0	0	0.06	25.01	0	100.49
Spectrum 70	57.02	0	0.6	0.28	14.22	0.09	0	0	0	0.06	0	0	0	0.06	27.67	0	97.79
Spectrum 71	58.55	0	0.09	0.32	13.97	0.19	0	0	0	0.12	0.05	0	0	0.05	26.66	0	97.34
Spectrum 72	58.05	0	0.3	0.24	13.98	0.08	0	0	0	0.08	0.03	0	0	0.06	27.17	0	98.36
Spectrum 73	57.41	0	0.31	0.23	14.4	0.04	0	0	0	0.07	0	0	0	0.06	27.49	0	98.63
Spectrum 74	57.23	0	0.6	0.28	14.26	0.07	0	0	0	0.07	0.03	0	0	0.06	27.4	0	98.41
Spectrum 75	56.89	0	0.46	0.32	13.99	0.03	0	0	0	0.07	0.03	0	0	0.06	28.15	0	98.33
Spectrum 76	57.24	0	0.54	0.26	13.9	0.1	0	0	0	0.07	0.03	0	0	0.06	27.79	0	98.01
Spectrum 77	56.96	0	0	0.18	0	0	0	0	0	0	0	0	0	0	42.86	0	95.36
Spectrum 78	52.04	0	0	0.16	0	0	0	0	0	0	0	0	0	0	47.79	0	95.71
Spectrum 79	52.15	0	0	0.15	0.04	0	0	0	0	0	0	0	0	0	47.66	0	95.54
Spectrum 80	52.15	0	0	0.14	0	0	0	0	0	0	0	0	0	0	47.71	0	95.42
Spectrum 81	51.55	0	0	0.18	0	0	0	0	0	0	0	0	0	0.03	48.24	0	95.82
Spectrum 82	57.3	0	0	0.16	0	0	0	0	0	0	0	0	0	0	42.54	0	95.83
Spectrum 83	56.97	0	0	0.16	0	0	0	0	0	0	0	0	0	0.03	42.84	0	95.87

Table C4: EDS analyses for sample HGA5. All elements were measured. Presented as normalised atomic% with the analytical total in wt% in the right hand column.

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 20	57.16	0	1.28	0.15	14.53	0.05	0	0	0	0.03	0	0	0	0.07	26.73	0	99.06
Spectrum 21	57.22	0	0.68	0.15	14.6	0.04	0	0	0	0.05	0	0	0	0.07	27.2	0	98.92
Spectrum 22	57.18	0	0.73	0.14	14.59	0	0	0	0	0.06	0	0	0	0.06	27.24	0	99.13
Spectrum 23	57.29	0	0.61	0.18	14.52	0.03	0	0	0	0.06	0	0	0	0.06	27.24	0	99.09
Spectrum 24	57.15	0	0.42	0.2	14.57	0.05	0	0	0	0.06	0	0	0	0.07	27.49	0	98.92
Spectrum 84	57.12	0	1.19	0.16	14.57	0	0	0	0	0.03	0	0	0	0.08	26.86	0	98.4
Spectrum 85	57.09	0	1.06	0.14	14.58	0.03	0	0	0	0.03	0	0	0	0.08	26.99	0	98
Spectrum 86	57.45	0	0.78	0.16	14.47	0.05	0	0	0.02	0.04	0	0	0	0.06	26.97	0	98.47
Spectrum 87	57.16	0	0.26	0.19	14.53	0.05	0	0	0	0.06	0	0	0	0.08	27.67	0	97.82
Spectrum 88	57.33	0	0	0.29	14.38	0.08	0	0	0	0.09	0.03	0	0	0.06	27.75	0	97.43
Spectrum 89	57.91	0.15	0	5.59	11.99	0.13	0	0	0.35	0.16	0.09	0	0	0.04	23.58	0	100.83
Spectrum 90	59.51	3.33	0	9.68	17.35	0.45	0.06	0.11	3.97	0.98	0.06	0	0	0.02	4.45	0.04	87.33
Spectrum 91	58.41	0.37	0	3.29	12.96	0.15	0	0	0.43	0.28	0.05	0.02	0	0.05	23.99	0	98.91
Spectrum 92	57.27	0	1.17	0.18	14.5	0	0	0	0	0.05	0	0	0	0.08	26.76	0	98.58
Spectrum 93	57.14	0	0.97	0.2	14.55	0	0	0	0	0.06	0	0	0	0.07	27	0	98.37
Spectrum 94	57.22	0	0.5	0.19	14.47	0.03	0	0	0	0.05	0	0	0	0.08	27.45	0	98.53
Spectrum 95	57.38	0	0.58	0.19	14.47	0	0	0	0	0.05	0	0	0	0.07	27.27	0	98.73
Spectrum 96	57.4	0	0.51	0.19	14.47	0	0	0	0	0.05	0	0	0	0.07	27.3	0	98.63
Spectrum 97	57.29	0	0.07	0.27	14.41	0.08	0	0	0.02	0.08	0	0	0	0.06	27.73	0	98.54
Spectrum 98	56.9	0	0	0.31	13.98	0.06	0	0	0.03	0.09	0.06	0	0	0.07	28.51	0	99.54
Spectrum 99	58.57	3.69	0	10.6	16.89	0.28	0.05	0	4.2	1.35	0.04	0	0	0	4.28	0.04	100.06
Spectrum 100	57.6	0.07	0	0.32	14.44	0.06	0	0	0.1	0.12	0.03	0	0	0.07	27.18	0	97.78
Spectrum 101	57.37	0	0.09	0.19	14.45	0.06	0	0	0	0.08	0	0	0	0.07	27.7	0	98.38
Spectrum 102	57.44	0	0.11	0.36	14.2	0.09	0	0	0.04	0.09	0.04	0	0	0.06	27.57	0	98.67
Spectrum 103	57.63	0	0.08	0.24	14.39	0.05	0	0	0.04	0.09	0	0	0.02	0.07	27.39	0	98.78
Spectrum 104	56.95	0.57	0.07	1.38	14.65	0.08	0	0	0.27	0.15	0.04	0	0	0.05	25.81	0	101.53
Spectrum 105	57.56	0	0	0.26	14.38	0.07	0	0	0.03	0.14	0	0	0	0.06	27.5	0	98.79

	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 106	57.43	0.41	0	1.04	14.48	0.18	0	0	0.32	0.19	0.05	0	0	0.07	25.84	0	100.59
Spectrum 107	57.55	0	0	0.3	14.4	0.06	0	0	0.06	0.14	0.04	0	0	0.05	27.4	0	98.7
Spectrum 108	57.61	0	0.05	0.6	14.12	0.11	0	0	0.12	0.12	0.04	0	0	0.07	27.17	0	98.48
Spectrum 109	57.59	0.17	0	0.68	14.44	0.09	0	0	0.16	0.11	0.02	0	0	0.06	26.68	0	99.91
Spectrum 110	59.28	0.72	0	18.42	6.98	0.1	0.02	0	1.74	0.3	0.29	0	0	0	12.16	0	102.24
Spectrum 111	59.06	3.57	0	10.13	17.66	0.34	0.05	0.03	4.59	1.12	0.09	0	0	0	3.33	0.04	100.75
Spectrum 112	59.46	3.34	0	9.44	17.99	0.35	0.05	0.02	4.71	1.02	0.08	0	0	0.02	3.49	0.04	99.82
Spectrum 113	59.31	0.43	0	20.24	4.68	0.06	0	0	1.31	0.29	0.44	0	0	0	13.23	0	103.6
Spectrum 114	57.68	0	0.28	0.26	14.36	0	0	0	0	0.06	0.02	0	0	0.07	27.26	0	98.5
Spectrum 115	57.66	0	0.7	0.23	14.5	0	0	0	0	0.06	0	0	0	0.07	26.79	0	98.55
Spectrum 116	57.84	0	0.77	0.21	14.39	0.05	0	0	0	0.05	0.02	0	0	0.08	26.57	0	98.43
Spectrum 117	57.81	0	0.24	0.28	14.34	0.09	0	0	0	0.06	0.03	0	0	0.07	27.09	0	98.34
Spectrum 118	57.79	0	0.07	0.36	14.35	0.06	0	0	0.06	0.1	0.04	0	0	0.06	27.11	0	98.62
Spectrum 119	57.89	0	0	0.38	14.25	0.07	0	0	0.03	0.12	0.04	0	0	0.06	27.16	0	97.88
Spectrum 120	57.81	0	0.08	0.3	14.37	0.03	0	0	0	0.08	0	0	0	0.07	27.25	0	98.19
Spectrum 121	57.91	0	0.15	0.28	14.33	0.04	0	0	0	0.07	0	0	0	0.06	27.16	0	98.66
Spectrum 122	57.96	0	0	0.77	14	0.15	0	0	0.09	0.17	0.04	0	0	0.06	26.75	0	98.91
Spectrum 123	58.38	0	0	23.06	1.3	0.03	0	0	0.45	0.09	0.5	0	0	0	16.18	0	100.33
Spectrum 124	57.5	0.1	0	11.32	8.91	0.1	0	0	0.24	0.18	0.18	0	0	0.04	21.44	0	102.2
Spectrum 125	58.17	0.22	0	23.13	1.59	0	0	0	0.38	0.06	0.47	0	0	0	15.97	0	102.16
Spectrum 126	57.84	0.14	0	1.18	13.79	0.14	0	0	0.17	0.2	0.06	0	0	0.06	26.43	0	98.54
Spectrum 127	59.67	3.16	0	9.68	17.29	0.44	0.05	0	4.14	1.33	0.1	0	0	0	4.09	0.05	100.62

Table C5: EDS analyses for sample HGA6. All elements were measured. Presented as normalised atomic% with the analytical total in wt% in the right hand column. These analyses were made with the backscatter detector in the chamber, leading to low totals.

Spectrum Label	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 8	57.33	0	0.86	0.19	14.5	0.04	0	0	0.02	0.14	0	0	0	0.08	26.83	0	98.09
Spectrum 9	57.32	0	0.94	0.27	14.42	0.04	0	0	0	0.14	0.04	0	0	0.07	26.77	0	98.18
Spectrum 10	57.37	0	0.87	0.15	14.51	0	0	0	0	0.15	0.02	0	0	0.07	26.86	0	98.22
Spectrum 11	57.45	0	0.55	0.13	14.52	0.04	0	0	0	0.17	0	0	0	0.07	27.07	0	98.21
Spectrum 12	57.56	0	0.19	0.27	14.54	0.05	0	0	0.07	0.25	0.03	0	0	0.09	26.95	0	98.54
Spectrum 13	51.87	0	0	0.54	0.4	0	0	0	0.04	0.03	0.38	0	0	0.04	46.7	0	95.72
Spectrum 128	57.72	0	1.38	0.17	14.5	0	0	0	0	0.09	0	0	0	0.09	26.04	0	98.36
Spectrum 129	57.55	0	1.51	0.14	14.58	0	0	0	0	0.11	0	0	0	0.09	26.02	0	98.4
Spectrum 130	57.71	0	1.08	0.19	14.45	0	0	0	0	0.12	0	0	0	0.08	26.37	0	98.45
Spectrum 131	57.74	0	1.2	0.16	14.44	0	0	0	0	0.11	0	0	0	0.09	26.26	0	98.36
Spectrum 132	58	0.08	0.76	0.17	14.43	0	0	0	0	0.14	0	0	0	0.09	26.34	0	98.83
Spectrum 133	57.75	0	1.63	0.26	14.32	0.06	0	0	0	0.11	0.03	0	0	0.1	25.75	0	98.3
Spectrum 134	57.46	0	1.36	0.15	14.54	0.03	0	0	0	0.12	0	0	0	0.08	26.25	0	98.37
Spectrum 135	57.53	0	1.06	0.14	14.48	0.04	0	0	0	0.14	0.03	0	0	0.1	26.49	0	98.39
Spectrum 136	59.24	3.82	0	9.38	15.7	0.35	0.06	0	2.46	2.13	0.1	0	0	0.02	6.74	0.02	99.33
Spectrum 137	59.93	0.7	0	9.97	19.84	0.03	0	0	9.07	0.05	0	0	0	0	0.38	0.04	101.25
Spectrum 138	60.29	0.64	0	9.91	20.25	0.03	0	0	8.57	0.04	0	0	0	0	0.26	0.01	101.2
Spectrum 139	60.68	0.71	0	9.78	19.96	0	0	0	8.21	0.04	0	0	0	0	0.63	0	101.47
Spectrum 140	60.14	0.67	0	9.98	20.25	0	0	0	8.58	0.04	0.02	0	0	0	0.31	0	101.32
Spectrum 141	60.02	0.69	0	9.94	20.34	0	0	0	8.67	0.05	0	0	0	0	0.29	0	100.62
Spectrum 142	57.9	0	0	0.27	14.28	0.09	0	0	0.09	0.52	0.06	0	0	0.08	26.71	0	98.43
Spectrum 143	57.57	0	0	22.28	0.18	0	0	0	0.02	0	1.66	0	0	0.03	18.27	0	99.04
Spectrum 144	70.92	0.06	0	1.72	8.17	0.17	0.44	0	0.04	0.02	0.03	0	0	0.03	18.4	0	94.66
Spectrum 145	57.77	0.07	0	0.2	14.33	0.12	0	0	0	0.53	0.04	0	0	0.07	26.88	0	98.18
Spectrum 146	57.58	0	0.18	0.27	14.33	0.09	0	0	0	0.26	0.05	0	0	0.07	27.18	0	98.19
Spectrum 147	57.5	0	0.35	0.23	14.4	0.11	0	0	0	0.22	0.04	0	0	0.07	27.09	0	98.08

Spectrum Label	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 148	57.89	0	0.91	0.16	14.33	0.06	0	0	0	0.15	0.02	0	0	0.09	26.4	0	98.64
Spectrum 149	57.84	0	0.19	0.36	14.2	0.09	0	0	0.09	0.29	0.07	0	0	0.08	26.78	0	98.08
Spectrum 150	57.56	0	0.75	0.21	14.5	0	0	0	0	0.14	0	0	0	0.08	26.76	0	98.55
Spectrum 151	57.43	0	1.29	0.18	14.47	0	0	0	0	0.1	0.02	0	0	0.1	26.41	0	98.8
Spectrum 152	57.42	0	1.67	0.24	14.36	0.05	0	0	0	0.1	0.02	0	0	0.1	26.03	0	98.69
Spectrum 153	59.4	3.8	0	8.56	15.01	0.49	0.14	0	1.21	2.93	0.14	0	0	0.02	8.3	0.02	99.68
Spectrum 154	57.72	0	0.05	0.22	14.27	0.18	0	0	0.08	0.54	0.06	0	0	0.08	26.8	0	97.98
Spectrum 155	57.8	0	0	22.35	0.23	0	0	0	0.08	0	1.32	0	0	0.03	18.19	0	100.44
Spectrum 156	53.12	0	0	1.23	0.46	0	0	0	0.22	0	0.77	0	0	0.05	44.14	0	96
Spectrum 157	52.62	0	0	0.94	0.95	0	0	0	0.37	0.03	0.47	0	0	0.03	44.59	0	96.88
Spectrum 158	57.23	0	0.71	0.15	14.5	0	0	0	0	0.14	0	0	0	0.1	27.18	0	99.04
Spectrum 159	57.3	0	1.13	0.16	14.48	0.04	0	0	0	0.12	0.03	0	0	0.08	26.66	0	99.2
Spectrum 160	56.34	0	1.27	0.17	14.8	0	0.05	0	0	0.12	0	0	0	0.08	27.17	0	97.28
Spectrum 161	54.63	0.21	1.4	0.19	15.34	0.06	0.2	0	0	0.18	0	0	0	0.08	27.7	0	94.46
Spectrum 162	54.45	0.21	1.46	0.18	15.39	0.04	0.21	0.03	0	0.19	0	0	0	0.09	27.75	0	94.22
Spectrum 163	57.18	0	1.47	0.18	14.49	0	0	0	0	0.11	0.03	0	0	0.09	26.46	0	99.1
Spectrum 164	57.22	0	1.97	0.13	14.55	0	0	0	0	0.09	0	0	0	0.1	25.94	0	98.86
Spectrum 165	57.35	0	1.79	0.13	14.53	0	0	0	0	0.09	0	0	0	0.09	26.02	0	98.83
Spectrum 166	57.29	0	1.67	0.14	14.47	0	0	0	0	0.11	0.02	0	0	0.08	26.23	0	99.04
Spectrum 167	57.14	0	1.44	0.18	14.57	0	0	0	0	0.11	0	0	0	0.09	26.47	0	98.49
Spectrum 168	5.34	0.86	0	0.33	0	0	0.44	0.07	0	0.15	0	0	0	0	92.8	0	94.54
Spectrum 169	57.56	0	0.68	0.17	14.43	0.04	0	0	0	0.15	0	0	0	0.07	26.91	0	98.82
Spectrum 170	57.39	0	1.22	0.2	14.35	0.1	0	0.03	0	0.13	0	0	0	0.08	26.51	0	98.82
Spectrum 171	57.33	0	1.19	0.15	14.43	0.03	0	0	0	0.12	0	0	0	0.1	26.65	0	98.91
Spectrum 172	57.45	0	1.31	0.19	14.4	0.08	0	0	0	0.12	0	0	0	0.08	26.37	0	98.64
Spectrum 173	57.37	0	1.41	0.16	14.4	0.06	0	0	0	0.1	0	0	0	0.09	26.39	0	98.67
Spectrum 174	57.47	0	1.27	0.22	14.36	0	0	0	0.03	0.13	0	0	0	0.09	26.44	0	98.43
Spectrum 175	57.55	0	0.22	0.19	14.46	0.05	0	0	0.03	0.25	0.02	0	0	0.08	27.15	0	98.46
Spectrum 176	57.48	0	0.53	0.15	14.52	0.05	0	0	0	0.17	0	0	0	0.06	27.05	0	98.34

Spectrum Label	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 177	57.5	0	0.79	0.17	14.46	0	0	0	0	0.14	0.03	0	0	0.08	26.82	0	98.62
Spectrum 178	57.33	0	0.92	0.21	14.49	0.05	0	0	0.02	0.15	0.03	0	0	0.08	26.73	0	98.45
Spectrum 179	57.5	0	0.93	0.16	14.44	0.04	0	0	0	0.15	0.02	0	0	0.08	26.68	0	98.43
Spectrum 180	57.51	0	0.22	0.16	14.53	0	0	0	0.04	0.23	0.04	0	0	0.09	27.18	0	98.51
Spectrum 181	59.13	2.42	0	8.42	16.29	0.27	0.07	0	3.45	1.52	0.09	0	0	0.02	8.31	0.03	100.1
Spectrum 182	59.14	2.56	0	9.13	16.14	0.29	0.08	0	3.56	1.64	0.09	0	0	0	7.35	0.02	100.14
Spectrum 183	57.39	0	0.67	0.18	14.47	0.03	0	0.03	0.03	0.16	0	0	0	0.07	26.96	0	98.52
Spectrum 184	57.47	0	0.86	0.18	14.43	0.04	0	0	0	0.13	0	0	0	0.07	26.82	0	98.54
Spectrum 185	57.27	0	0.73	0.12	14.48	0.04	0	0	0	0.16	0	0	0	0.08	27.12	0	98.43
Spectrum 186	57.35	0	1.12	0.22	14.42	0.06	0	0	0	0.13	0.03	0	0	0.07	26.6	0	98.6
Spectrum 187	57.28	0	1.03	0.17	14.46	0.03	0	0	0	0.13	0	0	0	0.09	26.82	0	98.5
Spectrum 188	57.46	0	0.82	0.14	14.46	0.03	0	0	0	0.15	0	0	0	0.09	26.87	0	98.81
Spectrum 189	57.29	0	0.97	0.23	14.41	0.08	0	0	0	0.13	0.03	0	0	0.07	26.78	0	98.53
Spectrum 190	57.35	0	0.64	0.18	14.49	0	0	0	0	0.17	0	0	0	0.09	27.09	0	98.72
Spectrum 191	57.17	0	0.53	0.23	14.36	0.06	0	0.02	0	0.18	0	0	0	0.08	27.36	0	98.49
Spectrum 192	57.36	0	0.41	0.24	14.33	0.07	0	0	0	0.19	0.04	0	0	0.08	27.28	0	98.63
Spectrum 193	57.33	0	0.32	0.37	14.2	0.09	0	0	0	0.2	0.07	0	0	0.09	27.34	0	98.72
Spectrum 194	54.88	0	0.39	0.43	9.32	0.05	0	0	0	0.1	0.21	0	0	0.07	34.54	0	102.95
Spectrum 195	57.43	0	0.25	0.25	14.37	0.06	0	0	0	0.22	0.05	0	0	0.07	27.29	0	98.92
Spectrum 196	57.63	0	0.16	0.24	14.25	0.09	0	0	0	0.26	0.07	0	0	0.07	27.22	0	99.11
Spectrum 197	51.53	0	0	0.87	0.28	0	0	0	0	0.02	0.45	0	0	0.05	46.79	0	96.39
Spectrum 198	52.24	0	0	0.88	0.3	0.05	0	0	0.04	0	0.46	0	0	0.04	45.99	0	95.88
Spectrum 199	52.56	0	0.09	1.13	0.58	0.04	0.05	0	0.13	0.05	0.35	0	0	0.06	44.94	0	92.45
Spectrum 200	9.15	0	0.17	0.31	2.04	0	0	0	0	0.07	0	0	0	0.04	88.22	0	97.73
Spectrum 201	1.13	0	0	0.28	0.18	0	0	0	0	0	0	0	0	0	98.41	0	94.78
Spectrum 202	7.5	0	0.17	0.28	1.94	0	0	0	0	0.05	0	0	0	0	90.06	0	96.02
Spectrum 203	1.59	0	0	0.38	0.13	0	0	0	0	0	0	0	0	0	97.91	0	91.59
Spectrum 204	57.41	0	1.88	0.14	14.55	0.03	0	0	0	0.09	0	0	0	0.08	25.82	0	98.34
Spectrum 205	57.39	0	1.81	0.15	14.5	0.06	0	0	0	0.09	0	0	0	0.07	25.93	0	98.14

Spectrum Label	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ba	Total
Spectrum 206	57.37	0	1.58	0.2	14.47	0.06	0	0	0	0.1	0	0.02	0	0.1	26.11	0	98.21
Spectrum 207	57.61	0	1.21	0.19	14.42	0.07	0	0	0	0.13	0	0	0	0.08	26.29	0	97.97
Spectrum 208	57.59	0	1	0.15	14.47	0.04	0	0	0	0.14	0	0	0	0.09	26.51	0	98.18
Spectrum 209	57.87	0	0.24	0.23	14.2	0.13	0	0	0	0.22	0.06	0	0	0.08	26.98	0	98.24
Spectrum 210	57.71	0	0.17	0.32	14.18	0.16	0	0	0	0.28	0.04	0	0	0.08	27.06	0	98.27
Spectrum 211	57.55	0	0.18	0.22	14.31	0.12	0	0	0	0.23	0.04	0	0	0.08	27.28	0	97.43
Spectrum 212	58.33	0	0.16	0.4	14.08	0.19	0	0	0	0.29	0.06	0	0	0.07	26.42	0	99.46
Spectrum 213	58.22	0	0.14	0.36	14.14	0.18	0	0	0	0.35	0.05	0	0	0.08	26.48	0	98.95
Spectrum 214	53.29	0	0.06	0.62	2.47	0.05	0	0	0	0.06	0.41	0	0	0.05	42.97	0	98.27
Spectrum 215	59.79	0.38	0.71	2.25	13.37	0.09	0.14	0	0.38	0.23	0.06	0	0	0.06	22.53	0	95.28
Spectrum 216	60.11	0.34	0.68	2.12	12.73	0.08	0.13	0	0.32	0.22	0.06	0	0	0.07	23.14	0	93.95
Spectrum 217	65.05	0.36	0.12	3.31	3.13	0.63	0.31	0.76	0.08	0.42	0	0	0	0	25.82	0	41.24
Spectrum 218	58.22	1.23	0.26	4.56	14.3	0.14	0.07	0	1.44	0.58	0.1	0	0	0.05	19.07	0	100.62
Spectrum 219	57.35	1.99	0.14	5.46	13.71	0.15	0.04	0	1.42	0.86	0.15	0	0	0.06	18.67	0	100.67
Spectrum 220	57.39	0.39	0.37	2.97	12.23	0.51	0.03	0.05	0.7	0.33	0.13	0	0	0.04	24.86	0	86.9

Table C6: EDS analyses for analytical standards.

22/09/2016										
Spectrum Label	O	Mg		Si				Fe	Ni	Total
Astimex standard	**44.09**	**30.74**		**19.45**				**5.64**	**0.29**	**100.20**
Spectrum 111	44.65	31.17		19.68				5.68	0.33	101.51
Spectrum 112	44.66	31.16		19.68				5.69	0.37	101.55
Spectrum 113	44.65	31.19		19.67				5.66	0.36	101.53
29/09/2016										
Spectrum Label	O	Mg	Al	Si	Ca	Ti	Mn	Fe	Ni	Total
Astimex standard	**44.09**	**30.74**		**19.45**				**5.64**	**0.29**	**100.20**
Spectrum 1	44.45	31.00	0.00	19.59	0.00	0.00	0.08	5.62	0.36	101.10
Spectrum 2	44.53	30.98	0.03	19.62	0.00	0.04	0.09	5.65	0.35	101.28
Spectrum 3	44.43	30.99	0.00	19.58	0.00	0.00	0.09	5.62	0.34	101.04
Astimex standard	**42.11**	**6.12**	**12.02**	**18.30**	**2.86**	**0.04**	**0.43**	**18.56**		**100.40**
Spectrum 14	42.75	6.05	11.98	18.86	2.85	0.00	0.47	18.59	0.08	101.63
Spectrum 15	42.61	6.03	11.91	18.76	2.86	0.05	0.48	18.62	0.07	101.39
Spectrum 16	42.78	6.07	12.00	18.82	2.85	0.06	0.51	18.61	0.06	101.75
MAC standard	**44.11**	**30.16**		**19.60**				**6.46**	**0.29**	**100.61**
Spectrum 17	44.28	30.27	0.09	19.51	0.05	0.00	0.12	6.64	0.31	101.29
Spectrum 18	44.31	30.32	0.07	19.55	0.07	0.00	0.11	6.58	0.34	101.33
Spectrum 19	44.36	30.30	0.09	19.58	0.04	0.00	0.11	6.60	0.35	101.44

I

X.3 appD: Locations of microanalyses and other SEM images

Plate A1

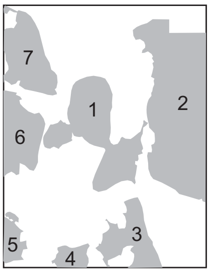


Plate A1: Sample HGA1. Tabular microresidues. Backscattered electron image montage of central part of mount with key to particles.

Plate A2

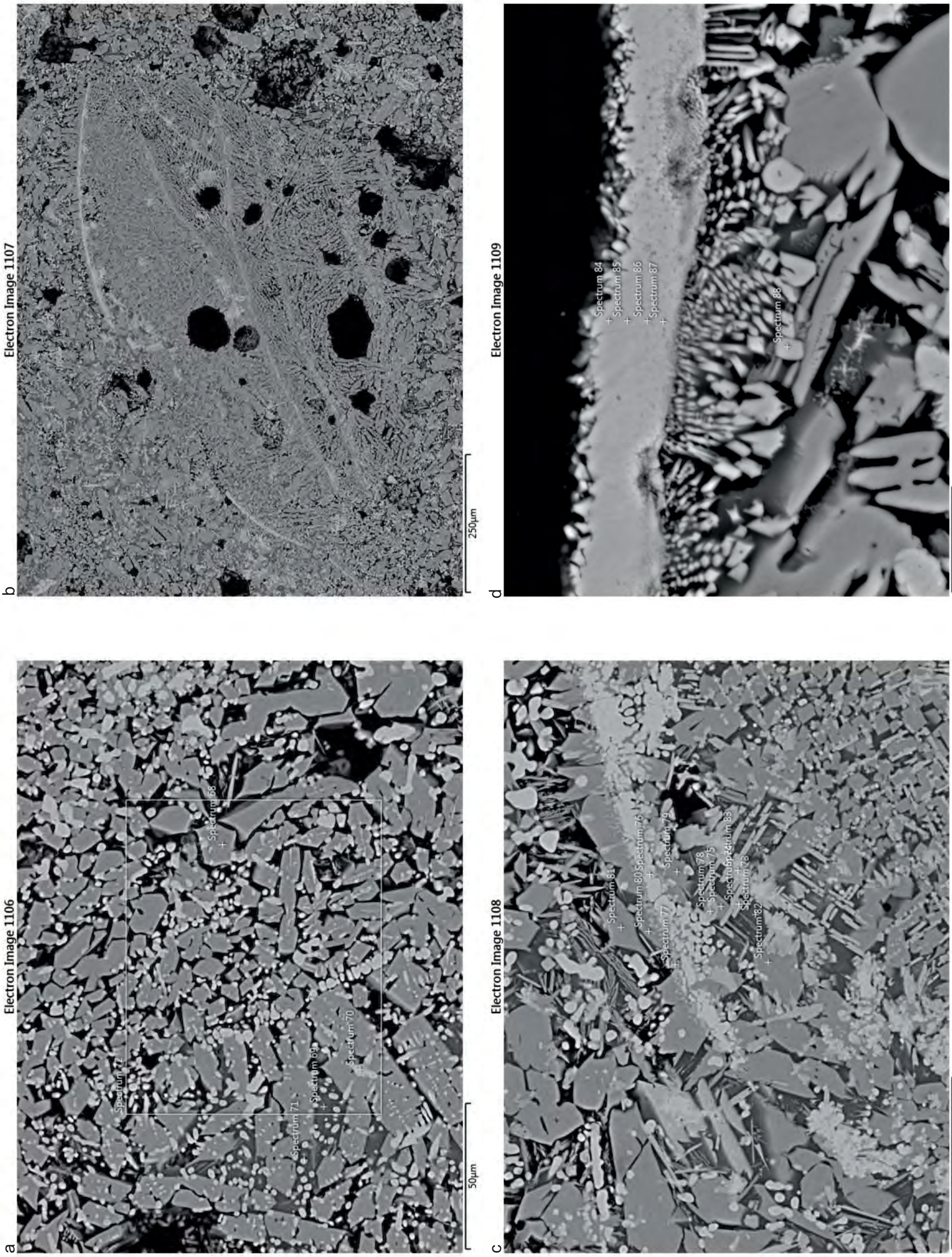


Plate A2: Sample HGA1, particle #T1
a. Site 1107, electron image 1106, backscattered electron image. b. Site 1108, electron image 1107, backscattered electron image.
c. Site 1109, electron image 1108, backscattered electron image. d. Site 1110, electron image 1109, backscattered electron image.

Plate A3

a

b

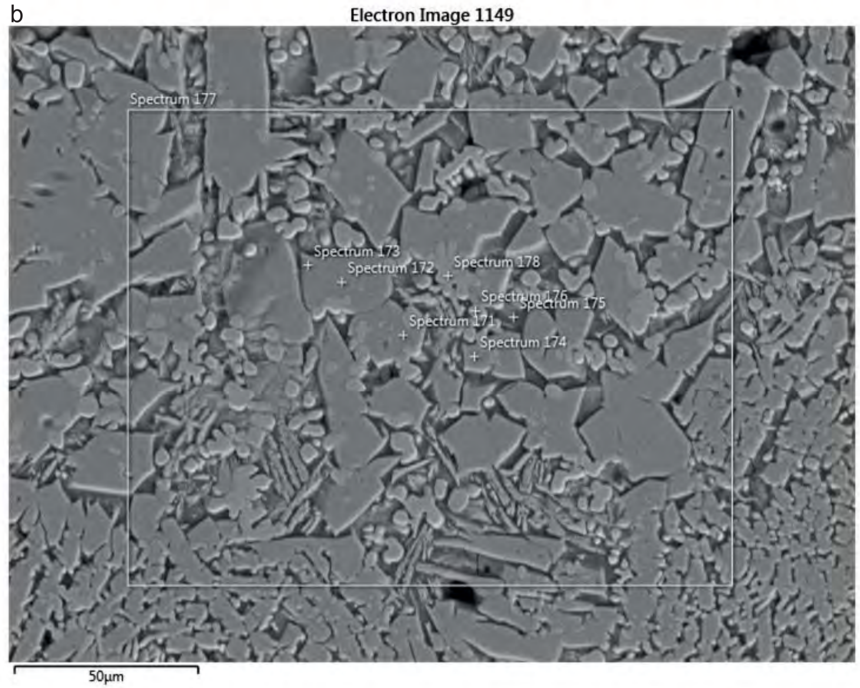
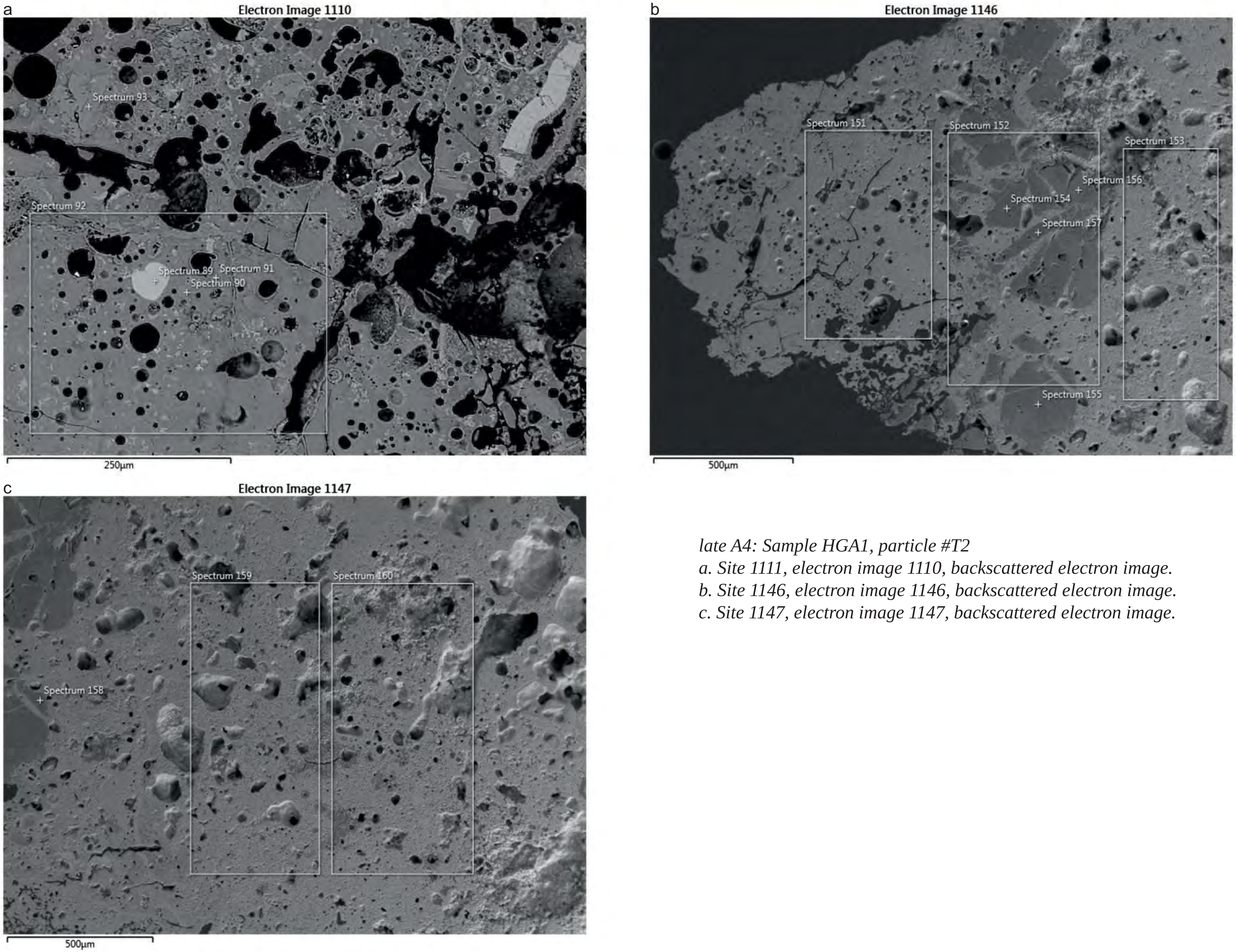


Plate A3: Sample HGA1. , particle #T1
a. Site 1148, electron image 1148, secondary electron image.
b. Site 1149, electron image 1149, secondary electron image.



late A4: Sample HGA1, particle #T2
a. Site 1111, electron image 1110, backscattered electron image.
b. Site 1146, electron image 1146, backscattered electron image.
c. Site 1147, electron image 1147, backscattered electron image.

Plate A5

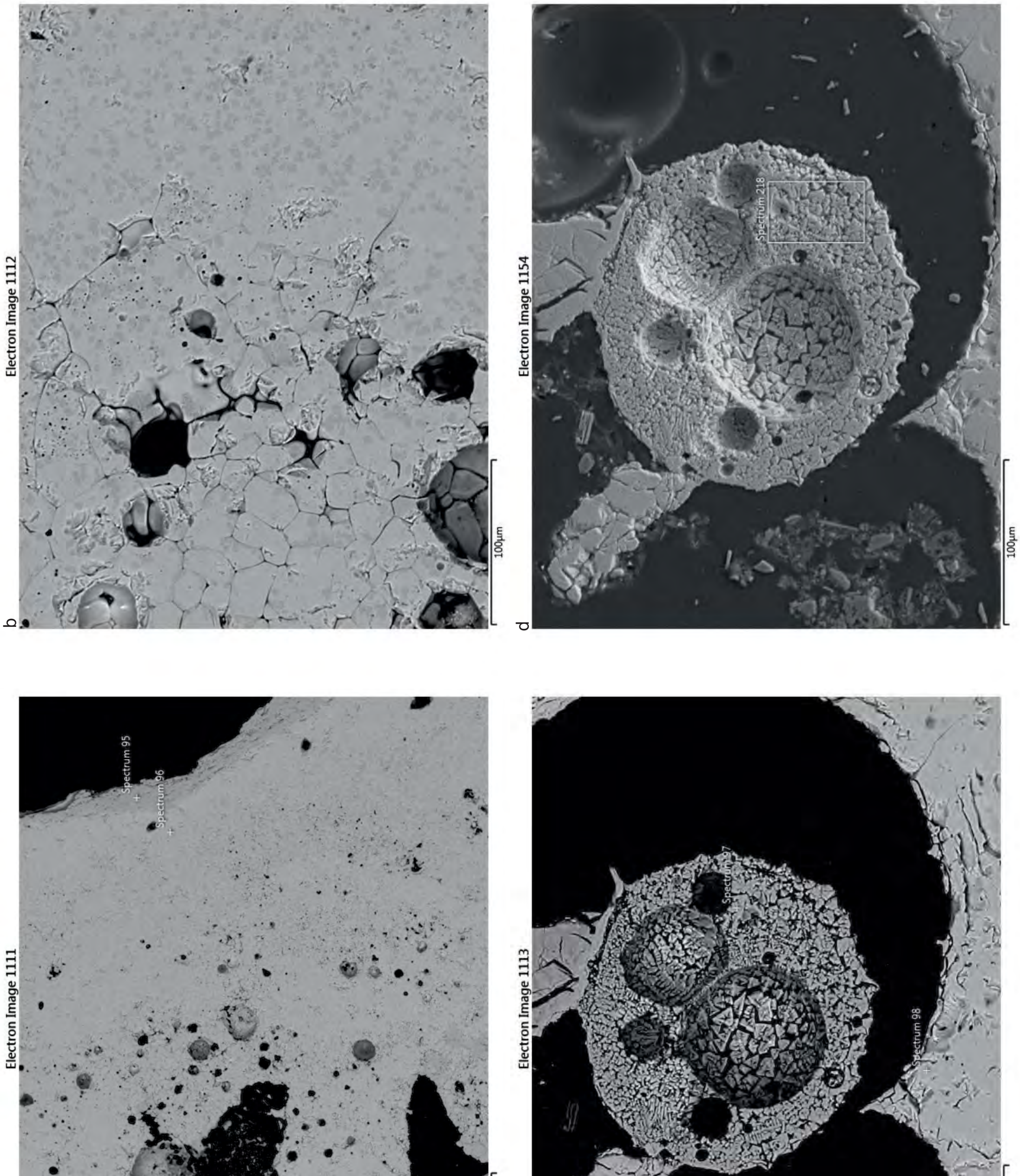
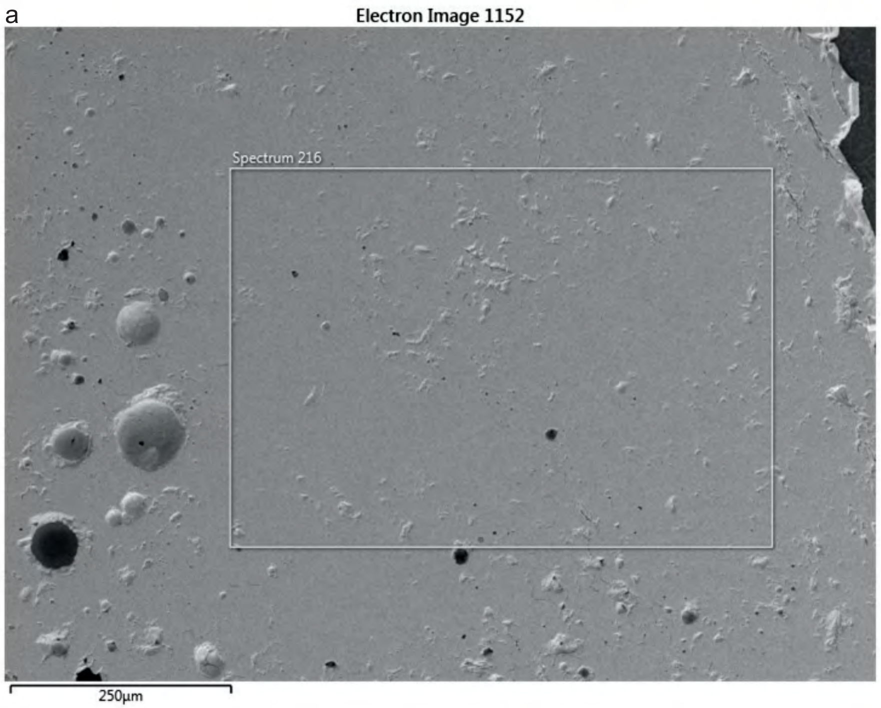


Plate A5: Sample HGA1, particle #T3
a. Site 1112, electron image 1111, backscattered electron image. b. Site 1113, electron image 1112, backscattered electron image. c. Site 1114, electron image 1113, backscattered electron image. d. Site 1154, electron image 1154, secondary electron image.

Plate A6

a



b

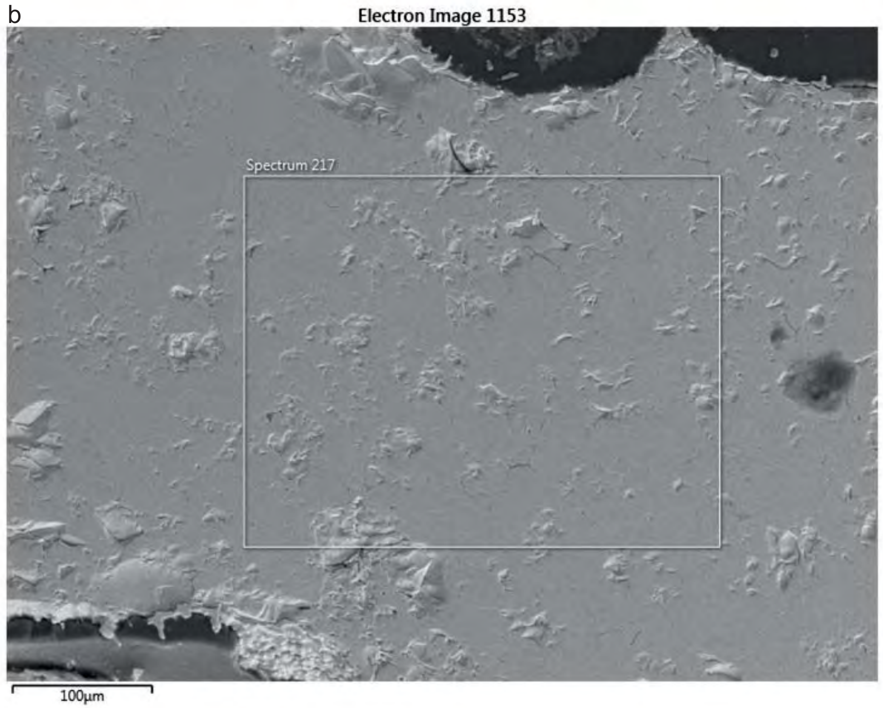
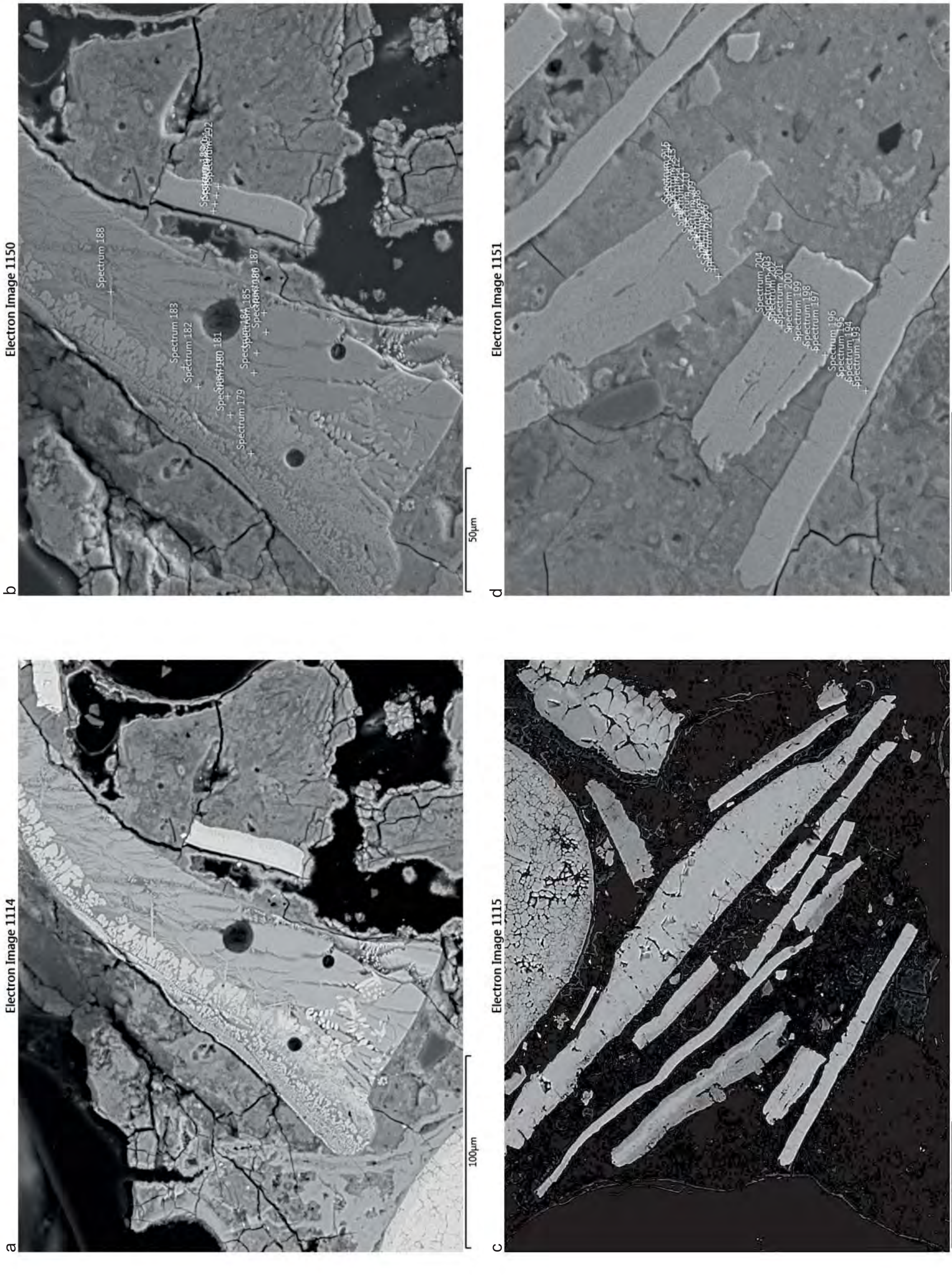
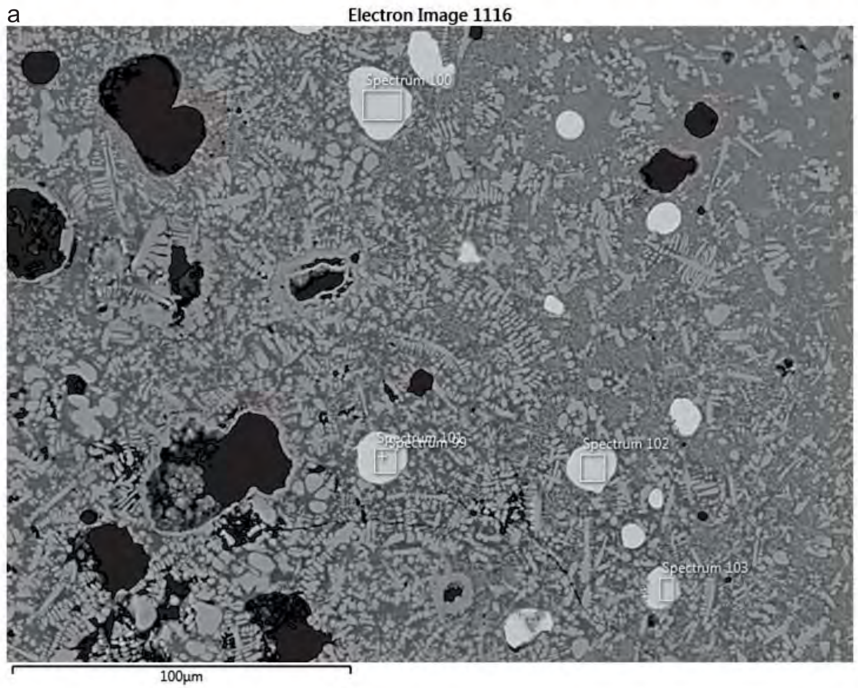


Plate A6: Sample HGA1, particle #T3
a. Site 1152, electron image 1152, secondary electron image.
b. Site 1153, electron image 1153, secondary electron image.

Plate A7

Plate A7: Sample HGA1, particle #T4
a. Site 1115, electron image 1114, backscattered electron image.
b. Site 1150, electron image 1150, secondary electron image.
c. Site 1116, electron image 1115, backscattered electron image.
d. Site 1151, electron image 1151, secondary electron image.





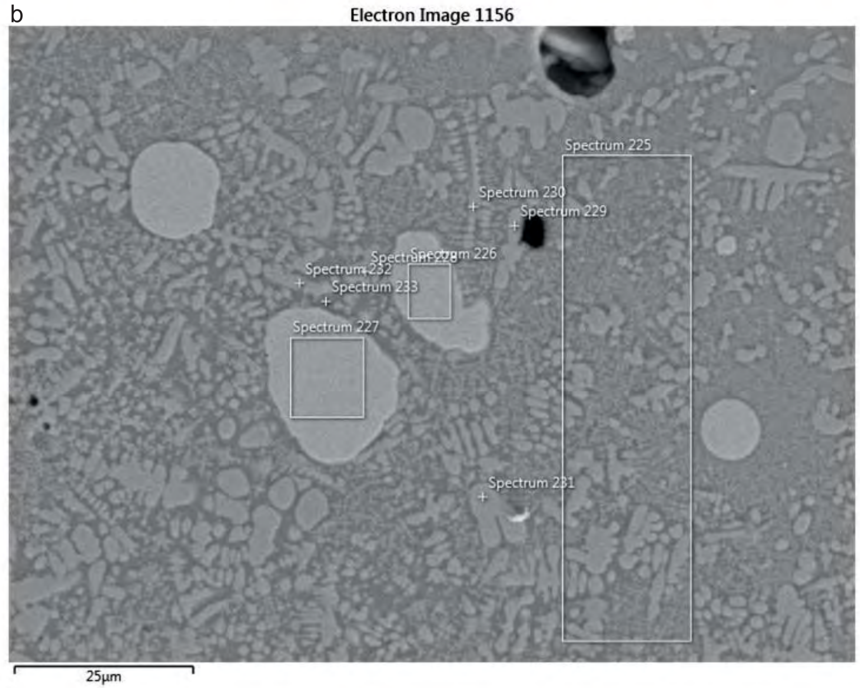
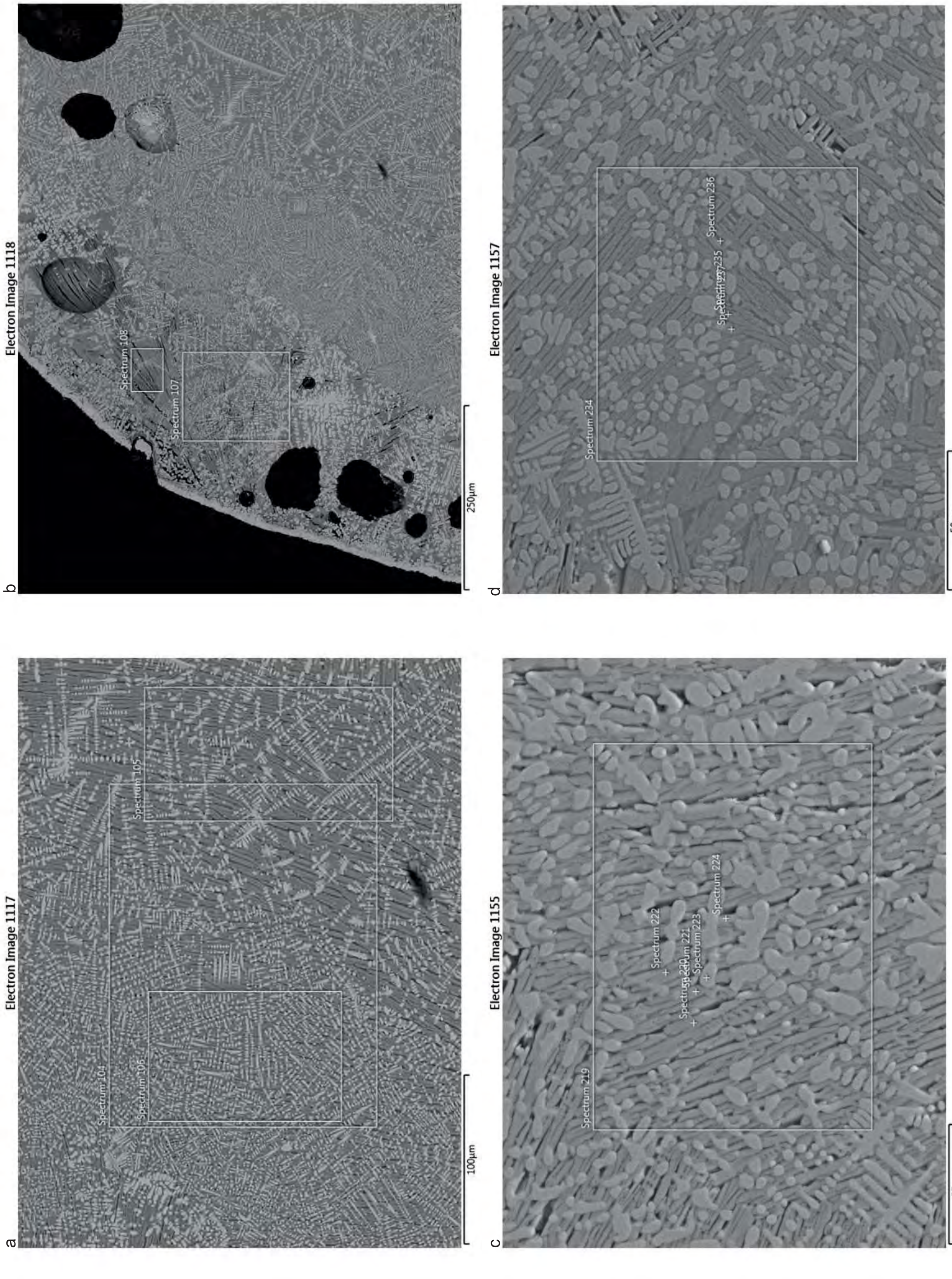


Plate A8: Sample HGA1, particle #T5
a. Site 1117, electron image 1116, backscattered electron image.
b. Site 1156, electron image 1156, secondary electron image.

Plate A9

Plate A9: Sample HGA1, particle #T7
a. Site 1118, electron image 1117, backscattered electron image.
b. Site 1119, electron image 1118, backscattered electron image.
c. Site 1155, electron image 1155, secondary electron image.
d. Site 1157, electron image 1157, secondary electron image.



a

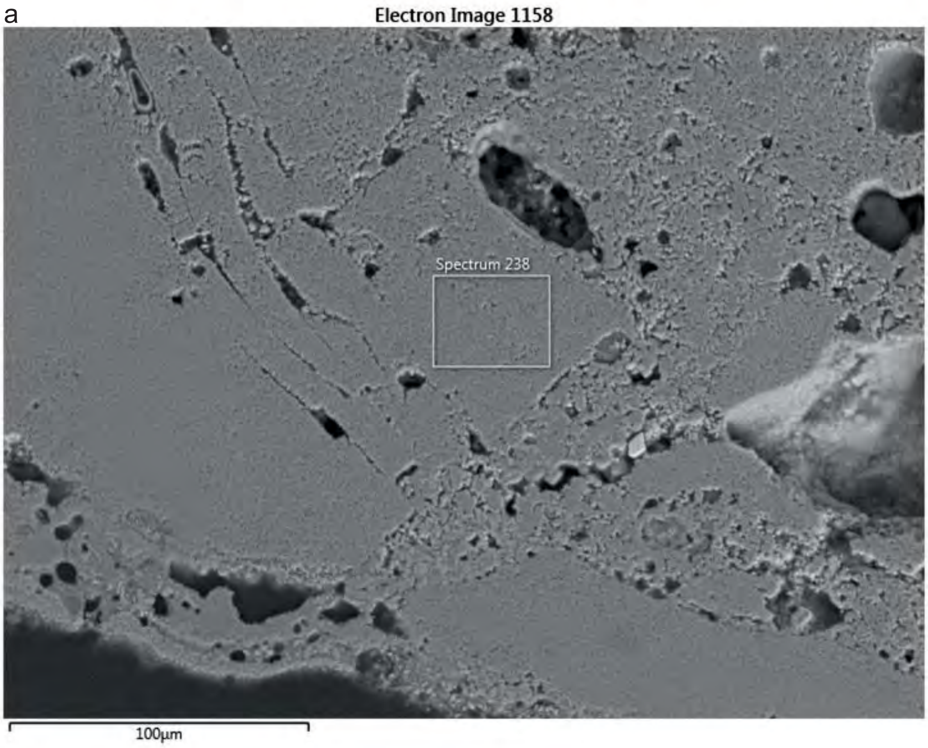


Plate A10: Sample HGA1, particle #T7
a. Site 1158, electron image 1158, secondary electron image.

Plate A11

Plate A10

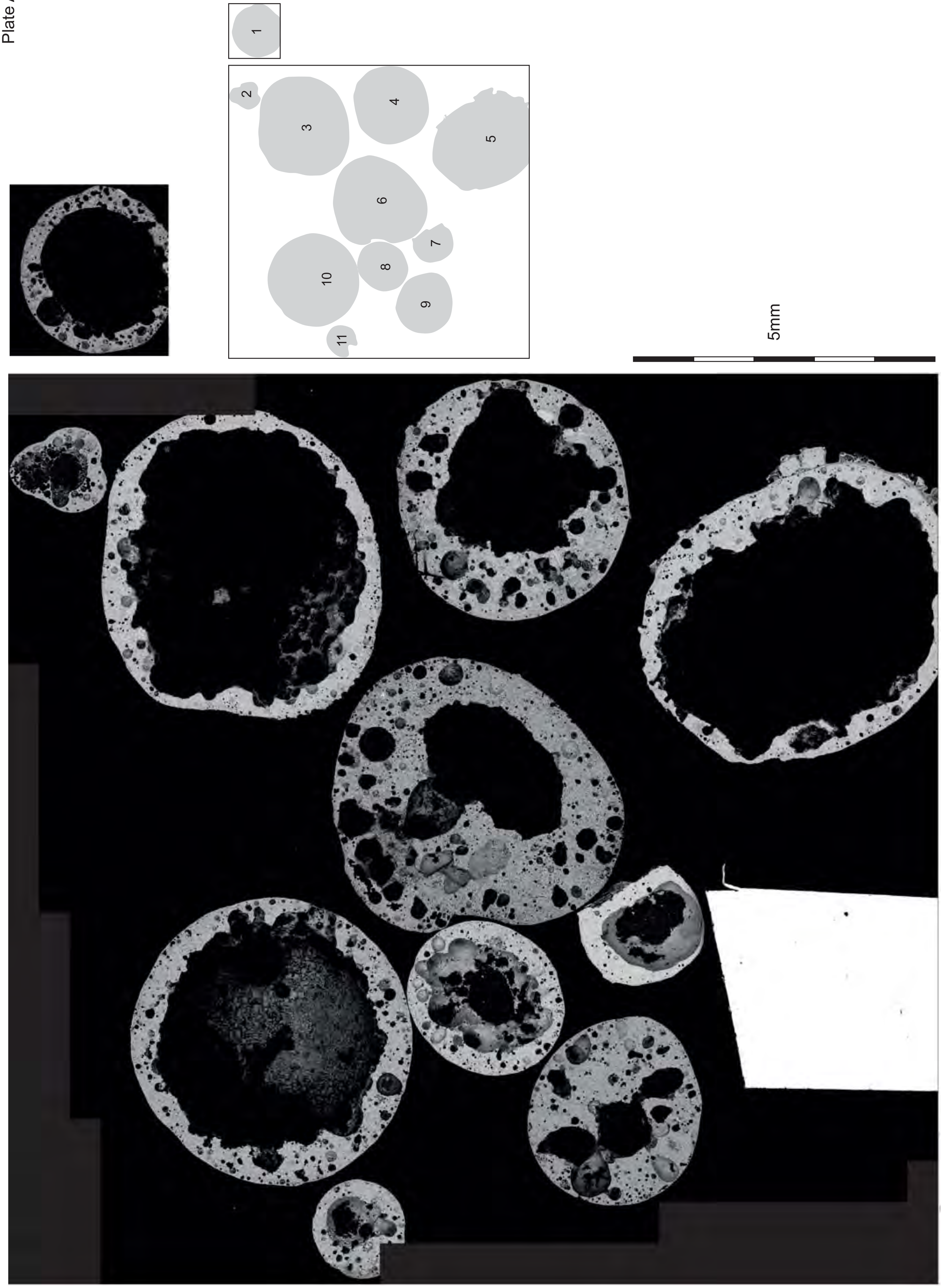


Plate A11: Sample HGA2, spheroidal microresidues. Backscattered electron image montages of mount with key to particles

a

b

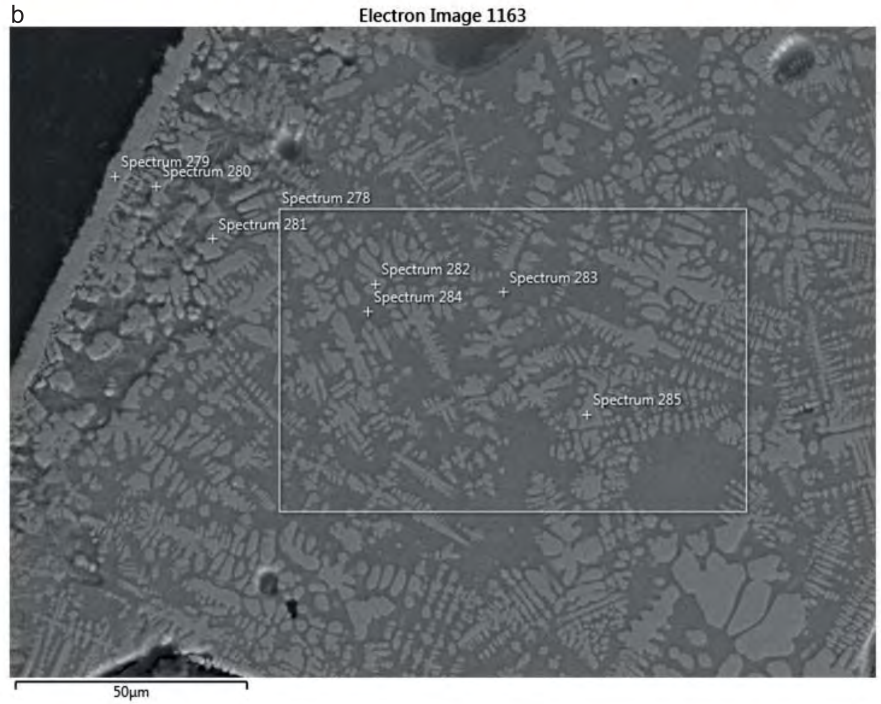
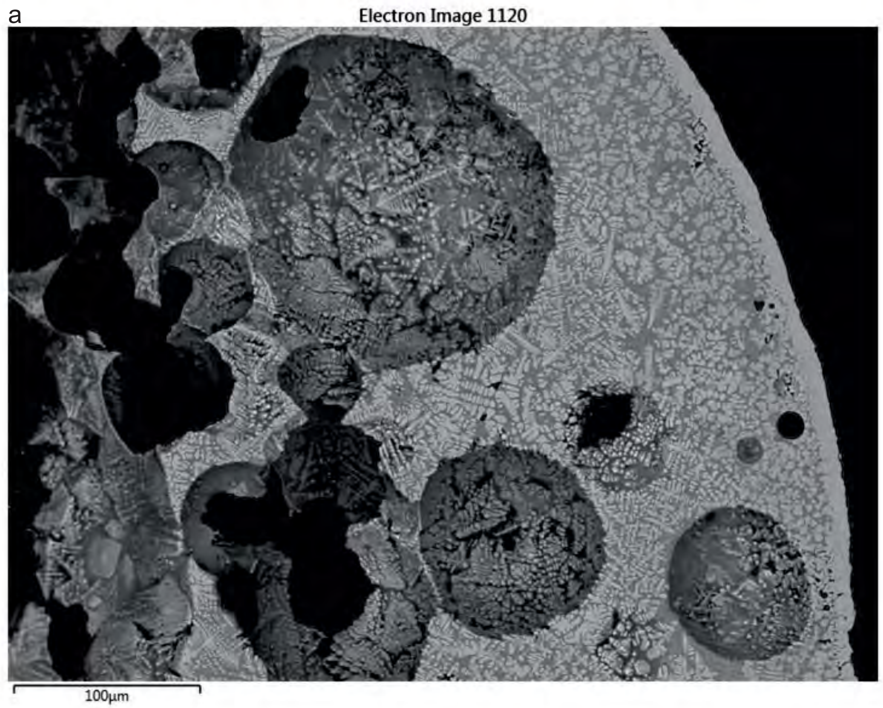


Plate A12: Sample HGA2, particle #S1
a. Site 1120, electron image 1119, backscattered electron image.
b. Site 1164, electron image 1163, secondary electron image.

a



b

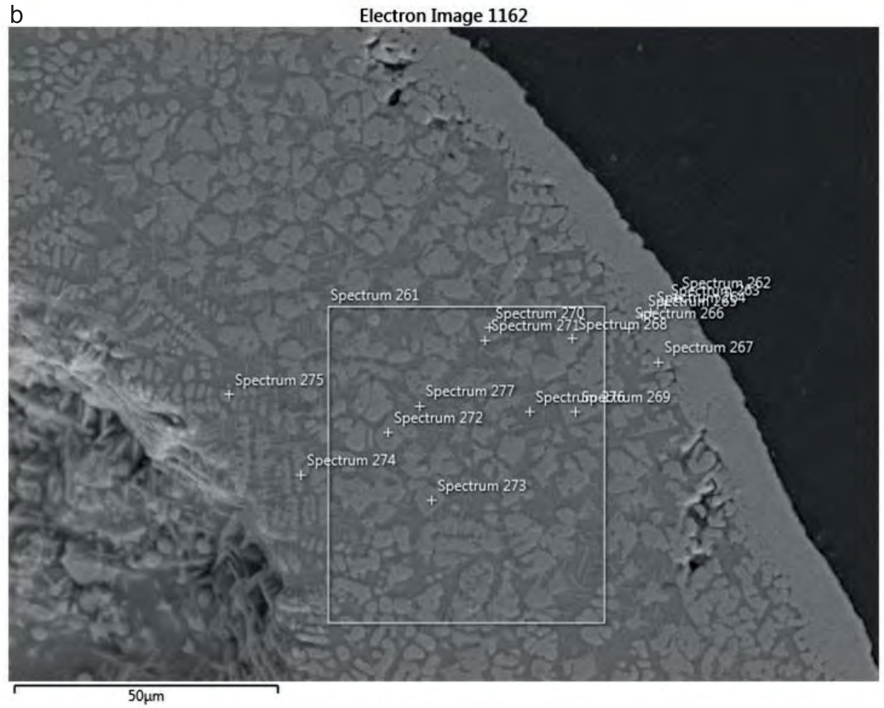
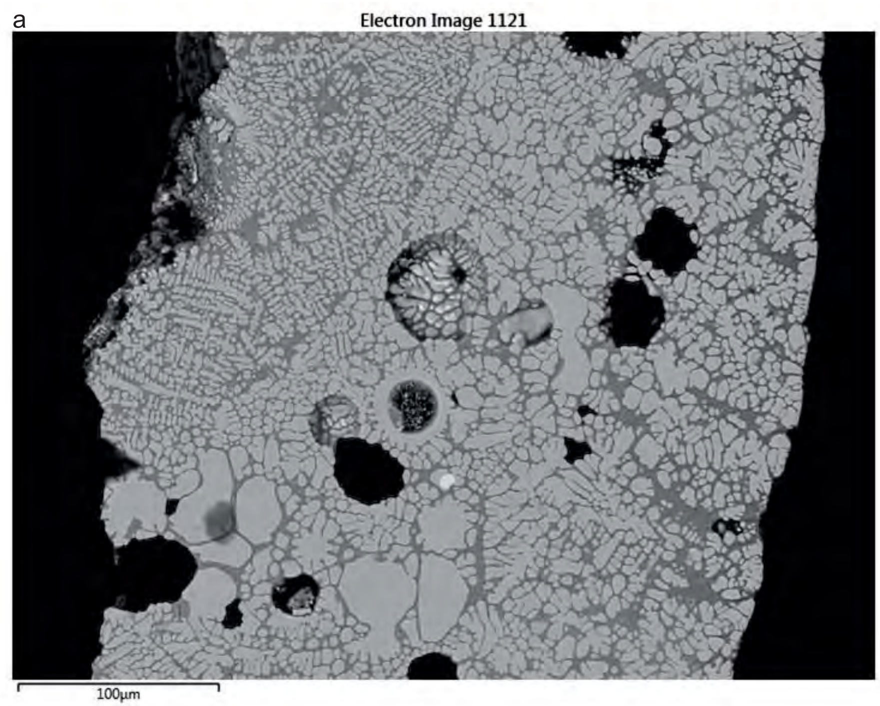


Plate A13: Sample HGA2, particle #S2
a. Site 1121, electron image 1120, backscattered electron image.
b. Site 1163, electron image 1162 secondary electron image.

Plate A14



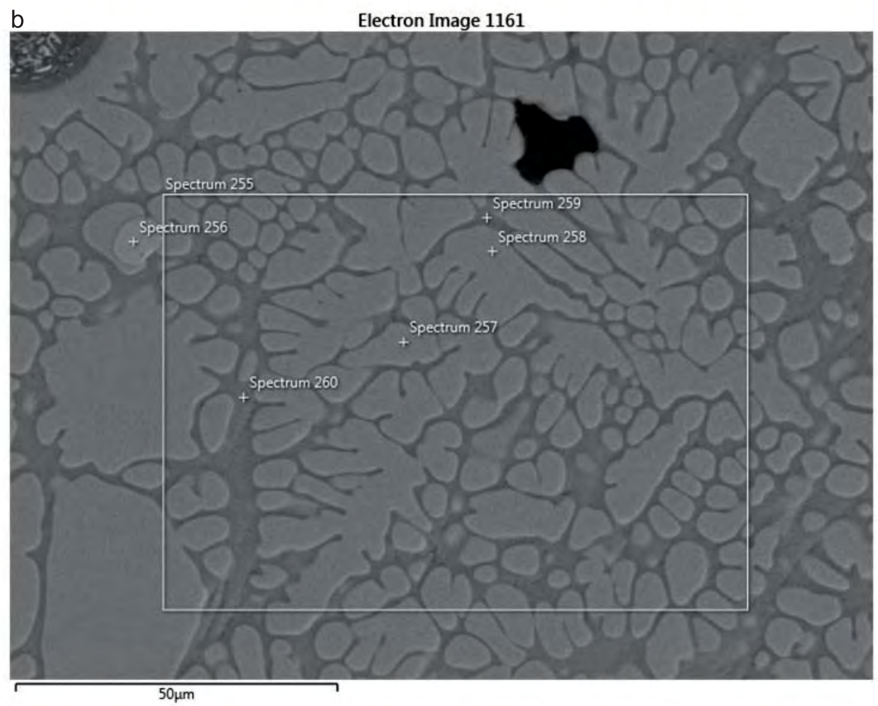
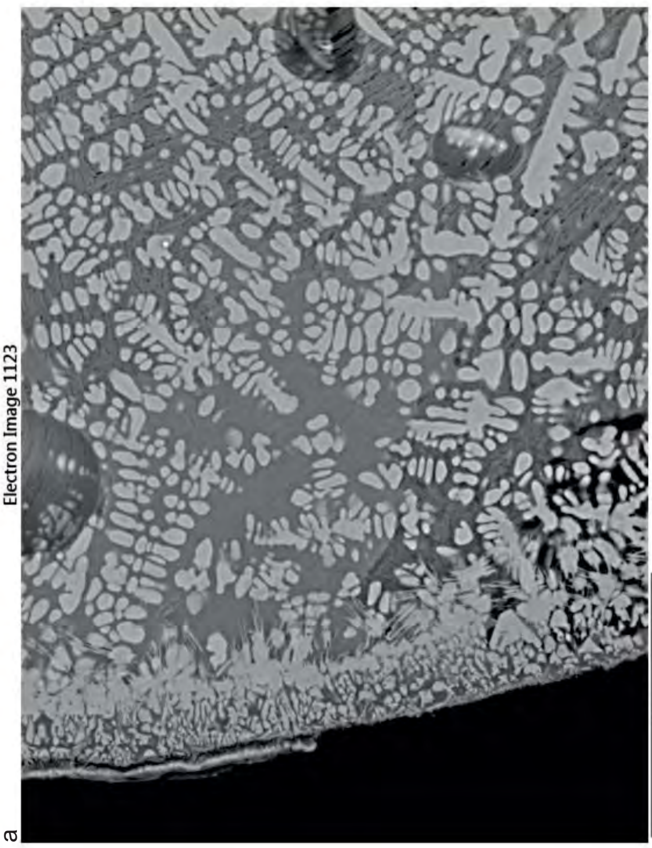


Plate A14: Sample HGA2, particle #S3
a. Site 1122, electron image 1121, backscattered electron image.
b. Site 1162, electron image 1161 secondary electron image.

Plate A15: Sample HGA2, particle #S4
a. Site 1124, electron image 1123, backscattered electron image.
b. Site 1161, electron image 1160, secondary electron image.
c. Site 1125, electron image 1124, backscattered electron image.
d. Site 1160, electron image 1159, secondary electron image.

a


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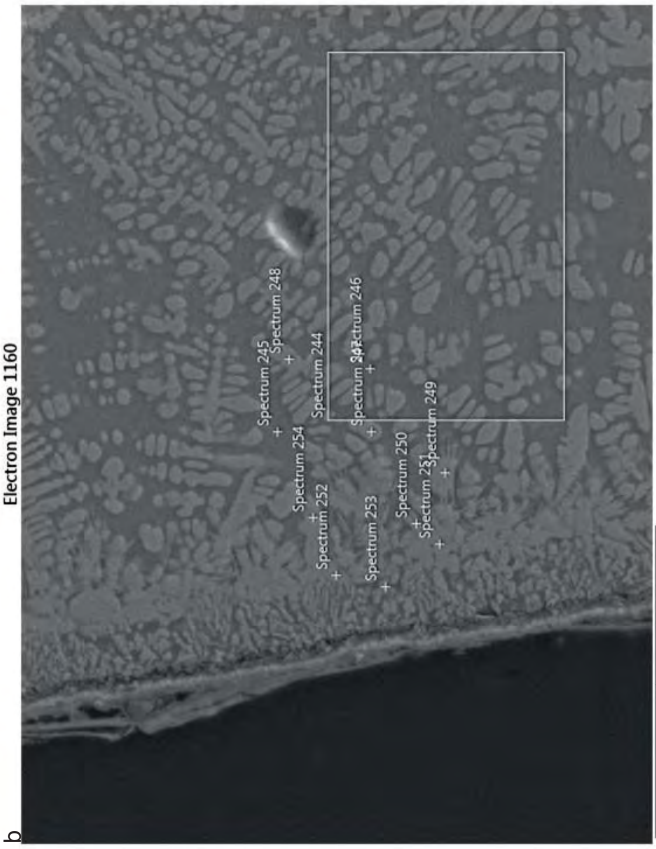
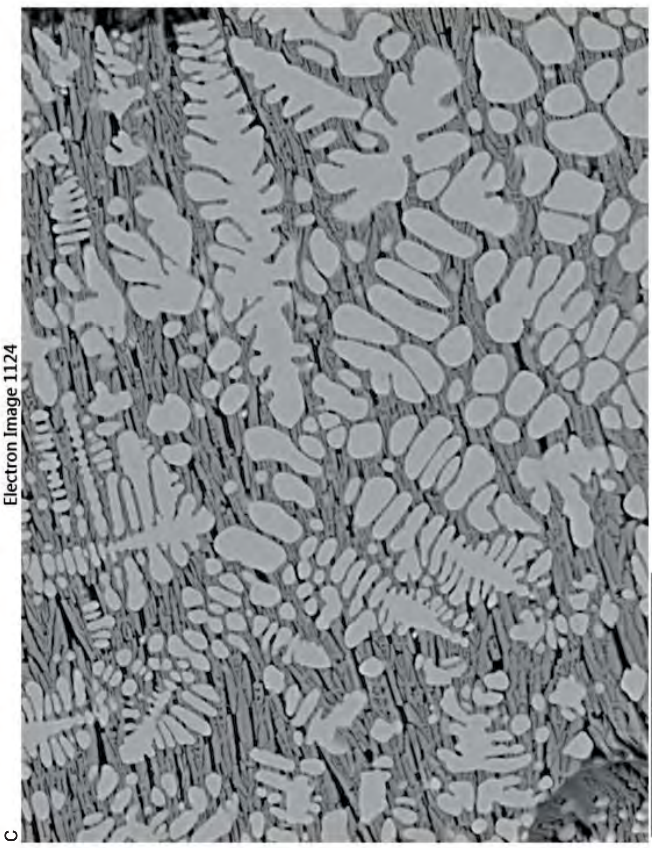
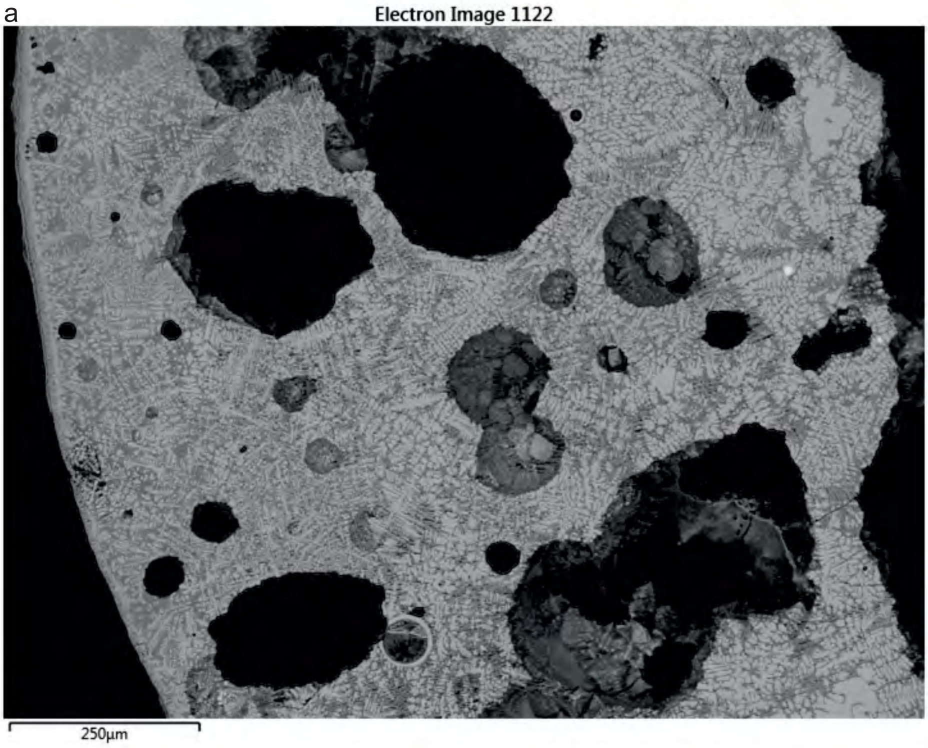


c


d


a

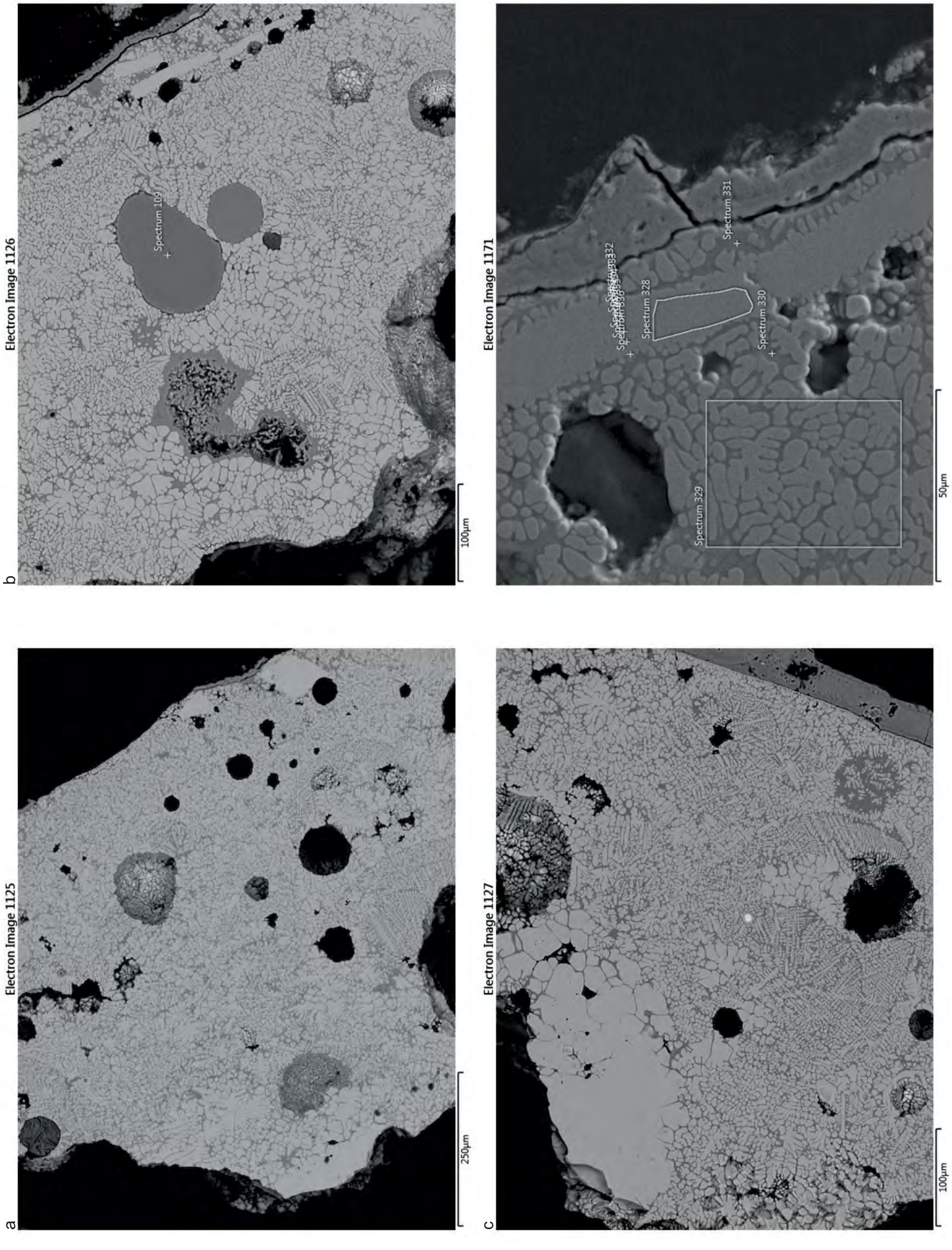


b

Plate A16: Sample HGA2, particle #S4
a. Site 1123, electron image 1122, backscattered electron image.

Plate A17: Sample HGA2, particle #S5

a. Site 1126, electron image 1125, backscattered electron image.
b. Site 1127, electron image 1126, backscattered electron image.
c. Site 1128, electron image 1127, backscattered electron image.
d. Site 1172, electron image 1171, secondary electron image.



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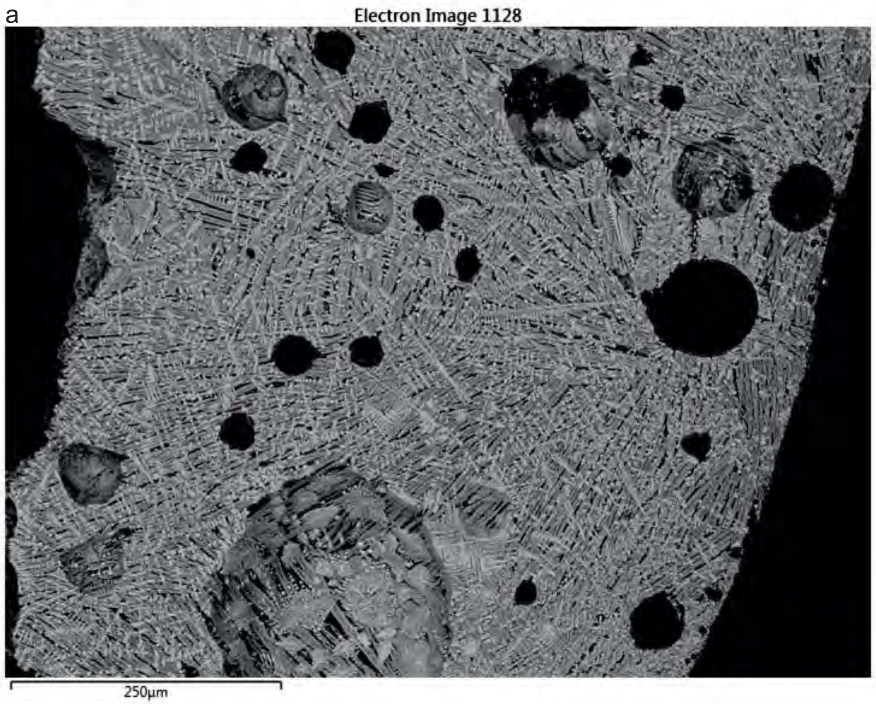

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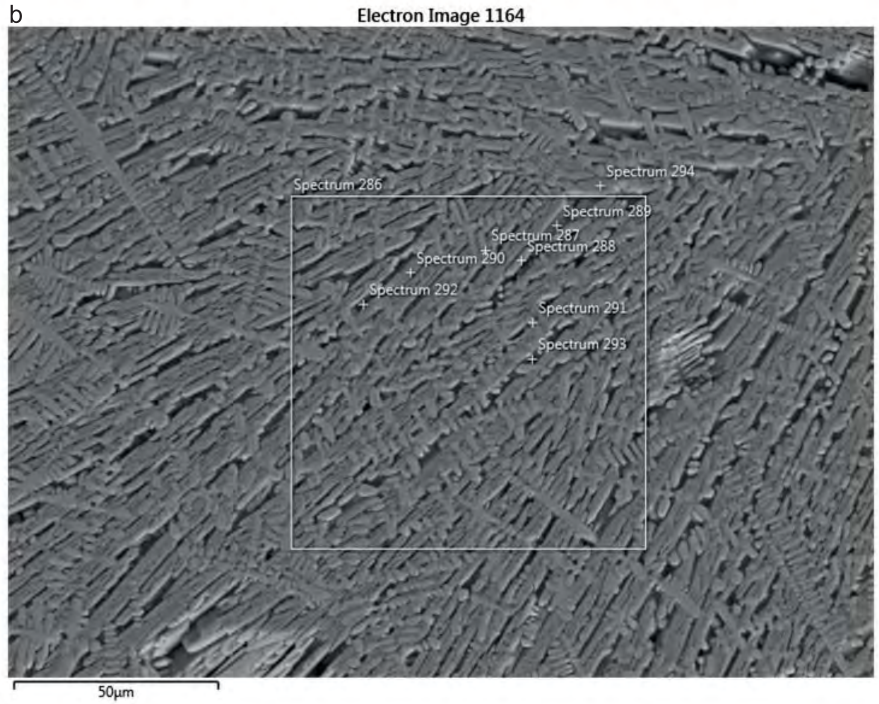

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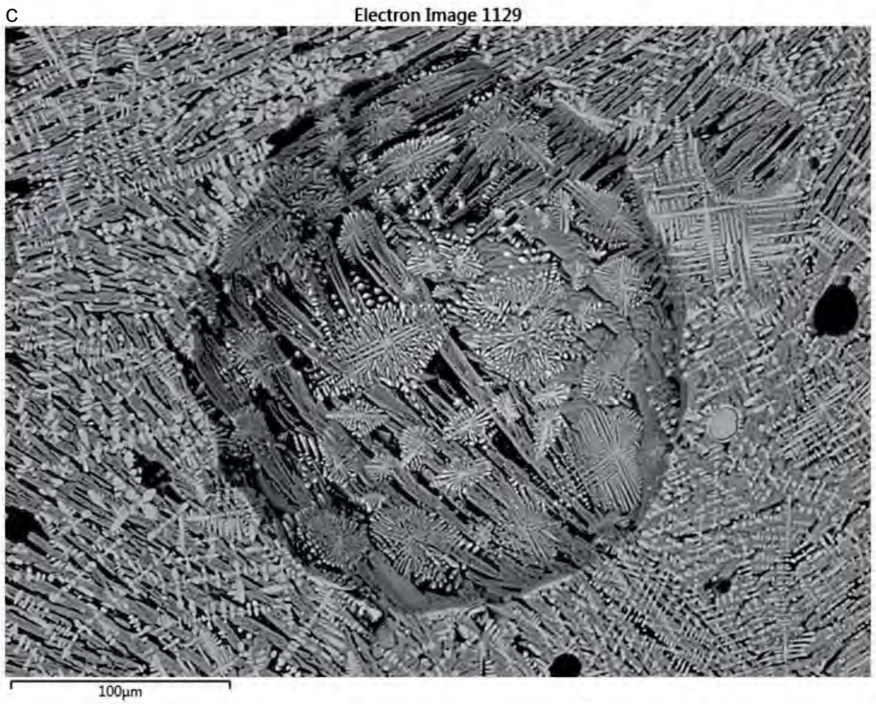


Plate A18: Sample HGA2, particle #S6
a. Site 1129, electron image 1128, backscattered electron image.
b. Site 1165, electron image 1164, secondary electron image.
c. Site 1130, electron image 1129, backscattered electron image.

a

b

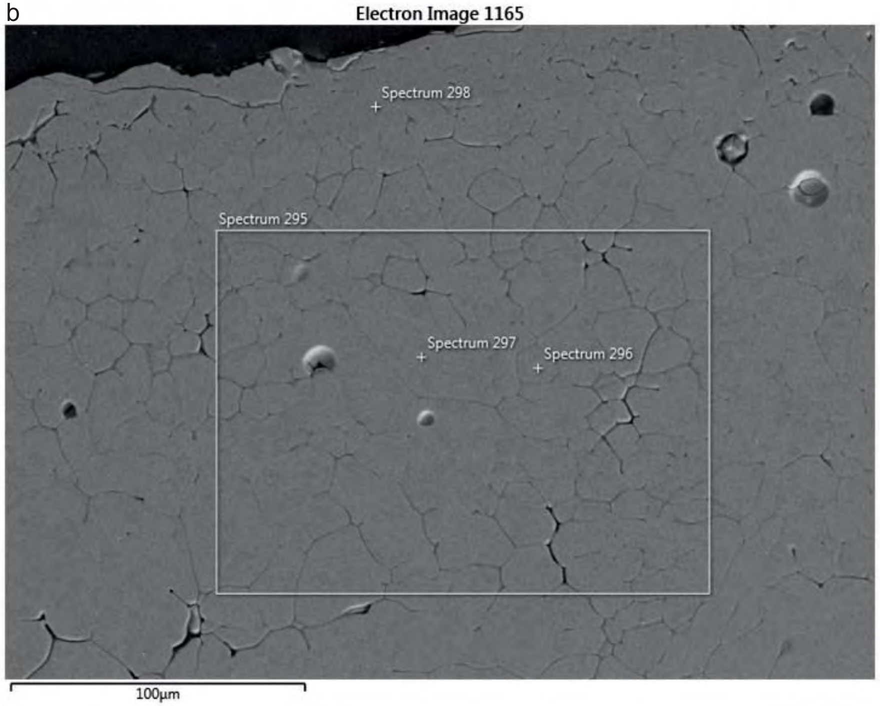
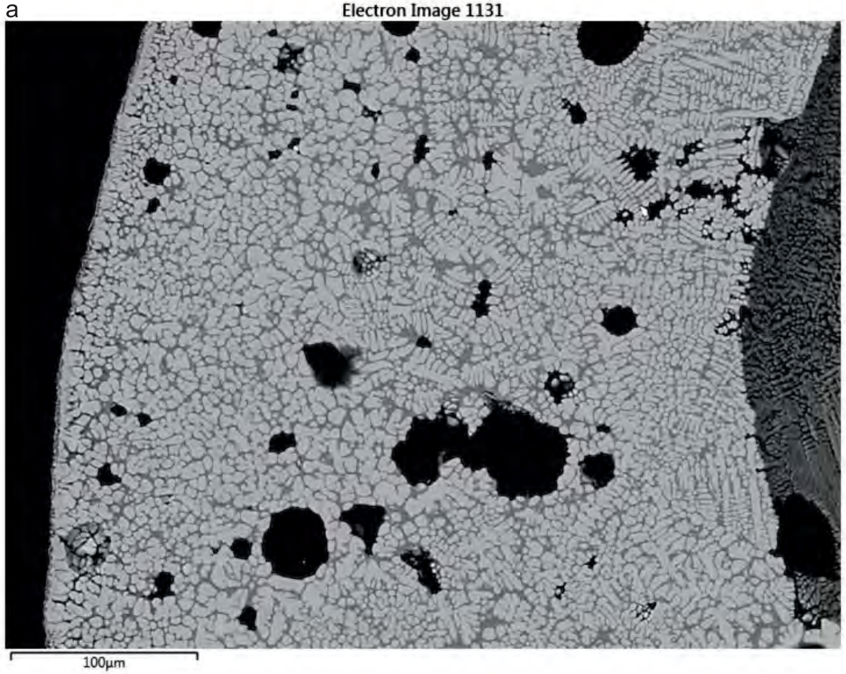


Plate A19: Sample HGA2, particle #S7
a. Site 1131, electron image 1130, backscattered electron image.
b. Site 1166, electron image 1165, secondary electron image.

Plate A20

a



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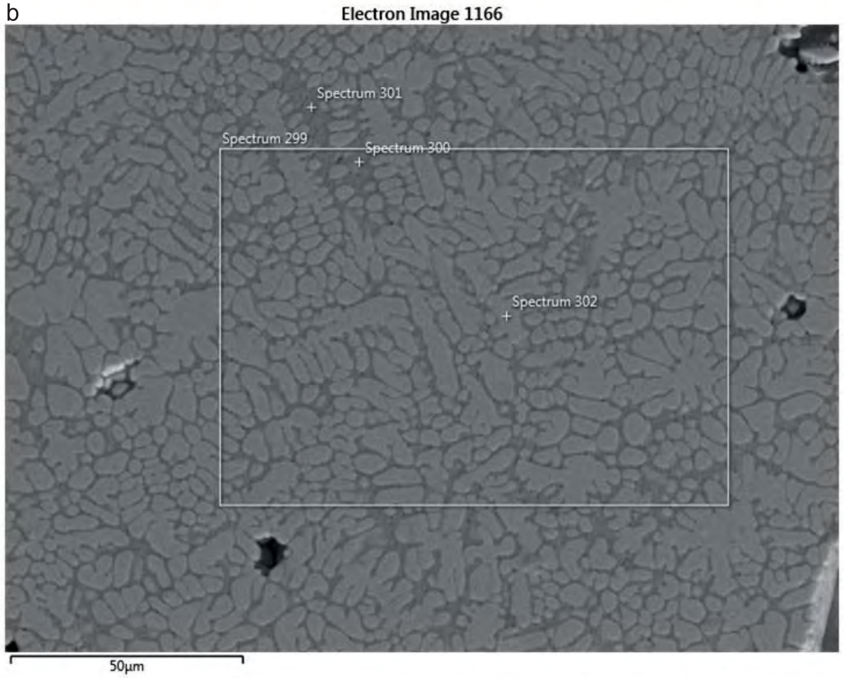

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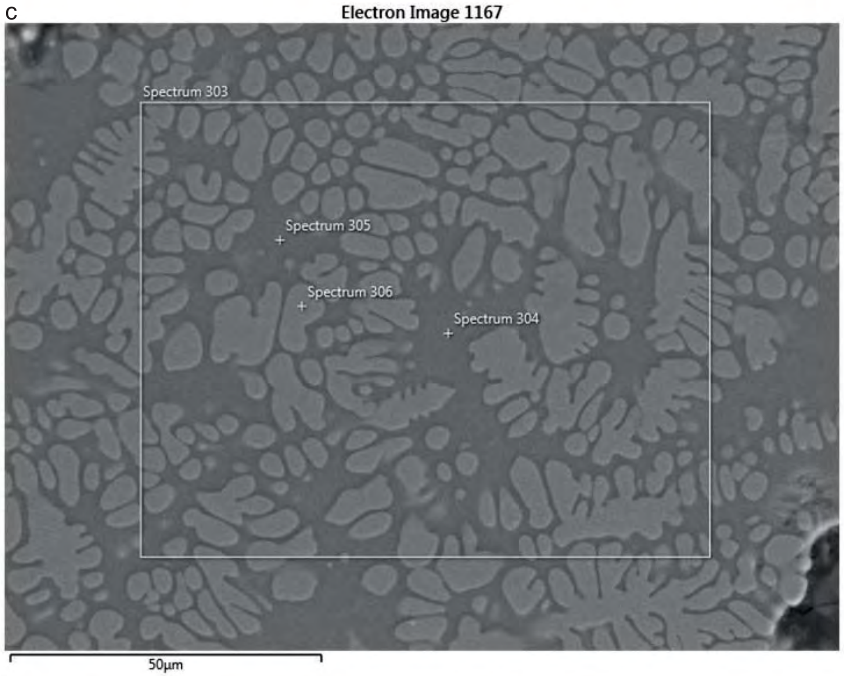
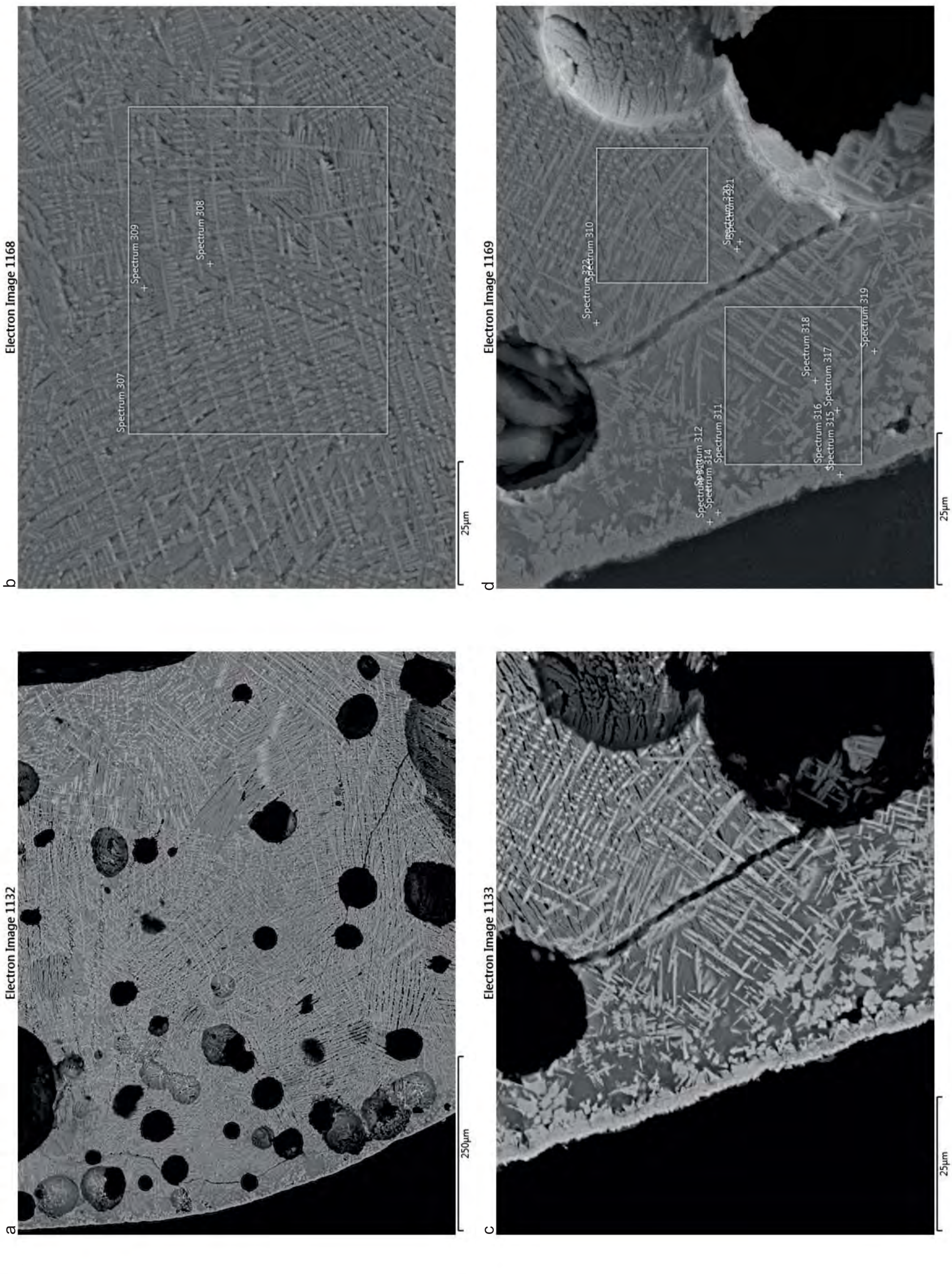


Plate A20: Sample HGA2, particle #S8
a. Site 1132, electron image 1131, backscattered electron image.
b. Site 1167, electron image 1166, secondary electron image.
c. Site 1168, electron image 1167, secondary electron image.

Plate A21: Sample HGA2, particle #S9
a. Site 1133, electron image 1132, backscattered electron image.
b. Site 1169, electron image 1168, secondary electron image.
c. Site 1134, electron image 1133, backscattered electron image.
d. Site 1170, electron image 1169, secondary electron image.



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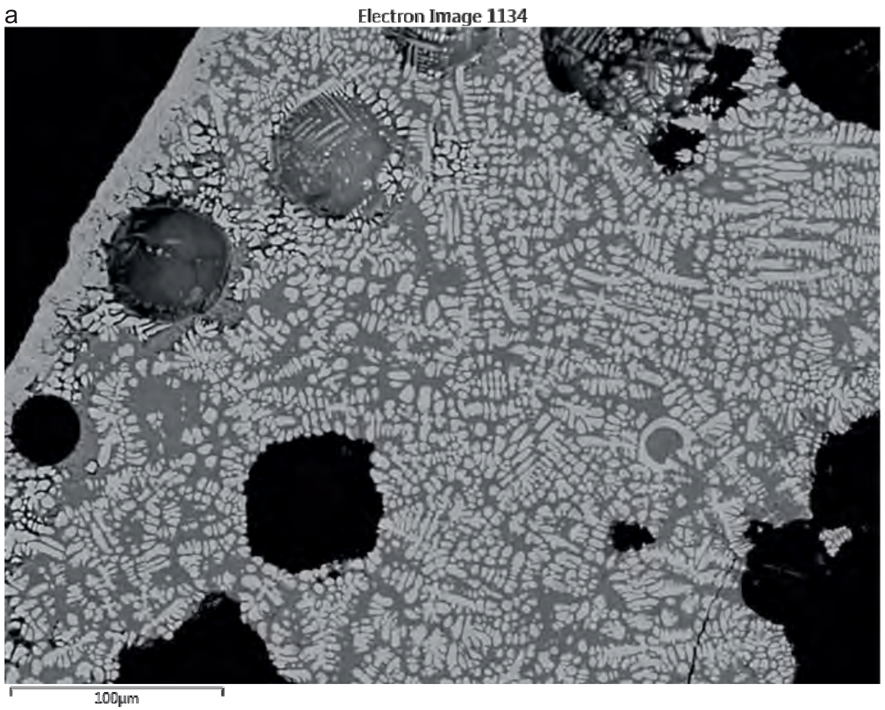

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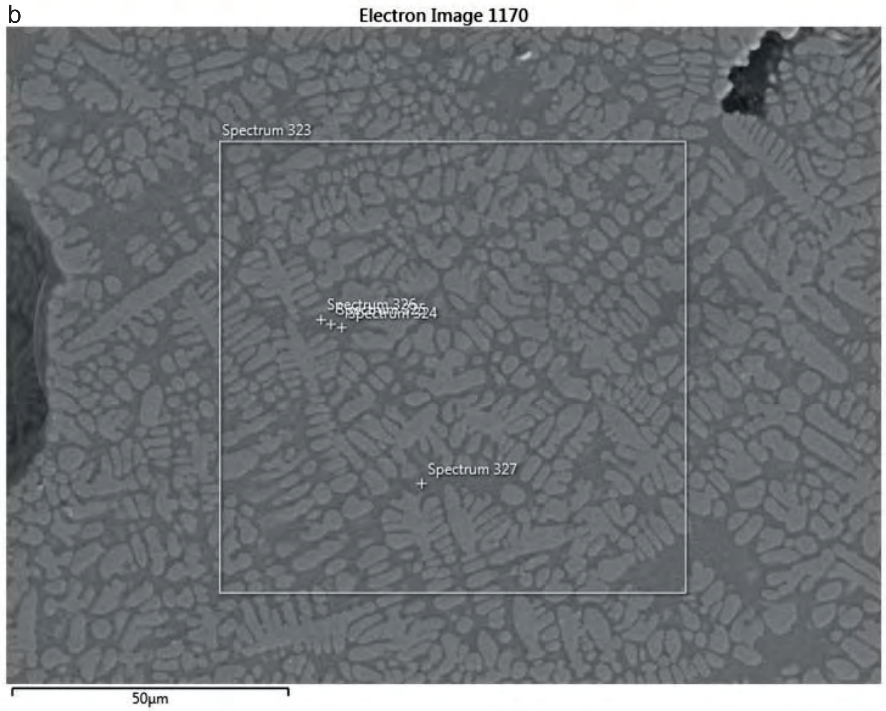
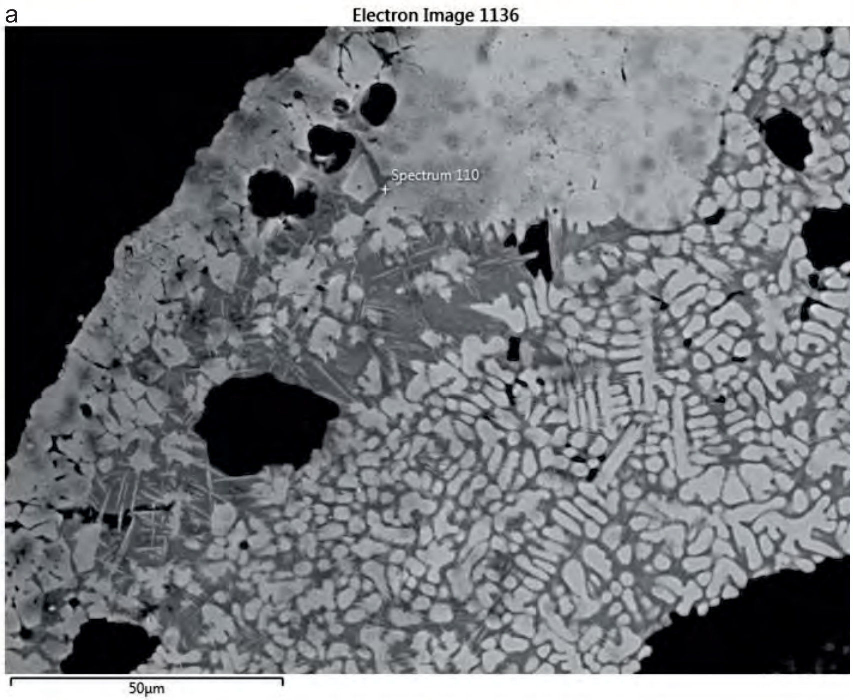


Plate A22: Sample HGA2, particle #S10
a. Site 1135, electron image 1134, backscattered electron image.
b. Site 11710, electron image 1170, secondary electron image.

a



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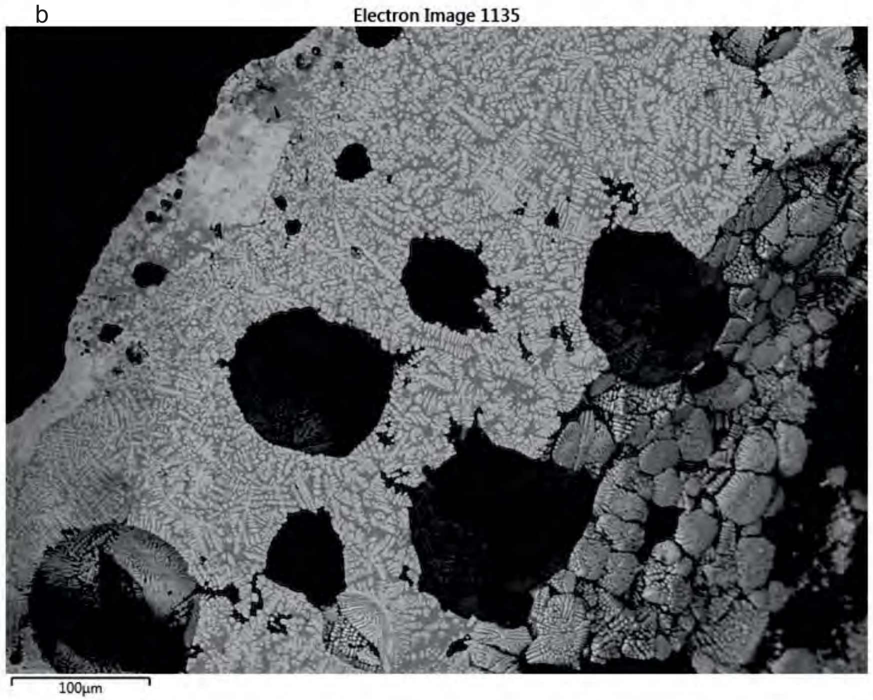


Plate A23: Sample HGA2, particle #S11
a. Site 1137, electron image 1136, backscattered electron image.
b. Site 1136, electron image 1135, backscattered electron image.

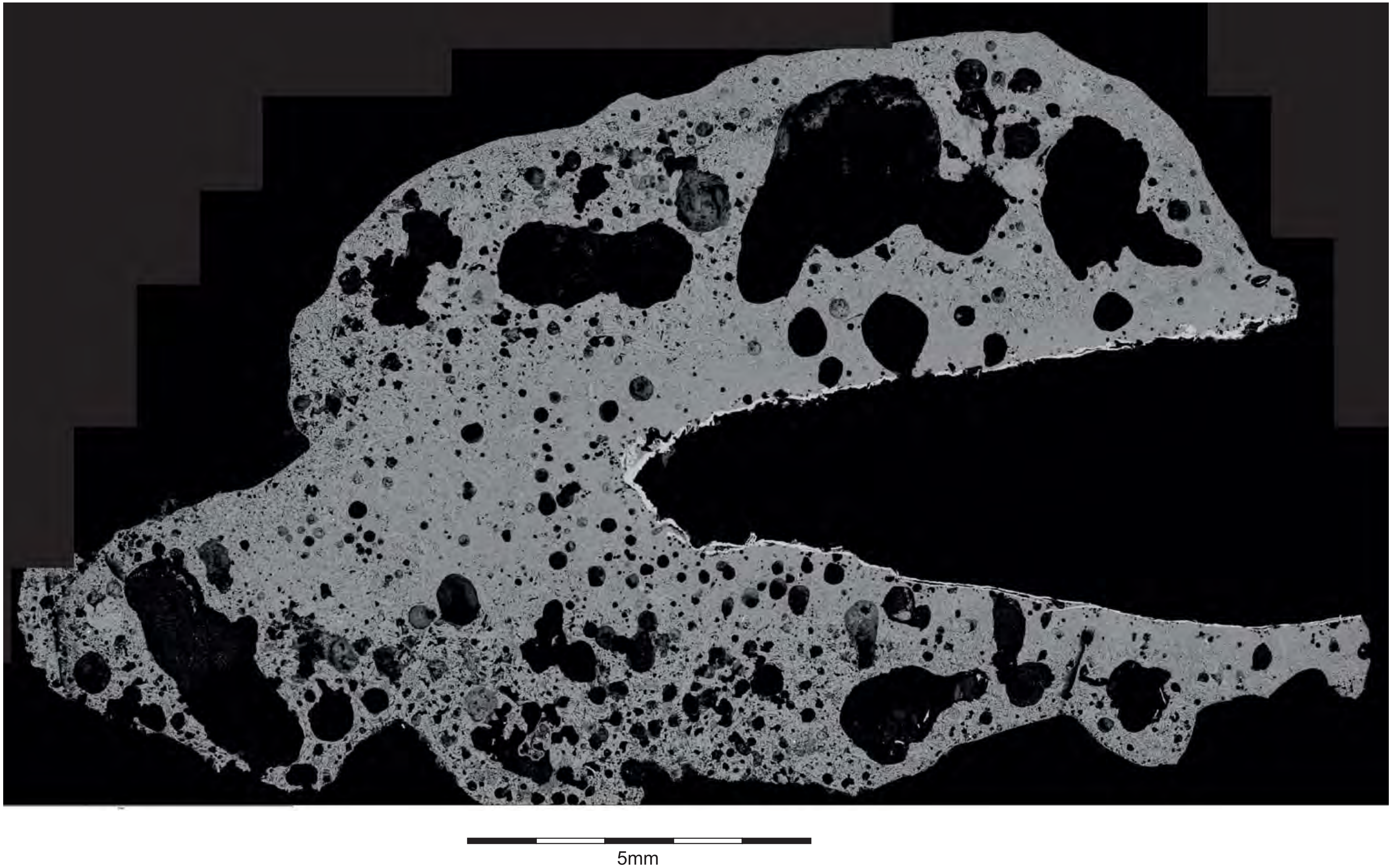


Plate A24: Sample HGA3, Slag film. Backscattered electron image montages of mount

Plate A25

Plate A25: Sample HGA3
a. Site 1130, electron image 1137, backscattered electron image.
b. Site 1130, electron image 1156, secondary electron image.
c. Site 1131, electron image 1138, backscattered electron image.
d. Site 1131, electron image 1157, secondary electron image.

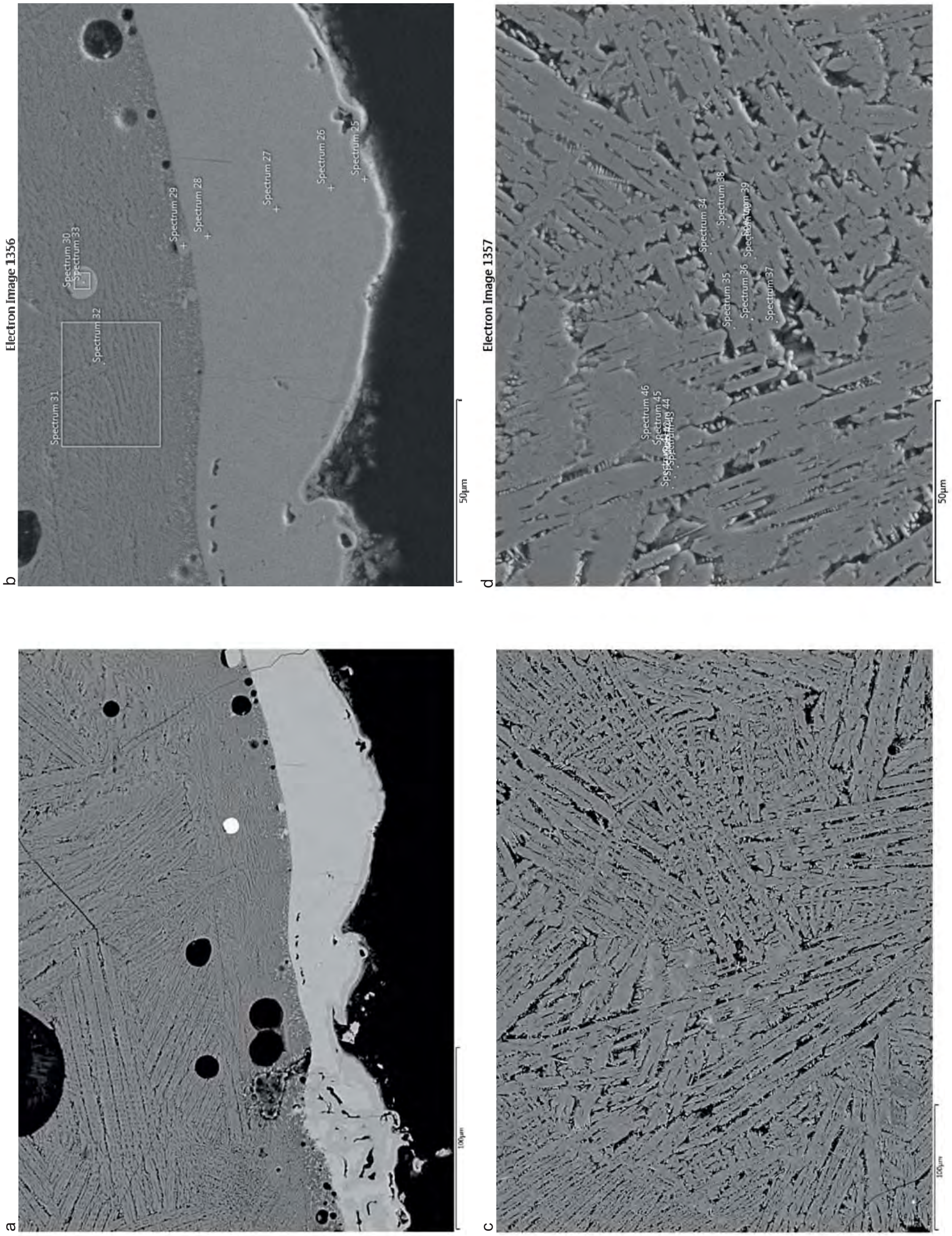
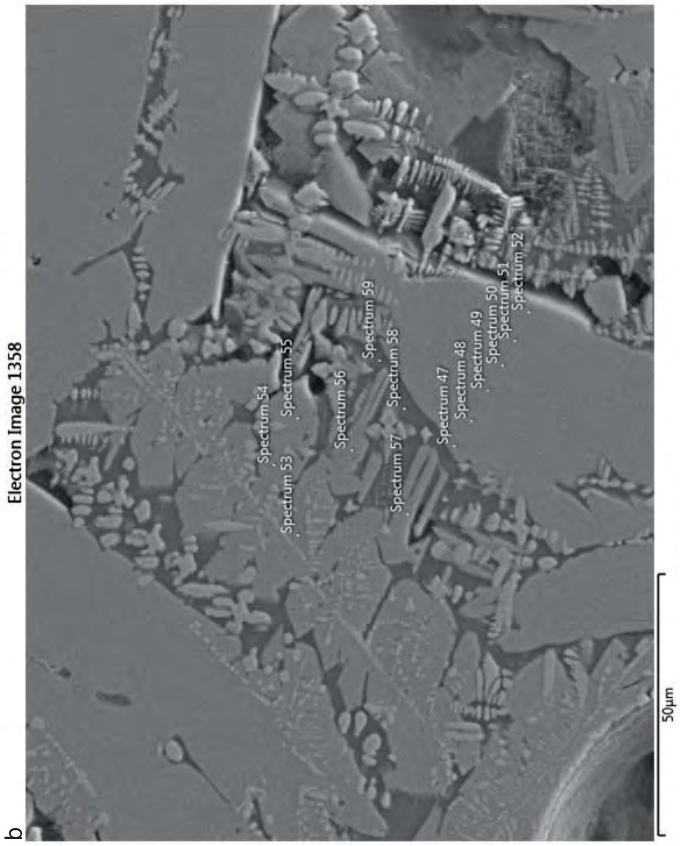


Plate A26

Plate A26 Sample HGA3
a. Site 1132, electron image 1139, backscattered electron image.
b. Site 1132, electron image 1158, secondary electron image.
c. Site 1133, electron image 1140, backscattered electron image.
d. Site 1133, electron image 1159, secondary electron image.

b



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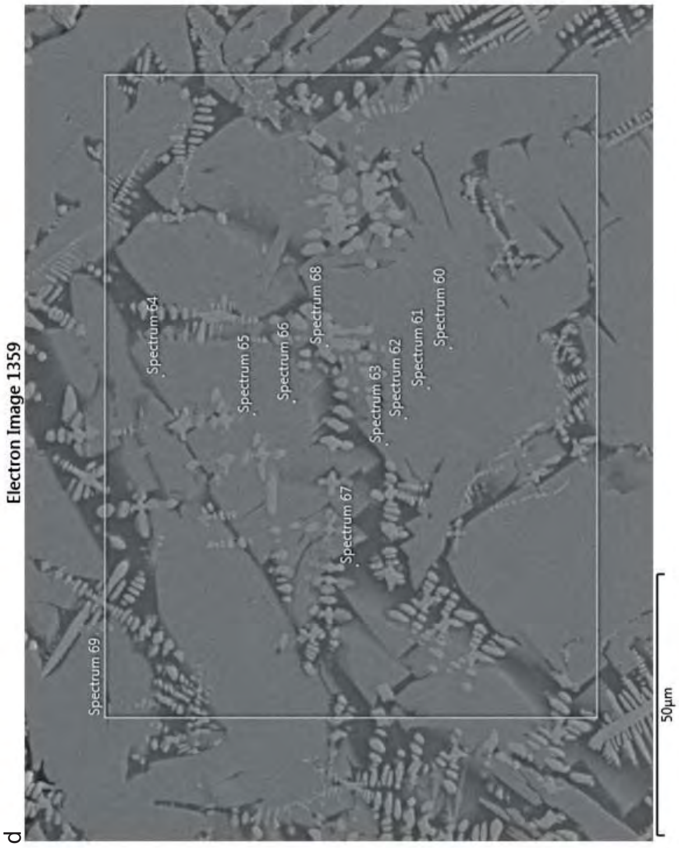

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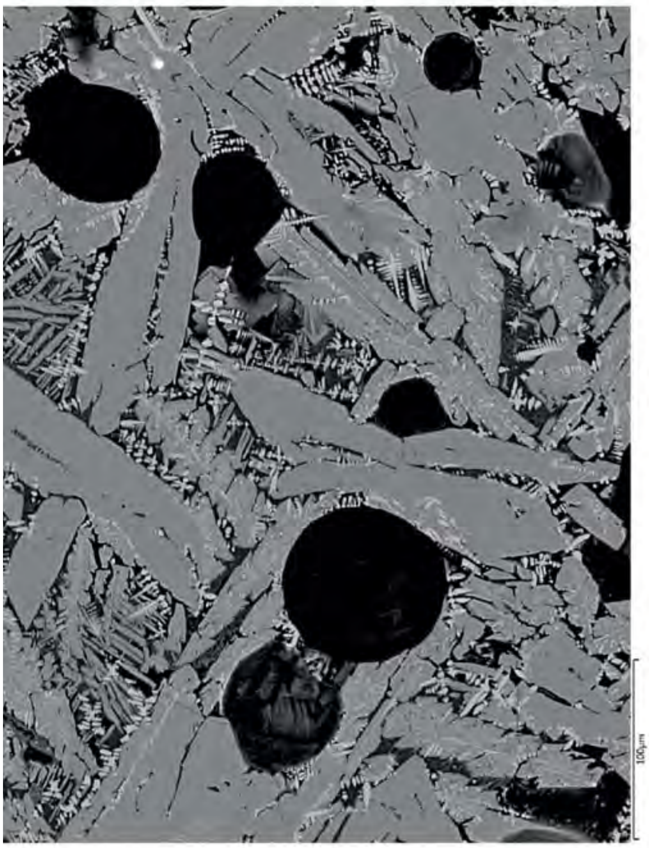

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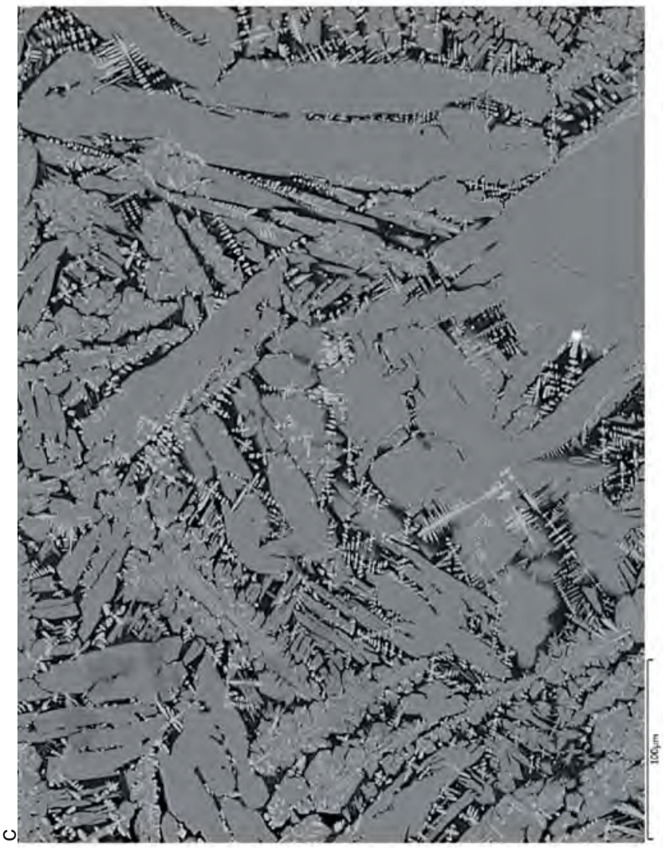
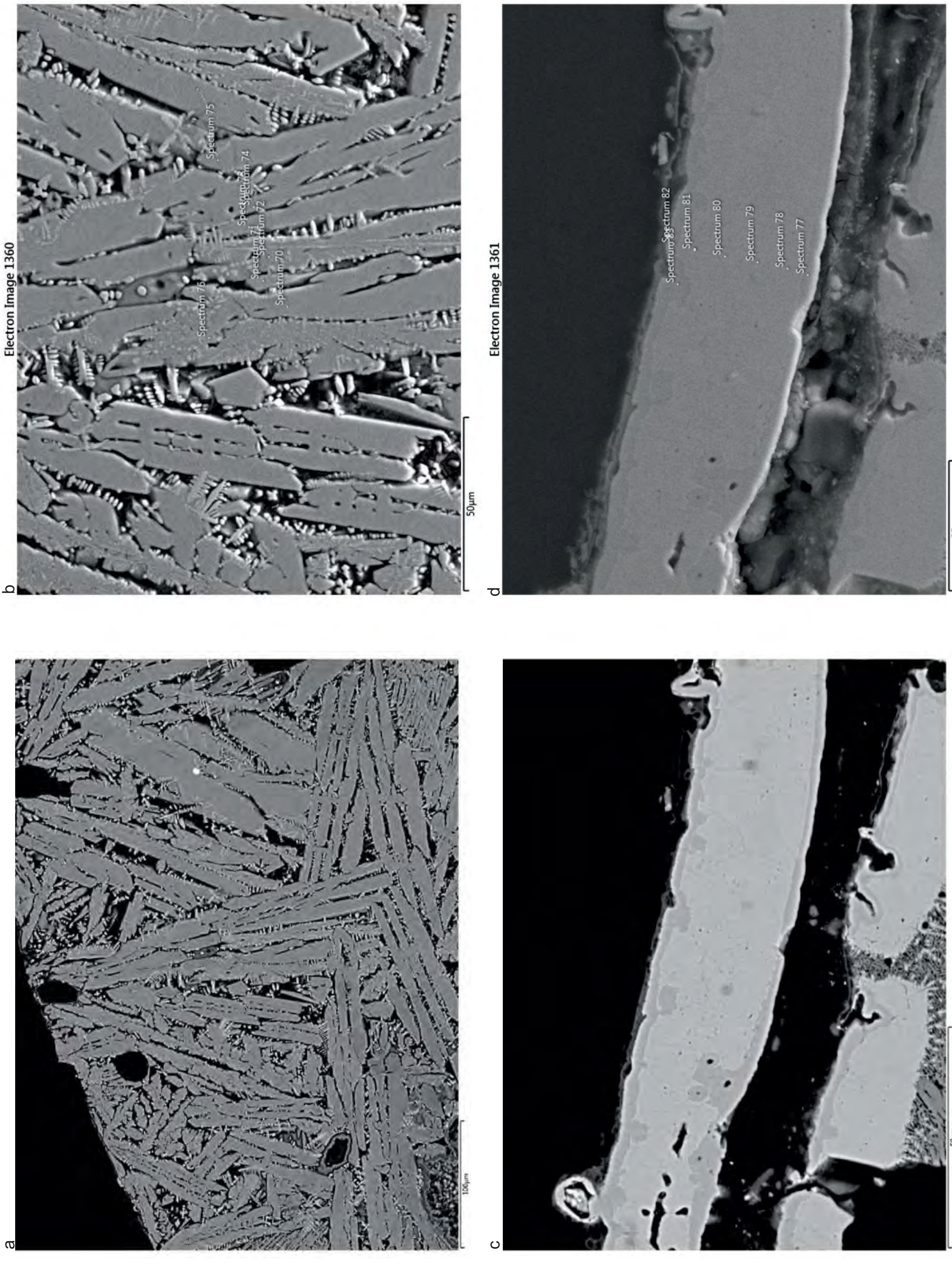


Plate A27

Plate A27 Sample HGA3
a. Site 1134, electron image 1141, backscattered electron image.
b. Site 1134, electron image 1160, secondary electron image.
c. Site 1135, electron image 1142, backscattered electron image.
d. Site 1135, electron image 1161, secondary electron image.



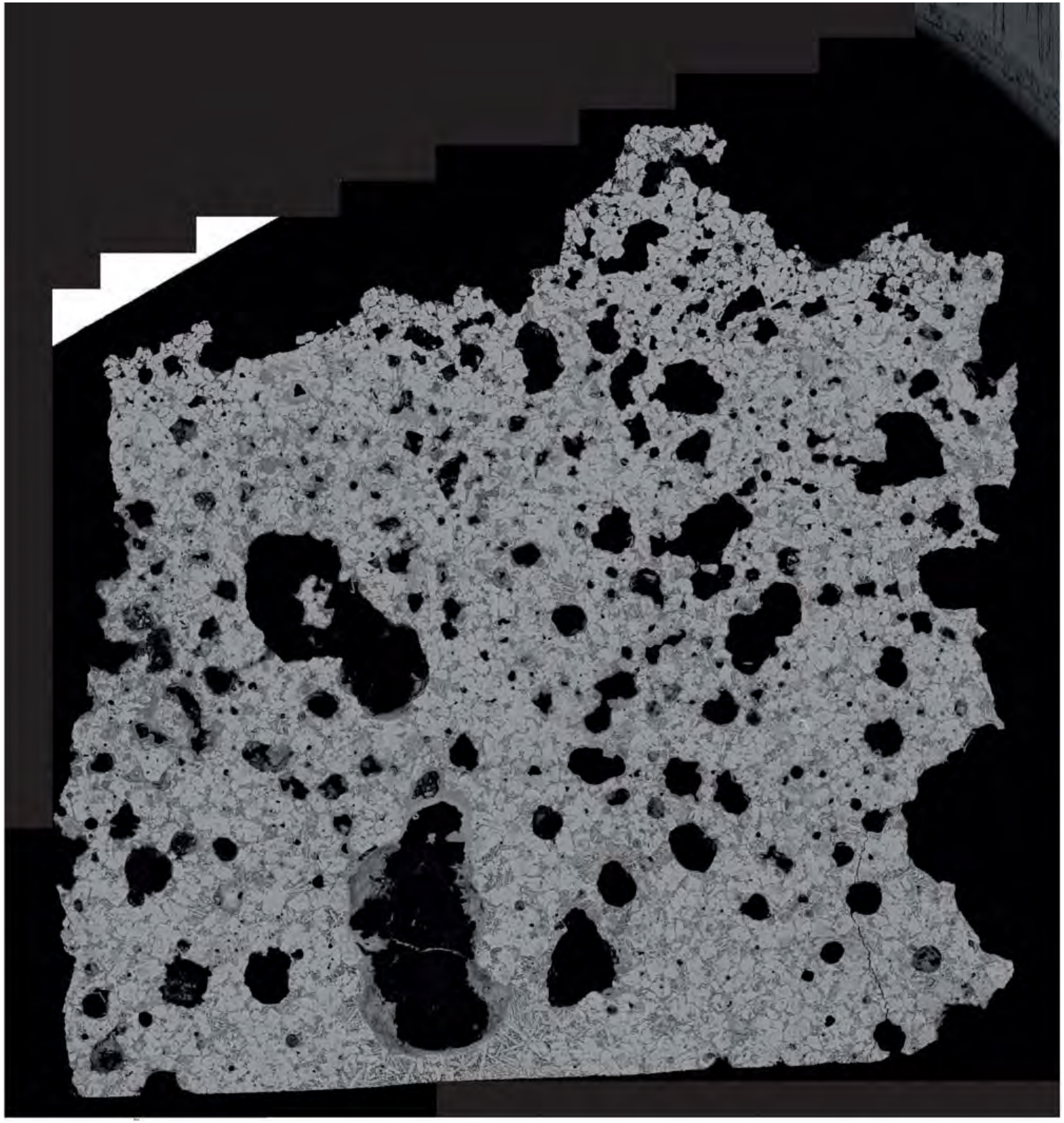


Plate A28: Sample HGA5, smithing hearth cake. Backscattered electron image montage of mount

5mm

Plate A29

Plate A29: Sample HGA5
a. Site 1336, electron image 1143, backscattered electron image.
b. Site 1336, electron image 1362, secondary electron image.
c. Site 1337, electron image 1144, backscattered electron image.
d. Site 1337, electron image 1155, secondary electron image.

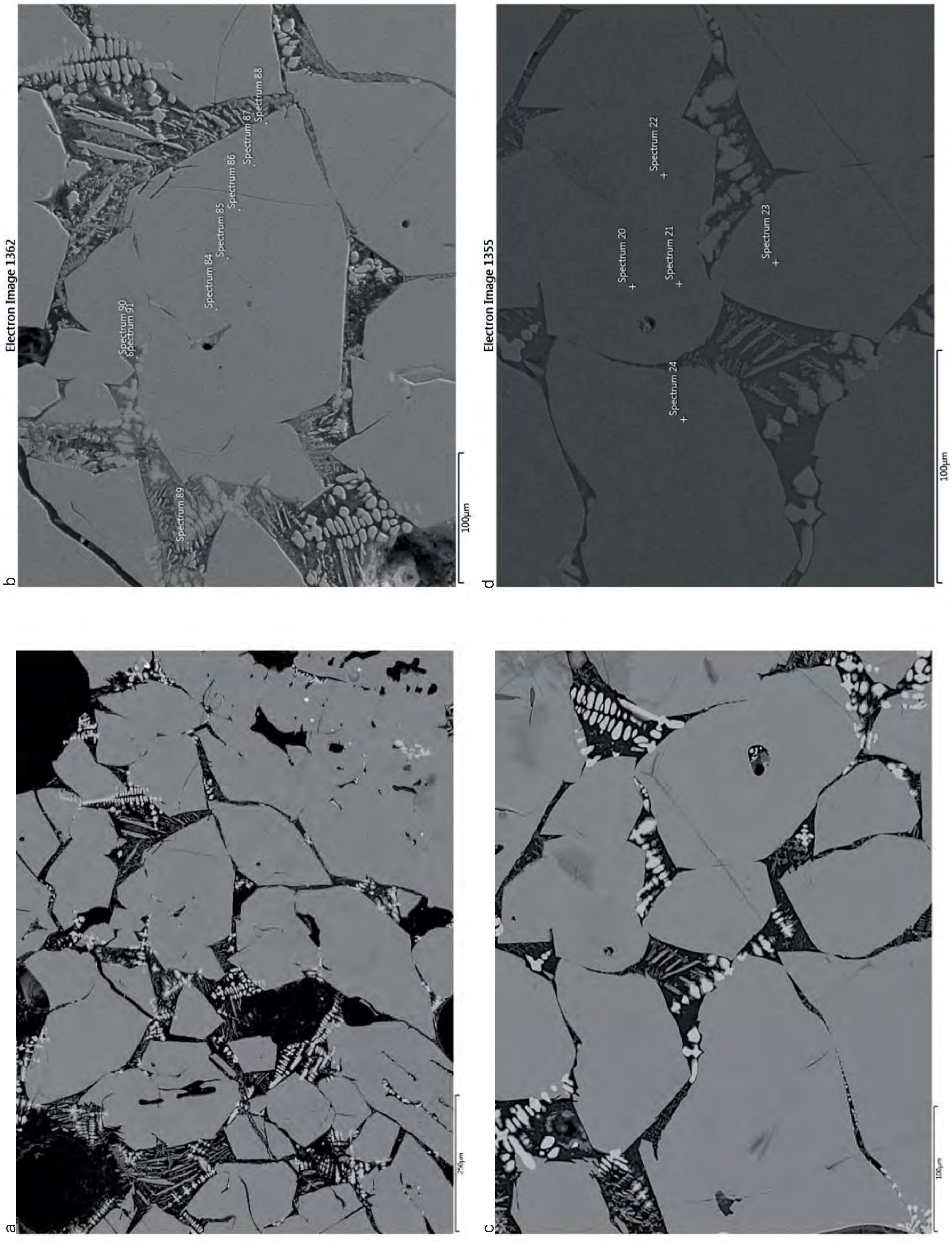
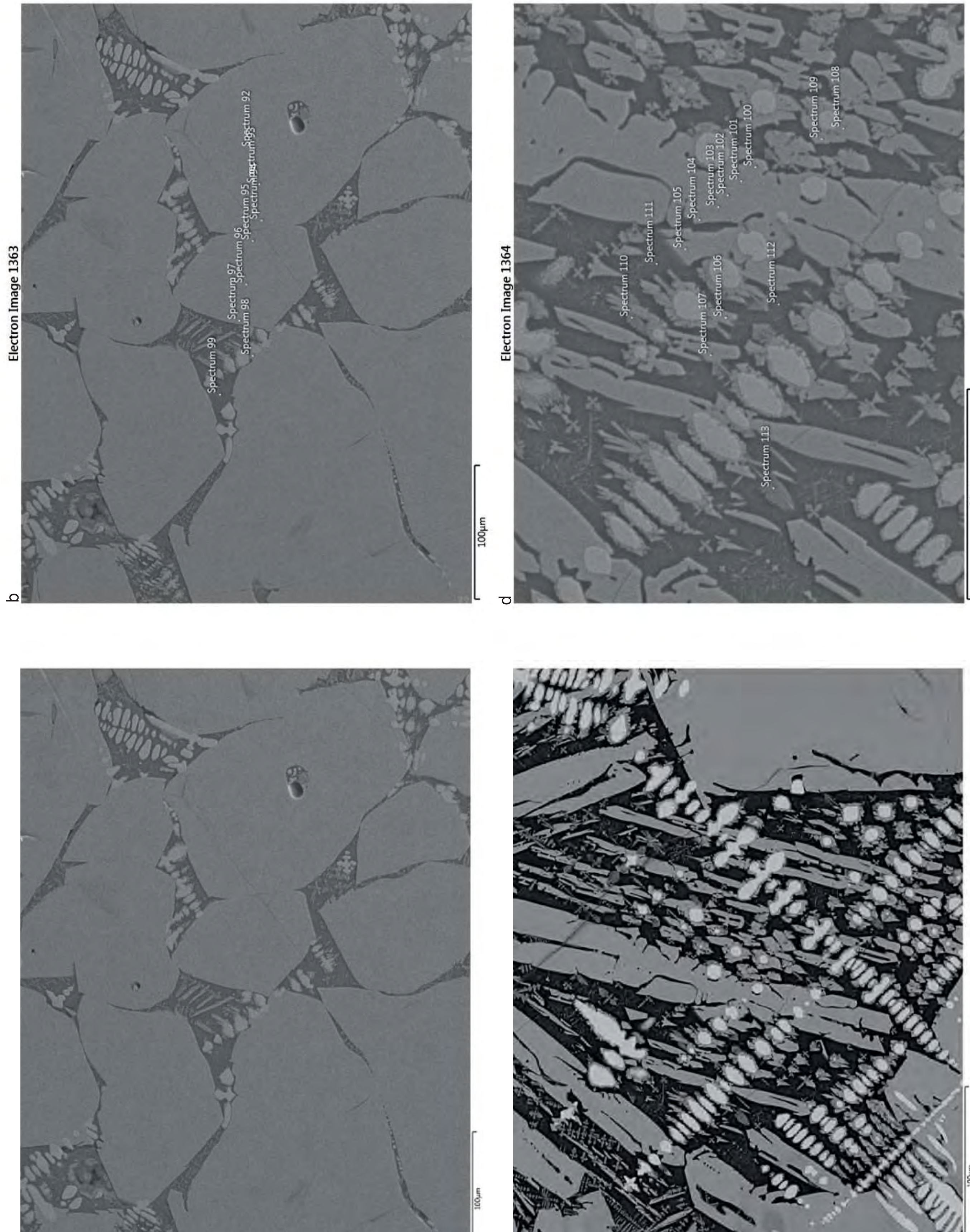
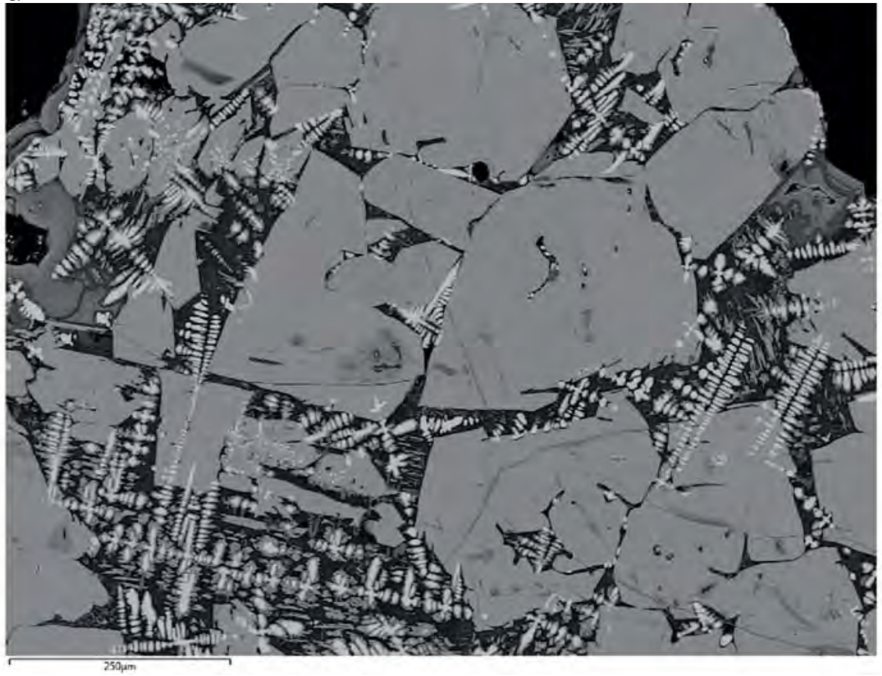


Plate A30

Plate A30 Sample HGA5
a. Site 1337b, electron image 1145, backscattered electron image.
b. Site 1337b, electron image 1363, secondary electron image.
c. Site 1338, electron image 1146, backscattered electron image.
d. Site 1338, electron image 1364, secondary electron image.



a



b

Plate A31 Sample HGA5
a. Site 1339, electron image 1147, backscattered electron image.
b. Site 1339, electron image 1365, secondary electron image.

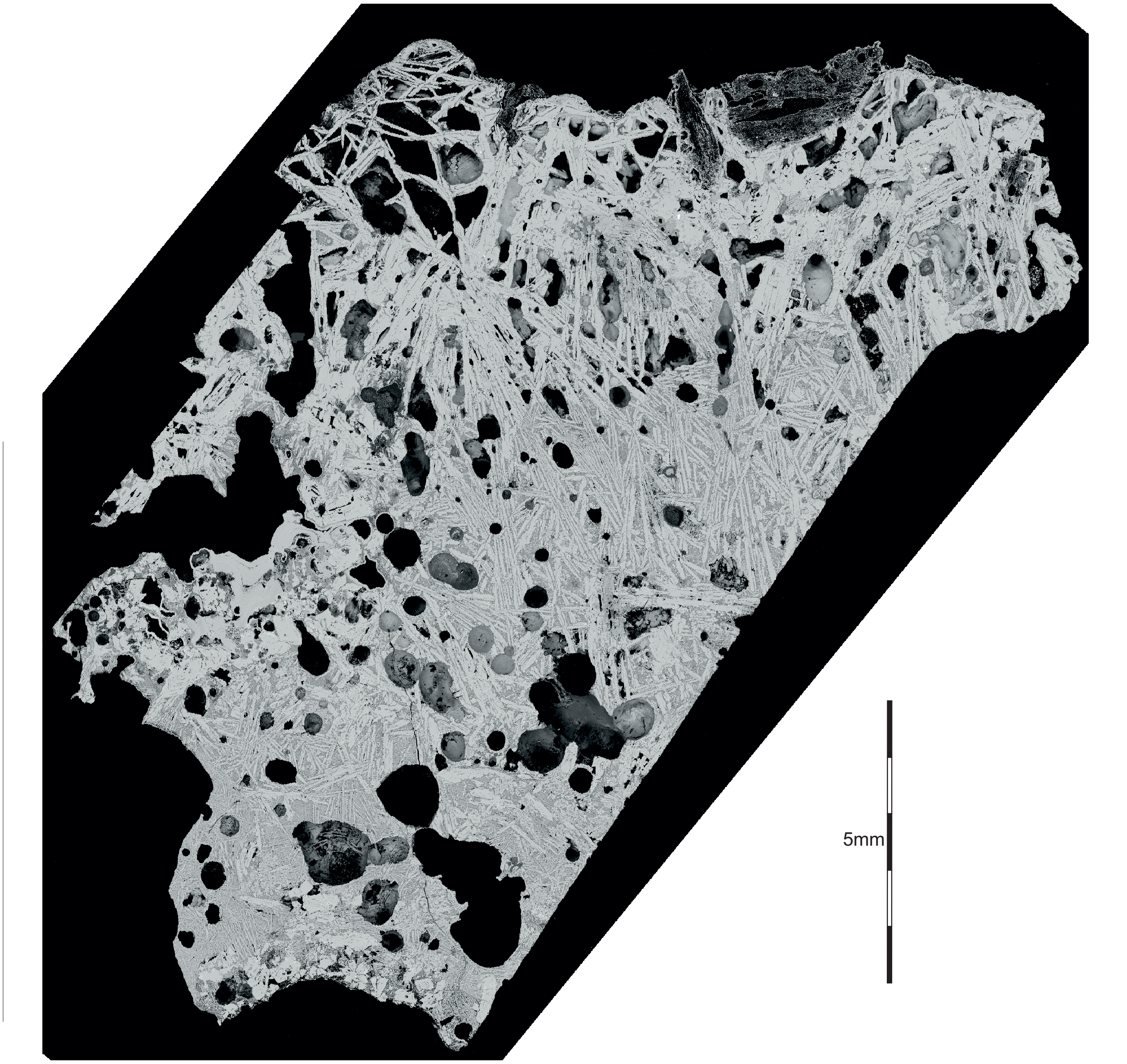
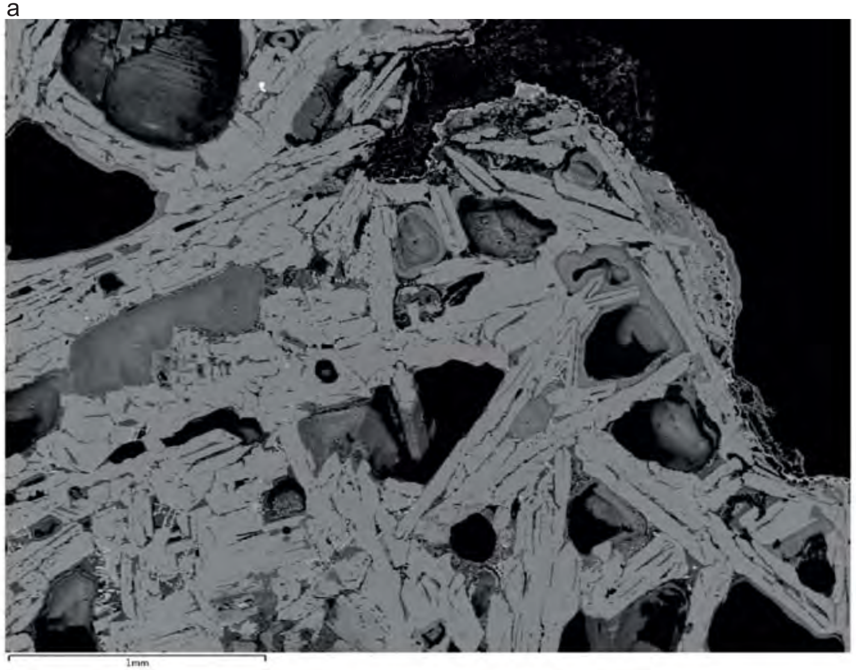


Plate A32: Sample HGA6, smithing hearth cake. Backscattered electron image montage of mount

a



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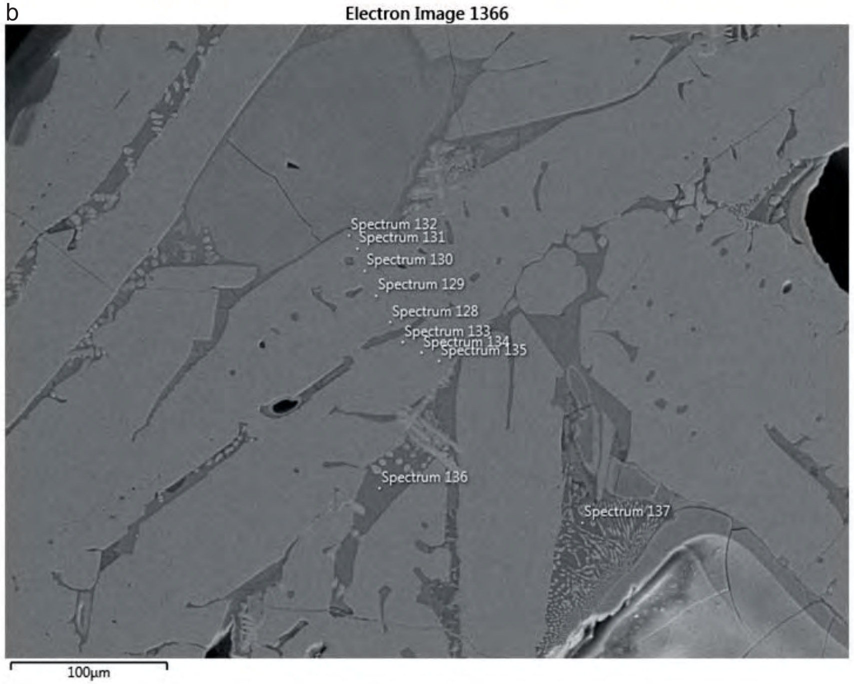

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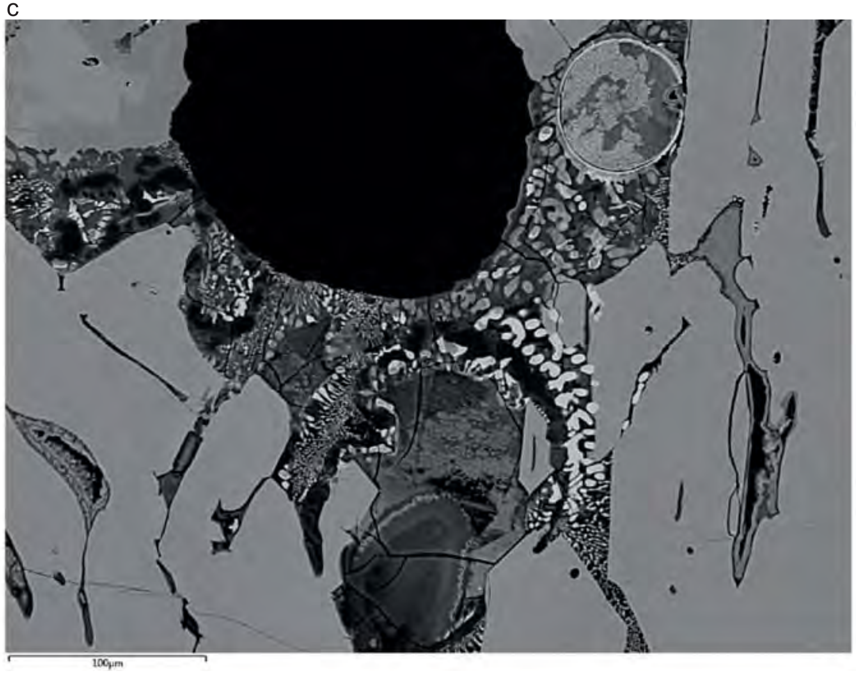
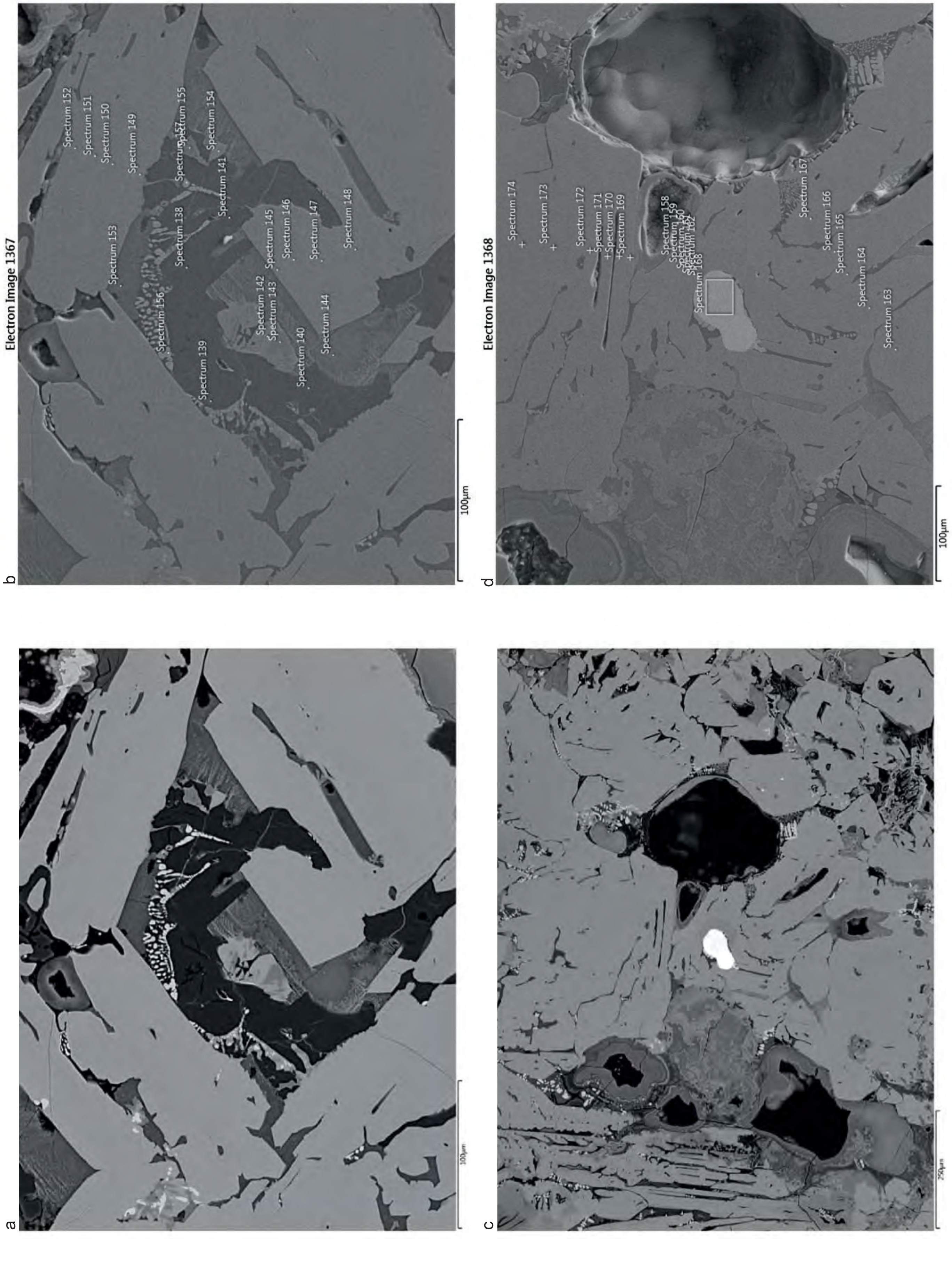


Plate A33 Sample HGA6
a. Site 1340, electron image 1342, backscattered electron image.
b. Site 1340, electron image 1366, secondary electron image.
c. Site 1341, electron image 1343, backscattered electron image.

Plate A34

Plate A34 Sample HGA6
a. Site 1342, electron image 1344, backscattered electron image.
b. Site 1342, electron image 1367, secondary electron image.
c. Site 1343, electron image 1345, backscattered electron image.
d. Site 1343, electron image 1368, secondary electron image.



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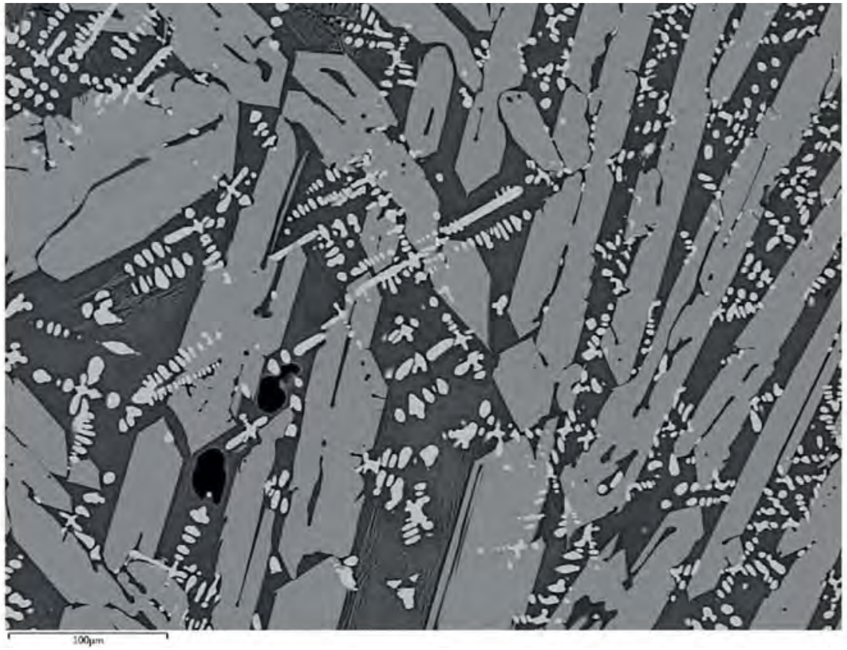

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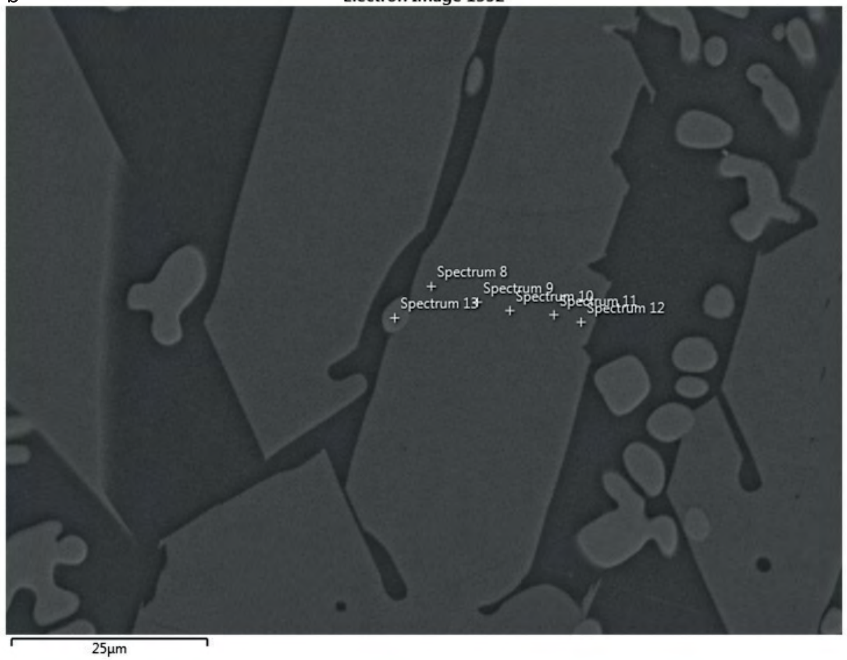

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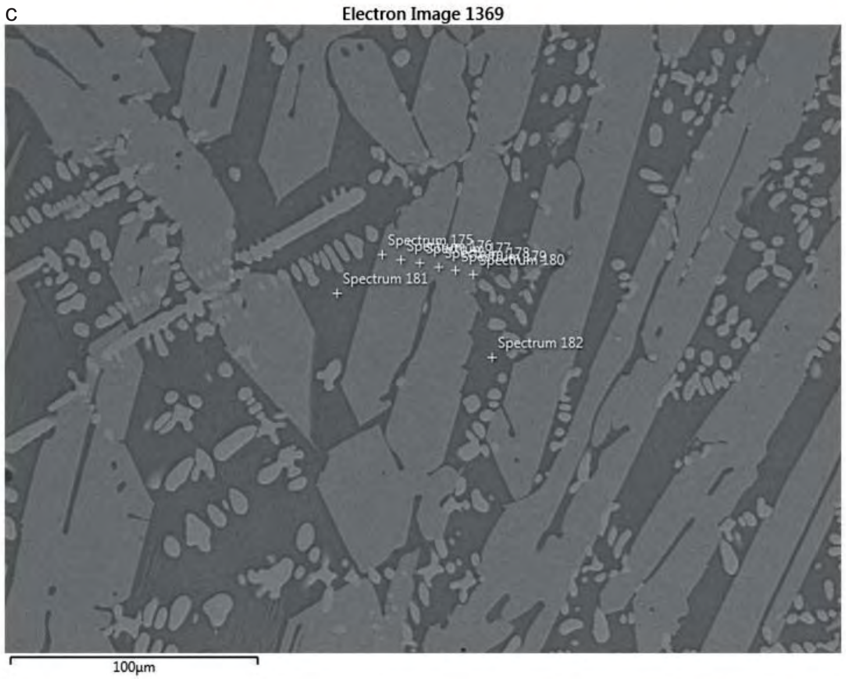
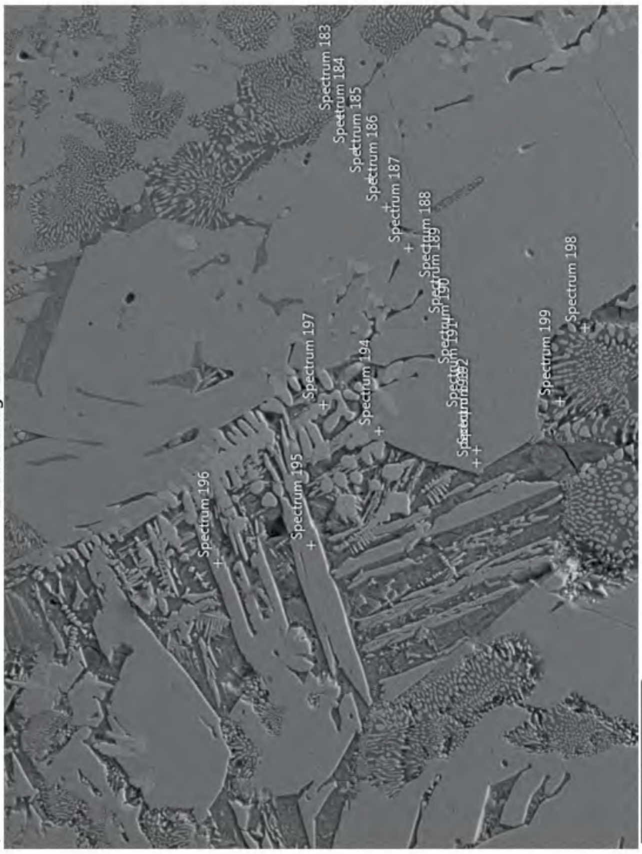


Plate A35 Sample HGA6
a. Site 1344, electron image 1346, backscattered electron image.
b. Site 1344, electron image 1152, secondary electron image.
c. Site 1344b, electron image 1369, secondary electron image.

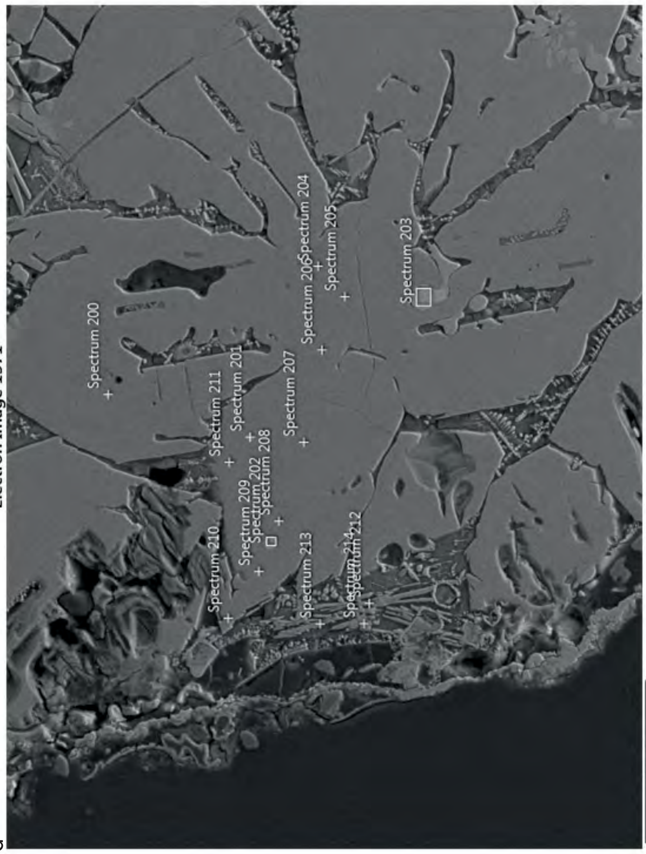
Plate A36

Plate A36 Sample HGA6
a. Site 1345, electron image 1347, backscattered electron image.
b. Site 1345, electron image 1370, secondary electron image.
c. Site 1346, electron image 1348, backscattered electron image.
d. Site 1346, electron image 1371, secondary electron image.

b



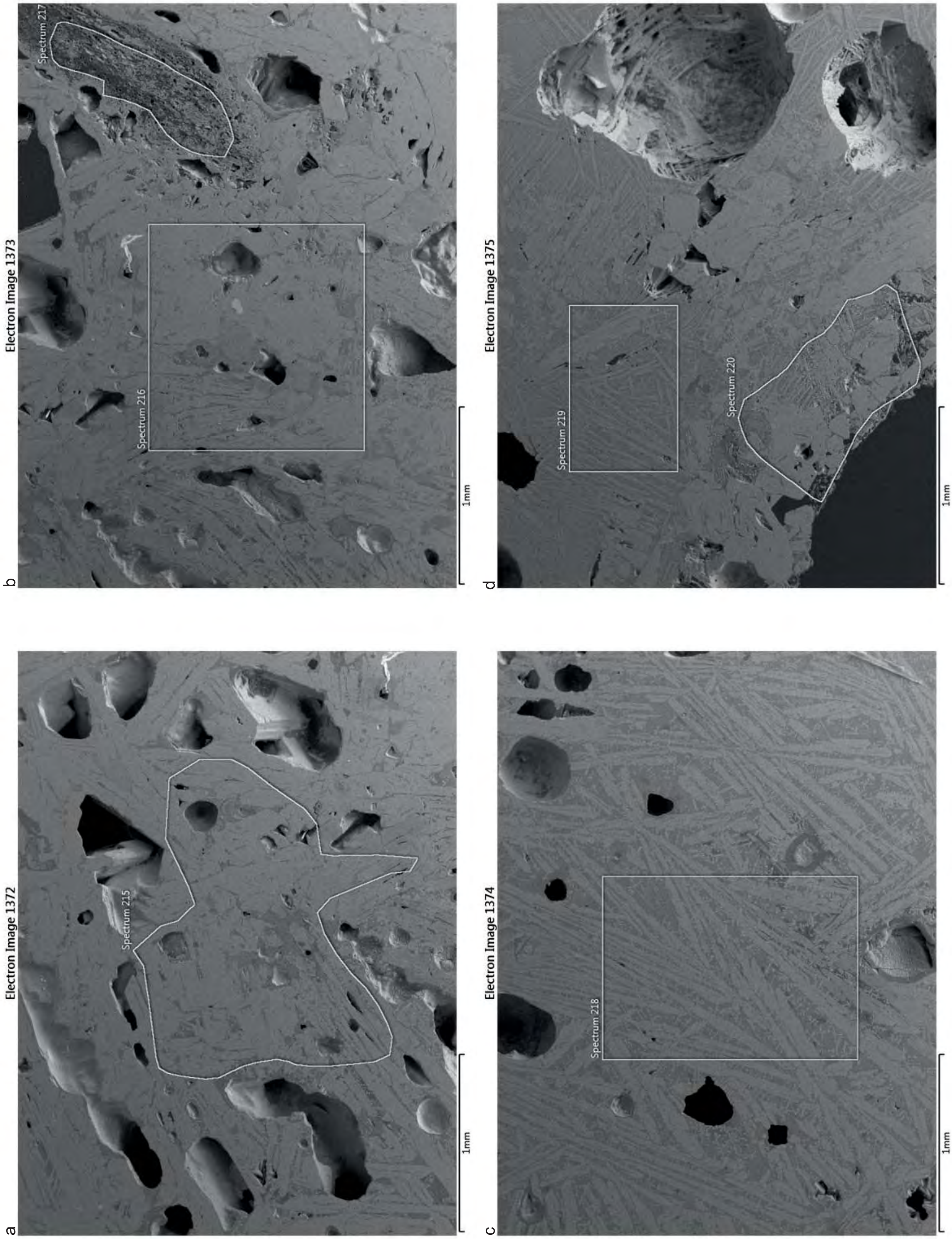
d



a

c

Plate A37 Sample HGA6
a. Site 1350, electron image 1372, secondary electron image.
b. Site 1355, electron image 1373, secondary electron image.
c. Site 1356, electron image 1374, secondary electron image.
d. Site 1357, electron image 1375, secondary electron image.



19. APPENDIX X: Lithics

G. H. Smith, Gwynedd Archaeological Trust

Non-flaked stone
SF146 Rubbing stone fragment
Sub-rounded fragment of very coarse gritstone with predominantly large quartz crystals, rather than a conglomerate.

Two faces at approximately 45° to each other have been worn flat with a slight polish. This wear even includes wear of quartz crystals. That could not have happened by any natural wear processes. The broken edges of the object are somewhat rounded rather than angular suggesting that it was broken by burning rather than just shattered. As both faces appear to be flat rather than curving it seems likely to be part of a rubbing stone that has been used on two faces rather than part of a saddle or rotary quern. Gritstone is used for querns and rubbers on Anglesey Iron Age sites, although a conglomerate rock is more common.

SF147 Natural piece
Concreted quartz-rich fine sand probably from a fossil beach, with preserved marine worm burrow. Not a local material. Similar pieces of material are found off Morfa Conwy when ancient intertidal deposits are exposed so this may have been brought to the site from elsewhere as a curiosity.

Flaked stone
Measurements in mm along and perpendicular to the striking platform for a flake or max length/breadth/depth for other pieces. () indicates incomplete (broken) dimension.

SF14 Flake
Yellow-brown pebble flint.
Small, thick, secondary, core-trimming flake. Probably punch-struck. 32 x 13 x 7.
There is a small area of steep secondary retouch close to the butt and later than the flake itself so is possibly just trample damage. A slight overall gloss suggests the piece has been exposed on the surface for a considerable time in the past. Probably Later Mesolithic or Early Neolithic.

SF36 Retouched flake fragment
Light grey flint. (17) x (28) x 6.
Mid-fragment of a broad flake with shallow secondary retouch on one sharp side edge. Undatable.

SF44 Natural piece
Light grey flint.
Accidentally broken fragment from a natural, angular ice-fractured (glacial) piece.

SF53 Utilised blade
Mottled light grey/mid-grey flint. 31 x 15 x 4.
Thin blade with butt removed by notching and snapping.
Utilisation is suggested by unifacial microchipping along one slightly concave sharp side edge. Notch and snap is a Mesolithic technique for production of microlithic points from blades.

SF54 Natural piece
Mid-grey flint.
Small fragment of accidentally broken glacial gravel.

SF67 Natural fragments
Five natural fragments of shattered and rolled glacial gravel.

General Comment
SF14, 36 and 53 could be associated and suggest a minor presence of Mesolithic or Neolithic activity here. A briefly used flint knapping or camp site would be appropriate for the location on a knoll overlooking a stream.

20. APPENDIX XI: Assessment of Post-Medieval Ceramics and Clay Tobacco Pipes

Jonathan Goodwin, Stoke-on-Trent Archaeology Service

Introduction
Stoke-on-Trent Archaeology Service was appointed by Gwynedd Archaeological Trust in April 2015 to undertake the assessment of a small assemblage of post-medieval pottery and clay tobacco pipe fragments recovered from excavations at Hen Gastell, Llanwnda, Gwynedd (SH 4713 5737).

Methodology
The small assemblage comprises 28 ceramic vessel sherds and eight clay tobacco pipe fragments. The majority of the finds (c.72%) were recovered from plough-soil layer (2002), supplemented by material from stakehole (004), the fill (2075) of a possible metal-working pit [2076], and an unstratified group. Most of the finds date to the 18th or 19th centuries, with a small number of earlier items, one of which (a single sherd from 2002) could be of late-medieval/ early post-medieval date (15th -16th century?).

The production of a basic catalogue of this material represents an appropriate level of recording. The assemblage is small and largely composed of finds recovered during the cleaning of plough-soil layer (2002). The ceramic catalogue in Table XI.1 provides details of ware/fabric types, vessel forms, decoration, completeness, quantity (by sherd count) and probable date. A similar methodology was applied to the clay tobacco pipes, which are listed in Table XI.2.

Further analysis of the material is unlikely to yield any further, significant information and, as such, is not considered necessary in this instance.

Acknowledgements
This report was written by Jonathan Goodwin of Stoke-on-Trent Archaeology Service. Thanks are due to Jane Kenney of Gwynedd Archaeological Trust.

References
Hemmingway, J. 1826. Chester Election, 1826. The Complete Poll Book. Chester: John Fletcher.
Oswald, A. 1975. *Clay Pipes for the Archaeologist*. British Archaeological Reports 14. Rutter, J.A. 1986. 'Chester's Clay Tobacco Pipes', *West Midlands Pottery Research Group Newsletter* ***7***.

Table XI.1. Ceramic vessel sherds from Hen Gastell
***Key:** **UGTP** – Under-Glaze Transfer Printed; **UGP** – Under-Glaze Painted; **UGSLD** – Under-Glaze Slip Decorated*

Context	Finds no	Ware/ fabric description	surface dec	dec in/on body	glazed	vessel form/ desc	Base	Body	rim/edge	spout	handle	profile	no. shds	Date	Notes
004	16	coarse e'ware			y	hollow ware		*					1	C19	Hard, fine orange/red fabric; iron-rich glaze on interior and exterior (partial) surfaces.
2002	56	iron-rich e'ware			n	hollow ware		*					1	late medieval?	Hard, fine orange fabric; occasional ill-sorted white sub- rounded inclusions; rare burnt-out organic(?) inclusions.
		slipware	trailed slip		y	hollow ware		*					1	late C17-early C18	Brown slip over fine buff fabric; lead glaze.
		slipware	trailed slip		y	press-moulded dish	*						1	late C17-early C18	Cream and brown slip over fine orange fabric; lead glaze on upper surface.
		coarse e'ware			y	pan		*					1	C18/C19	Hard, fine red fabric; iron-rich glaze on interior and partial exterior.
		coarse e'ware			y	pan		*					1	C18/C19	Hard, fine red/orange fabric; patches of iron-rich glaze survive on interior and exterior; abraded.
		coarse e'ware			y	jar?		*					1	C19	Hard, fine red/orange fabric with oc-casional ill-sorted, sub- rounded white inclusions (clay pellets?); iron-rich glaze on interior and exterior surfaces - possible traces of slip coat beneath.
		coarse e'ware			y	jar?		*					1	C18/C19	Hard, fine red/purple fabric with white/ cream laminae and occasional, ill-sort-ed, sub- rounded white inclusions; one large stone inclusion; iron-rich glaze on interior and exterior surfaces.
2002 (cont.)	56 (cont.)	coarse e'ware			y	jar?		*					1	C18/C19	Hard, fine red/purple fabric with oc-casional, ill-sorted, sub- rounded white inclusions; iron- rich glaze on interior and exterior surfaces.

Context	Finds no	Ware/ fabric description	surface dec	dec in/on body	glazed	vessel form/ desc	Base	Body	rim/edge	spout	handle	profile	no. shds	Date	Notes
		coarse e'ware			y	jar?		*					1	C18/C19	Hard, fine red fabric with rare, ill-sorted, sub-rounded white inclusions; iron-rich glaze on exterior surface, slightly reduced on interior.
		coarse e'ware			y	jar?		*					1	C19	Hard, fine red/purple fabric; iron-rich glaze on interior and exterior surfaces.
		coarse e'ware			y	jar/jug					*		1	C19	Hard, fine red/orange fabric; iron-rich glaze on interior and exterior surfaces.
		coarse e'ware			y	cylindrical mug?	*						1	C19	Hard, fine red/orange fabric with rare, ill-sorted, sub- angular black inclusions (iron- ore?); iron-rich glaze on interior and exterior surfaces; possible slip coat on exterior at least.
		coarse e'ware			y	hollow ware		*					1	C19	Hard, fine red/orange fabric; iron-rich glaze on interior and exterior surfaces.
		coarse e'ware			y	small hollow-ware – bowl?			*				1	C19	Hard, fine red/orange fabric; iron-rich glaze on interior and exterior surfaces.
		coarse e'ware			y	small hollow ware		*					1	C19	Hard, fine red fabric; iron-rich glaze on interior and exterior surfaces – pitted on exterior.
2002 (cont.)	56 (cont.)	tin-glazed e'ware			y	plate	*						1	late C18	
		creamware?			y	bowl			*				1	early C19	
		pearlware			y	plate	*						1	c.1820s/30s	
		pearlware	UGTP - blue		y	saucer		*					1	1st half C19	
		pearlware/ white e'ware	UGTP - blue		y	saucer			*				1	mid C19	Unknown print with coral/seaweed motif.

Context	Finds no	Ware/ fabric description	surface dec	dec in/on body	glazed	vessel form/ desc	Base	Body	rim/edge	spout	handle	profile	no. shds	Date	Notes
		pearlware/ white e'ware	UGTP - blue		y	saucer			*				1	mid C19	Same print and form as above, but probably not part of the same vessel.
		white e'ware	UGTP - black		y	plate			*				1	mid C19	
		pearlware	UGP - blue		y	cup/bowl		*					1	early C19	
		pearlware	UG-SLD?	turned	y	cylindrical mug							1	c.1820s/30s	Base/lower body of vessel; possible hint of blue slip within turned band.
		white e'ware			y	jug?	*						1	late C19	
		white e'ware			y	hollow ware		*					1	mid-late C19	
		bone china	UGTP - blue		y	cup			*				1	early-mid C19	'Two Temples' pattern.
2002 (cont.)	56 (cont.)	porcelaneous fabric?			y	hollow ware		*					1	late C19?	Dense, highly fired fabric with tight-fitting glaze on interior and exterior surfaces; somewhat reminiscent of porcelain or china, but is not translucent; exterior glaze is slightly reduced which could indicate an over-fired white e'ware.
2075	41	blackware			y	cup		*					1	late C17-early C18	Hard-fired, fine purple fabric with iron-rich glaze on interior and exterior surfaces.
							Total						**28**		

Table XI.2. Catalogue of clay tobacco pipes from Hen Gastell

context	finds no.	decor-tion/mark	stem	bowl	profile	total no. fragments	date	notes
004	16	Worn impressed mark comprising a shield with a design of three wheat sheaves and a sword; 'CHESTER' features beneath.	*			1	1710+	This design first appears on tobacco pipes produced in Chester during the period 1710-40 (Rutter 1986, 21).
u/s	24			*		1	late C18/early 19?	
				*		1	late C18/early C19?	
			*			4	C18/C19?	
		Impressed mark – 'AIRES CHESTER'	*			1	late C18/early C19	The Aires family of pipe makers is recorded in Chester from the mid/late C18 until at least the early C19. Samuel Aires appears in 1767; his son, Thomas, was active between at least 1798 and 1826 (Oswald 1975, 162; Hemingway 1826, 98). A John Aires is also listed in c.1800 (Oswald 1975, 162).
			Total			**8**		

21. APPENDIX XII: A note on a sherd of medieval pottery

A note on a sherd of pottery from Hen Gastell, Llanwnda near Caernarfon - G2246 SF151 from context 2075

Julie Edwards, Chester West and Chester Historic Environment Team

A single abraded sherd (2g) of an earthenware with a reduced grey/black core and interior surface and an oxidised red/brown exterior (find no. 151). The exterior is abraded and it is not possible to determine whether the surface was once glazed. The sherd has no distinguishing characteristics that would indicate vessel form.

Context (2075) did not produce any evidence, other than the fragment of pottery, which would indicate a deposition date however it is part of a complex of pits related to a forge which radiocarbon analysis dates to 1021-1155 cal AD (pers comm Jane Kenney).

Discussion
The size and condition of this fragment limits any definite identification regarding ware-type, date or provenance. Its condition may also suggest that it is potentially residual to the context in which it was found. There is a lack of evidence for significant pottery use in the medieval period in North Wales before the thirteenth century therefore the association with deposits dated to the 11th and first part of the 12th century is potentially significant. The size and condition of the sherd however reduces the level of significance.

During the thirteenth and early fourteenth centuries red/grey fired earthenwares were produced at kiln sites in Cheshire and also at Rhuddlan, Denbighshire. They are relatively common finds in Cheshire and North Wales particularly on castle sites where they are linked to the campaigns of the English kings to extend their rule in Wales and the provisioning role of Chester at this time.

The fabric of this piece (see description below) is very similar to Fabric 179 in the Cheshire West and Chester Fabric Reference Collection, which is a sample of pottery associated with a dump of pottery production waste found in the Frodsham Street area, to the east of the walled city of Chester (Rutter 1990). There is also some similarity with the published description of fabric MA2, identified as being from the kiln site at Rhuddlan (Owen 1994, 192).

There is not enough evidence to link the sherd with either of these specific production sites and the associated radiocarbon date discounts those sites but the similarity of fabrics suggest that there may be a common clay source which in the Cheshire/North Wales area. A source outside that area cannot be excluded however.

It is recommended that the sherd is retained as part of the project archive to enable comparison with any material of contemporary date that may be found in the future.

Fabric description
Colour: dark brown/black core with black margins, a brownish red exterior surface and a black interior.

The fabric is soft with a rough feel and an irregular texture.

Inclusions:
Moderate ill-sorted fine-medium quartz grains varying in colour from grey to colourless that are largely sub-angular but with the sparse presence of rounded examples. Sparse very coarse (<2.5 mm) are also present.

Moderate-sparse ill-sorted red and black iron-rich inclusions fine to coarse in size (<0.75 mm).

Sparse angular - coarse (<1.5 mm) fine grained angular rock fragments black/grey in colour, these are potentially derived from igneous or metamorphic rocks.

Sparse coarse (0.75 mm) angular grey fine grained rock (flint/chert?).

Sparse coarse (0.5 mm) mica flakes.

Surface treatment: slight undulations are apparent on the interior (reduced) surface but it is unclear whether they represent wipe marks or throwing lines.

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22. APPENDIX XIII: Burnt stone petrology

Dr David Jenkins, freelance geological specialist, formerly of Bangor University

The fragmentary rock types within two deposits excavated at Hen Gastell have been examined. Sample 11 (comprising 2 sample buckets) is from context 2023, one of the burnt stone deposits overlying the inner bank, and sample 27 is from context 2070, the fill of post void in posthole [2068]. Information may thereby be obtained about the geographical provenance of the pebbles involved, and also about their selection and utilization: a summary of this analytical data is given in the attached table.

Provenance can be in terms of the geological terrain from which the pebbles were derived and of choice of properties for any specific usage that might have been involved. The assemblage of rock types shown in Table XIII.1, however, is seen to be dominated by fine-grained silicic igneous extrusive rocks – various rhyolites, some suggesting a glassy early stage, and in associated tuffs grading into sandstones. Such rock types are common in the Palaeozoic strata that form Snowdonia. Dolerites, dark mafic igneous intrusive rocks, are sometimes preferred in fires/furnaces for their thermal properties, but they are only sparsely present in the samples examined, although they are also present in Snowdonia. This suggests that, although limited, the range of pebble types available locally was adequate for requirements which were not apparently demanding.

In terms of practical usage, provenance also involves the nature of the source, in this case of rounded to sub-rounded pebbles. These sources are common locally in the form of the widespread glacial tills and fluvio-glacial deposits on the Arfon platform and in more recent derived river and sea-shore gravels. Subsequently, such pebbles have cracked within a fire to give the fragments defined by remnant convex surfaces and the rough cracked fracture surfaces often stained a dark red.

More generally, provenance can be revealed by distinctive "tracer" rock types. Two such tracers may be represented by firstly the angular fragments of a distinctive bright red porphyritic rhyolite found in two of the samples (27 and 11.1), their colour probably deriving from a geological process (such as metasomatism) rather than the darker localized red from a small scale fire. However, the source of this rock material has yet to be identified. Similarly, the rare pebbles of microgranite in one of the samples (11.2) are distinctive and could derive from local intrusions to the south-west.

This analysis suggests that the three pebble samples were derived from local sources such as river or beach deposits from the local solid geology. To develop the project any further would require more detailed petrographic analysis of thin–sections of the pebbles under a microscope and also field-work to identify specific sources of pebbles.

Table XIII.1: Properties of the three samples:

Sample no.	**27**	**11.1**	**11.2**
Context no.	2070	2023	2023
Weight of samples (kg)	7	12	10
Number of stones in sample	63	74	52
Size range max (cm)	16x7x6	102x36x4	13x9x6
min (cm)	4x3x1	3x2x1	4x3x1
Shape: rounded (attrition) pebble	1	-	-
rounded + fracture surfaces	25	21	17
fracture only (planar-conchoidal)	35	9	19
surface reddening	50%	45%	68%
on the curved/joint			
distinct/mod/weak - none	9/3/7 - 8	6/4/5 - 5	4/4/7 - 12
on the 19 fractured only			
distinct/mod/weak - none	8/3/2 – 23	5/9/11 - 29	4/6/4 - 11

Rock types identified: xx - common; x – occasional

Sample no.	**27**	**11.1**	**11.2**
Context no.	2070	2023	2023
Red porphyritic rhyolites * (NB included in counts)	x	x	-
Rhyolites and tuffs	xx	xx	xx
Microgranites	-	-	x
Dolerites	x	x	-
Sandstones and tuffs	xx	xx	x
Mudstones/phyllites	-	x	x

23. APPENDIX XIV: Radiocarbon dating

23.1. Report on Radiocarbon dating and Bayesian modelling

Derek Hamilton, Scottish Universities Environmental Research Centre, East Kilbride

A total of 14 samples of charred plant material (grain, nut shell, charcoal) were processed for radiocarbon dating from features excavated at the small enclosure site of Hen Gastell, Llanwnda, Wales. The samples were recovered from a range of features that included pits, postholes and post-pipes, and discrete burnt deposits containing large quantities of heat-affected stone. All the samples were short-lived single entities (Ashmore 1999), and were processed and dated at the Scottish Universities Environmental Research Centre, East Kilbride (SUERC). Samples were pretreated, combusted, graphitised, and measured by Accelerator Mass Spectrometry (AMS) as described by Dunbar et al. (2016). The SUERC radiocarbon laboratory maintains rigorous internal quality assurance procedures, and participation in international inter-comparisons (Scott 2003; Scott et al. 2010) indicate no laboratory offsets; thus validating the measurement precision quoted for the radiocarbon ages.

The results in Table XIV.2 are conventional radiocarbon ages (Stuiver and Polach 1977), quoted according to the international standard set at the Trondheim Convention (Stuiver and Kra 1986). The results have been calibrated with the internationally agreed IntCal13 atmospheric curve of Reimer et al. (2013), using OxCal v4.2 (Bronk Ramsey 1995; 1998; 2001; 2009). The date ranges in Table XIV.2 have been calculated using the maximum intercept method (Stuiver and Reimer 1986), and quoted with the endpoints rounded outward to 10 years. The probability distributions seen in Figure XIV.1.1 were obtained by the probability method (Stuiver and Reimer 1993).

The samples

From the evaluation trench (Trench 1) there are four dates from two stratigraphically related contexts. There are two results (SUERC-54223 and -54227) on samples of charred hazel nutshell and willow/poplar charcoal, respectively, that were in a deposit (21) of charred remains mixed into a buried soil. This soil was under the inner bank, and so is indicative of pre-bank activity on the site. The two results are not statistically consistent (T'=5.0; ν=1; T'(5%)=3.8; Ward and Wilson 1978), suggesting the material is not of a similar age and accumulated over an unknown period of time. The fill (17) of a slot cut into the inner bank returned two results (SUERC-54221 and -54222). These measurements are not statistically consistent (T'=7.2; ν=1; T'(5%)=3.8; Ward and Wilson 1978).

From Trench 2 there is another sequence of radiocarbon dates that bracket the construction of the inner bank. There are two results (SUERC-64228 and -64229) on a fragment of charred hazel nutshell and a charred cereal grain, respectively, from layer (2082) that contained burnt bone and charcoal and runs underneath the inner bank (2116) in this location. This layer (2082) sits above the buried soil (21) that was identified in Trench 1. The two results are statistically consistent (T'=0.0; ν=1; T'(5%)=3.8; Ward and Wilson 1978), and could be the same actual age. At some point the inner side of bank (2116) was cut and a deposit of burnt stone (2003) was laid down. From this there is a single date (SUERC-64221) on a charred cereal grain. A similar deposit (2023) of burnt stone formed on the inside of the enclosure where a different section of the inner bank (2118) had been truncated. There is a single result (SUERC-64222) on a fragment of charred hazel nutshell from (2023). While the two burnt deposits – (2003) and (2023) – are not demonstrably coeval, their composition and location suggests that they may be part of the same general activity. The two results are statistically consistent (T'=0.1; ν=1; T'(5%)=3.8; Ward and Wilson 1978), so that the two samples could be the same actual age.

There are four radiocarbon dates, all on single fragments of charred hazel nutshell, from the fills of two post-holes located within the interior of the enclosure. In both cases, there is samples from the material used to pack the post and a second sample submitted that was recovered from the fill of the post-pipe. From post-hole [2068], there is a date (SUERC-64226) from the packing deposit (2069) and a date (SUERC-64227) from the fill (2070) of the post-pipe. The two results are statistically consistent (T'=0.0; ν=1; T'(5%)=3.8; Ward and Wilson 1978) and could be the same actual age. Post-hole [2092] had a date (SUERC-64230) packing deposit (2093) and a date (SUERC-64231) from fill (2097) of the post-pipe [2096]. These two measurements are also statistically consistent (T'=0.4; ν=1; T'(5%)=3.8; Ward and Wilson 1978).

There are a final two dates from the base of pit [2078]. The first result (SUERC-64232) is on a fragment of charred hazel nutshell that was embedded in a lump of fire-reddened clay (2098). This was lying on the base of the pit, on a thin charcoal-rich deposit (2099) from which a charred cereal grain was also dated (SUERC-64236). The two results are statistically consistent (T'=0.0; ν=1; T'(5%)=3.8; Ward and Wilson 1978) and could be the same actual age.

It is interesting to note that all the results are not statistically consistent (T'=27.6; ν=13; T'(5%)=22.4; Ward and Wilson 1978). Even after removal of the four results from the pre-bank deposits, the remaining results are not statistically consistent (T'=18.9; ν=9; T'(5%)=16.9; Ward and Wilson 1978). This suggests that while there is a high degree of internal consistency within the pit, post-holes and the post-bank burnt deposit, the radiocarbon results do not reflect a single 'event', but rather activity over a protracted period.

The model
The initial Bayesian model for the results adhered to the observed field stratigraphy and supposed chronological relationships, based on taphonomic understanding of the contexts. For the deposits related directly to the inner ditch, they are placed into two groups: pre- and post-bank deposits. Therefore (21) and (2082) are earlier than (17), (2003), and (2023). Furthermore, the model calculates the probability of an event between the two sets of deposits to provide a date estimate for when the bank was constructed. For the two post-holes, the dates of the material in the packing deposit should date to when the post was put into the ground or before, while the material in the post-pipe should date activity that occurred around the post, with the material falling into voids around the post as it decayed (Reynolds 1995). Therefore, the material from the post-packing should pre-date the material from the post-pipe, and this is reflected in the model as well. While the clay lump on the base of pit [2078] is stratigraphically later than the deposit on the base, the two may very well actually be part of the same event and have been left as an unordered pair in the model.

The results
This model has good agreement between the radiocarbon dates and the archaeology (Amodel=61). The model estimates that the dated activity at Hen Gastell began in *cal AD 995–1145* (*95% probability*; Fig. 1; *start: Hen Gastell*), and probably in either *cal AD 1010–1050* (*38% probability*) or *cal AD 1070–1115* (*30% probability*). The inner bank was constructed in *cal AD 1045–1155* (*95% probability*; Fig. 1; *build: Inner Bank*), and probably in either *cal AD 1050–1060* (*6% probability*) or *cal AD 1090–1150* (*63% probability*). Activity on the site ended in either *cal AD 1050–1115* (*18% probability*; Fig. 1; *end: Hen Gastell*) or *cal AD 1120–1125* (*18% probability*; Fig. 1; *end: Hen Gastell*) or *cal AD 1120–1225* (*77% probability*), and probably in either *cal AD 1130–1210* (*68% probability*). The overall span of dated activity is *1–200 years* (*95% probability*; Fig. 2; *span: Hen Gastell*), and probably *10–130 years* (*68% probability*).

Sensitivity analysis
An alternative model was constructed to test the sensitivity of the modelled data to the inclusion of the sequencing of the post-hole dates. That model has poor agreement between the radiocarbon dates and model assumptions (Amodel=54). This suggests that ordering of the samples, as inferred from the archaeology, is critical to the production of a robust chronological model.

Discussion
The chi-square tests between pairs of dates show that the results on paired samples from many of the features are statistically consistent, indicating the measurements could be the same age. This suggests the material is likely to be closely related in date. However, because the overall chi-squares for measurements on all the samples, and just those that do not clearly pre-date the inner bank construction, are not statistically consistent, it is likely that the activity within the enclosure was not necessarily short lived. The modelling suggests that it perhaps covered a period of three or four generations sometime in the 11th and 12th centuries cal AD.

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Figures

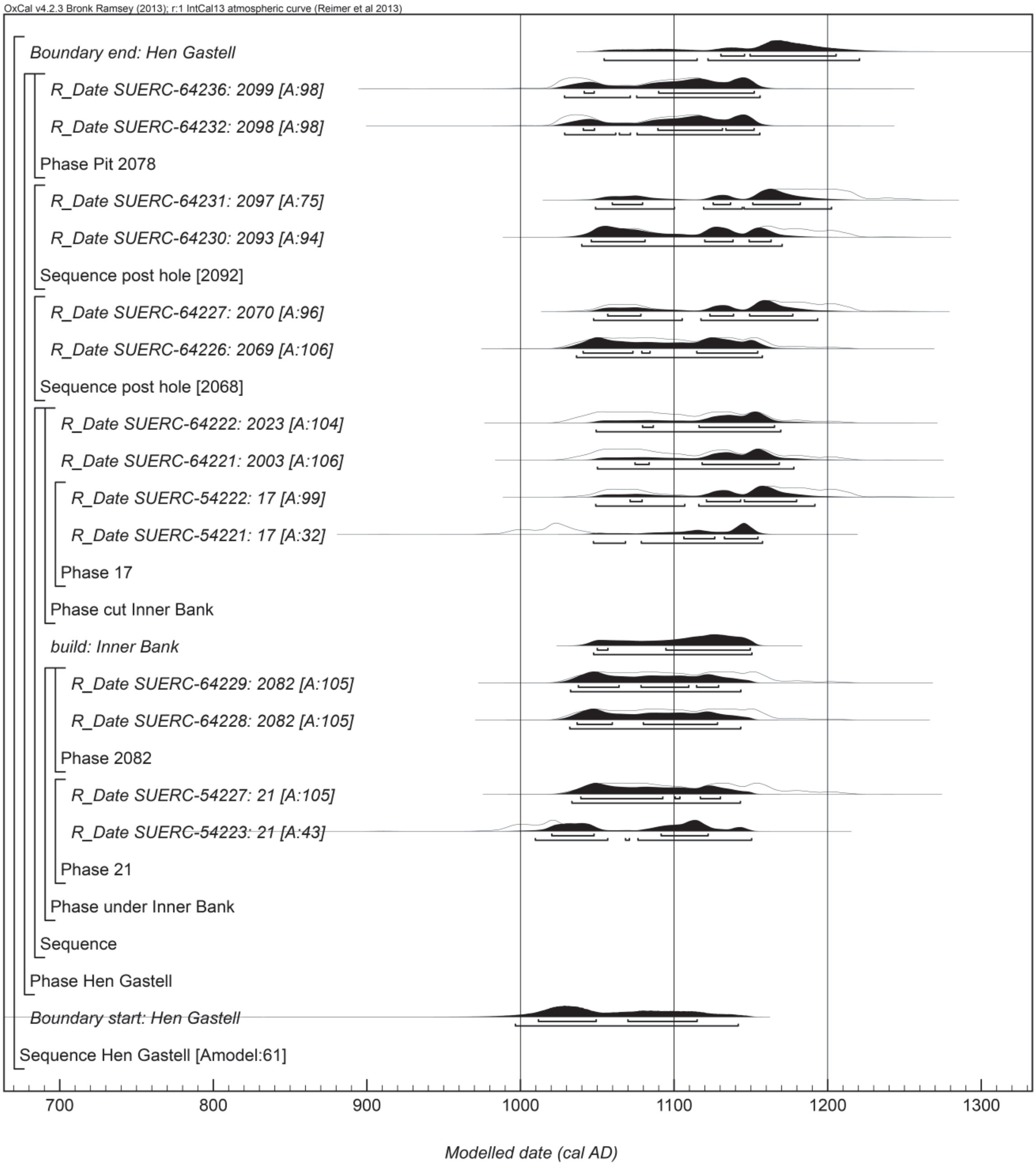

Figure XIV.1.1: Chronological model for the dated activity associated with the enclosure at Hen Gastell, Llanwnda. Each distribution represents the relative probability that an event occurred at some particular time. For each of the radiocarbon measurements two distributions have been plotted, one in outline which is the result of simple radiocarbon calibration, and a solid one which is based on the chronological model use. The other distributions correspond to aspects if the model. For example, '*start: Hen Gastell'* is the estimated date that the activity began at the site. The large square 'brackets' down the left-hand side along with the OxCal keywords define the overall model exactly.

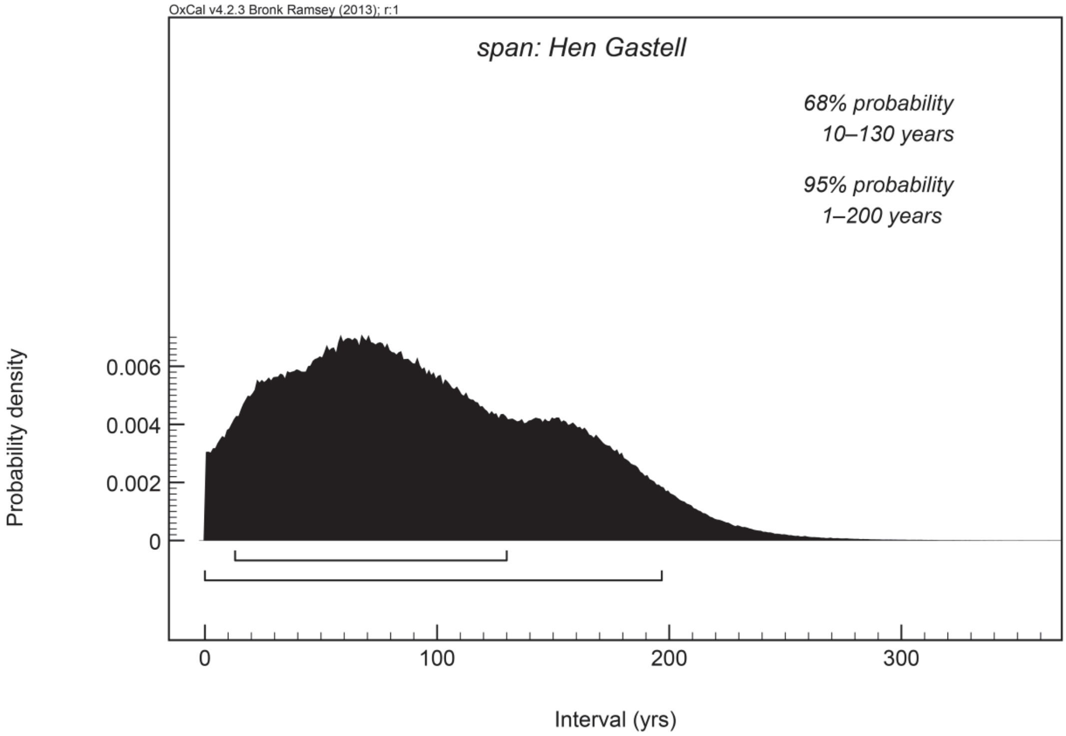

Figure XIV.1.2: Probability distribution for the number of years over which activity at the Hen Gastell took place. The probability is derived from the model defined in Figure appXIV.1.1.

23.2. **XIV.2: Table of radiocarbon dates from Hen Gastell**

Lab ID	**Context description**	**Material**	**δ^{13}C (‰)**	**Radiocarbon age (BP)**	**Calibrated date (95% confidence)**
SUERC-54221	Fill (17) of slot in the inner bank in Trench 1. Contained burnt stone deposits	charred hazel nutshell	–27.3	999 ±30	cal AD 980–1150
SUERC-54222	Context (17). Same context as SUERC-54221	charred cereal grain: *Avena* sp.	–26.3	885 ±30	cal AD 1040–1220
SUERC-54223	Buried soil (21) under the inner bank in Trench 1. Charred remains are mixed into the buried soil here and represent pre-bank activity.	charred hazel nutshell	–27.6	1010 ±30	cal AD 980–1120
SUERC-54227	Context (21). Same context as SUERC-54223	charcoal: *Salix/Populus* sp.)	–28.2	915 ±30	cal AD 1020–1210
SUERC-64221	Burnt layer (2003) with an abundance of angular and heat-fractured stone	charred grain: indeterminate	–23.8	908 ±29	cal AD 1030–1220
SUERC-64222	Burnt stone layer (2023) over bank 2018. Contained charcoal and heat-fractured stones.	charred hazel nutshell	–24.0	919 ±29	cal AD 1020–1210
SUERC-64226	Packing deposit (2069) in posthole [2068]	charred hazel nutshell	–28.2	922 ±29	cal AD 1020–1190
SUERC-64227	Deposit (2070) filling the post-pipe in posthole [2068]. The deposit contained a high proportion of burnt stone.	charred hazel nutshell	–25.7	883 ±27	cal AD 1040–1120
SUERC-64228	Layer (2082) of burnt bone and charcoal underlying bank 2116.	charred hazel nutshell	–26.4	929 ±29	cal AD 1020–1170
SUERC-64229	Layer (2082) of burnt bone and charcoal underlying bank 2116 and above the buried pre-bank soil.	charred cereal grain: indeterminate	–23.8	925 ±29	cal AD 1020–1190
SUERC-64230	Packing deposit (2093) in posthole [2092] with some burnt and heat-affected stones.	charred hazel nutshell	–25.8	890 ±29	cal AD 1030–1220
SUERC-63231	Fill (2097) of post void [2096] in posthole [2092].	charred hazel nutshell	–27.1	865 ±29	cal AD 1050–1250
SUERC-64232	Lump (2098) of heat reddened clay in the base of pit [2078]. Possibly part of the lining of a collapsed superstructure.	charred hazel nutshell	–24.8	958 ±27	cal AD 1020–1160
SUERC-64236	Thin charcoal-rich fill (2099) in the base of pit [2078]	charred cereal grain: indeterminate	–23.8	960 ±29	cal AD 1010–1160

23.3. Radiocarbon Certificates

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RADIOCARBON DATING CERTIFICATE
05 August 2014

Laboratory Code SUERC-54221 (GU34486)

Submitter Jane Kenney
Gwynedd Archaeological Trust
Craig Beuno, Ffordd y Garth
Bangor
Gwynedd LL57 2RT

Site Reference Hen Gastell, Llanwnda, Gwynedd, North Wales
Context Reference context 17: fill of slot in inner bank
Sample Reference G2246.17.01

Material Charred nut shell : Hazel (Corylus avellana)

$\delta^{13}C$ relative to VPDB -27.3 ‰

Radiocarbon Age BP 999 ± 30

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

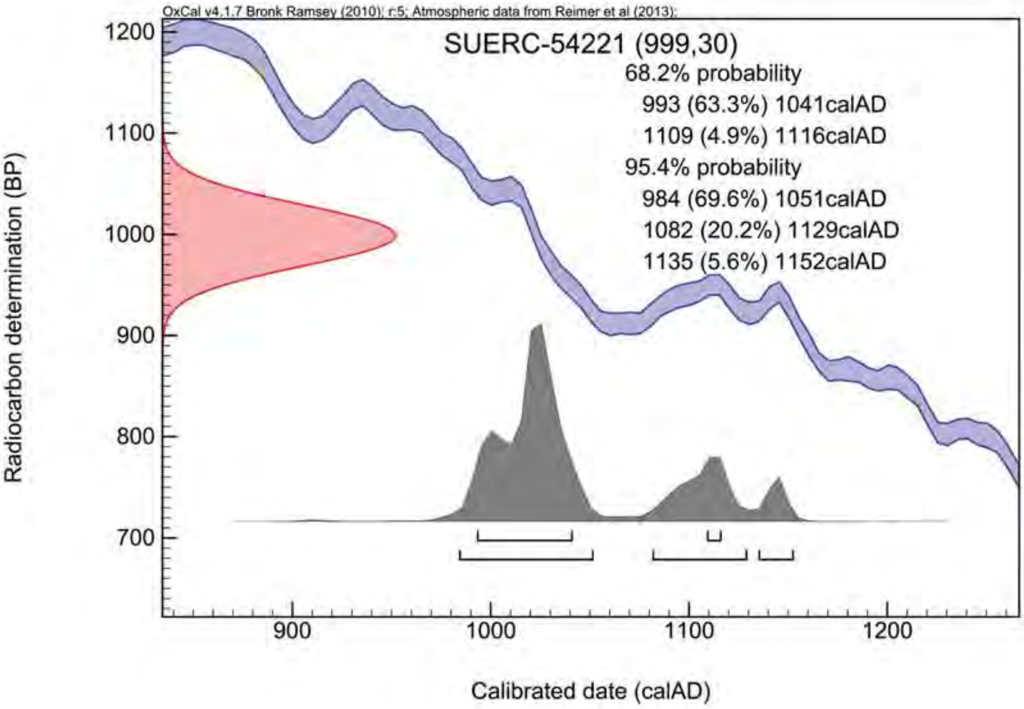
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- Date :- 05/08/2014

Checked and signed off by :- P. Naysmith Date :- 05/08/2014

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

05 August 2014

Laboratory Code	SUERC-54222 (GU34487)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	Hen Gastell, Llanwnda, Gwynedd, North Wales
Context Reference	context 17: fill of slot in inner bank
Sample Reference	G2246.17.02
Material	Charred cereal grains : Oats (Avena species)
$\delta^{13}C$ relative to VPDB	-26.3 ‰
Radiocarbon Age BP	885 ± 30

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

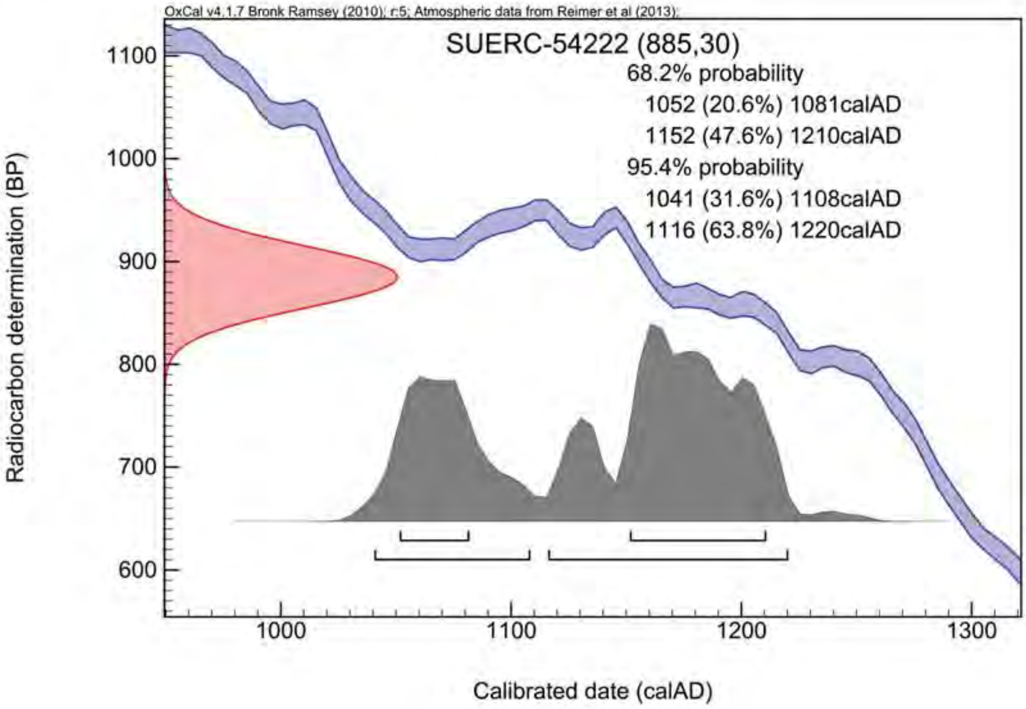
Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- Date :- 05/08/2014

Checked and signed off by :- P. Naysmith Date :- 05/08/2014

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

05 August 2014

Laboratory Code	SUERC-54223 (GU34488)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	Hen Gastell, Llanwnda, Gwynedd, North Wales
Context Reference	context 21: buried soil under inner bank
Sample Reference	G2246.21.01
Material	Charred nut shell fragment : Hazel (Corylus avellana)
$\delta^{13}C$ relative to VPDB	-27.6 ‰
Radiocarbon Age BP	1010 ± 30

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

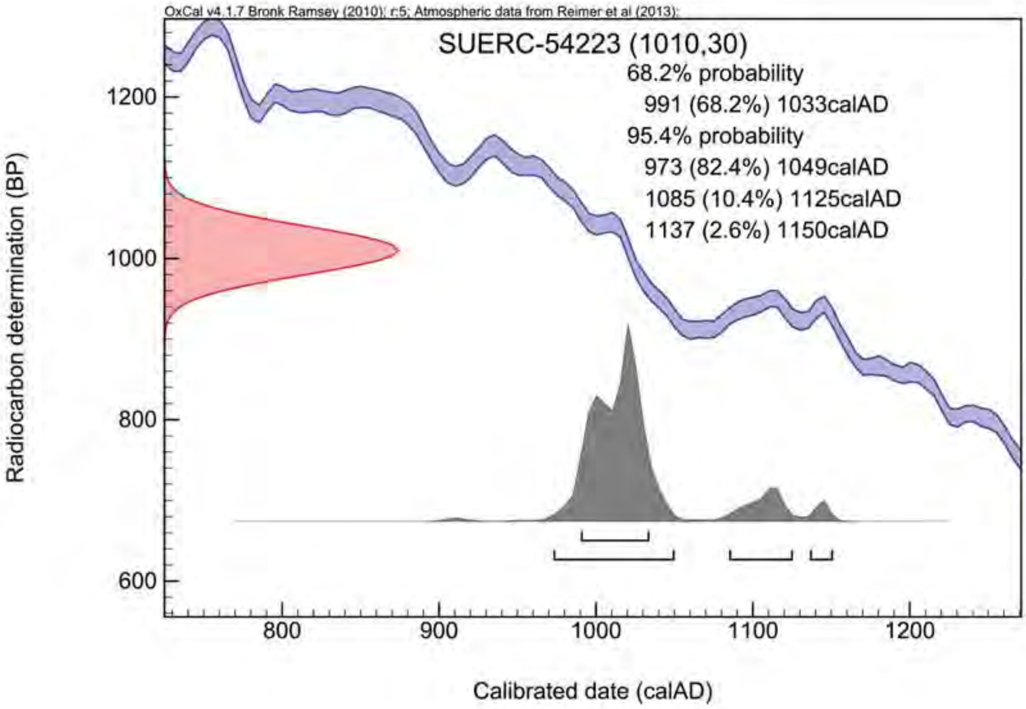
Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- [signature] Date :- 05/08/2014

Checked and signed off by :- [signature] Date :- 05/08/2014

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

05 August 2014

Laboratory Code	SUERC-54227 (GU34489)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	Hen Gastell, Llanwnda, Gwynedd, North Wales
Context Reference	context 21: buried soil under inner bank
Sample Reference	G2246.21.02
Material	Charcoal : Willow/poplar (Salix/Populus)
$\delta^{13}C$ relative to VPDB	-28.2 ‰
Radiocarbon Age BP	915 ± 30

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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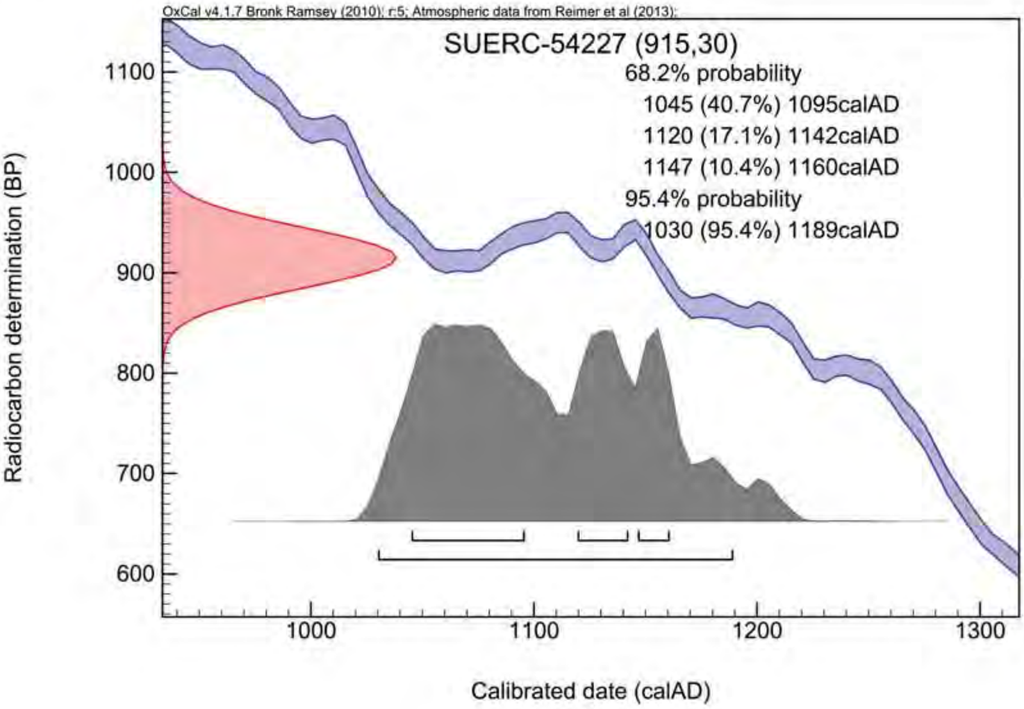
Conventional age and calibration age ranges calculated by :- [signature] Date :- 05/08/2014

Checked and signed off by :- P. Naysmith Date :- 05/08/2014

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code	SUERC-64221 (GU39272)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	G2246 Hen Gastell
Context Reference	2003 - burnt stone deposit
Sample Reference	G2246 HG/08
Material	Charred plant remains : Cereal gains (unidentifiable)
$\delta^{13}C$ relative to VPDB	-23.8 ‰
Radiocarbon Age BP	908 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

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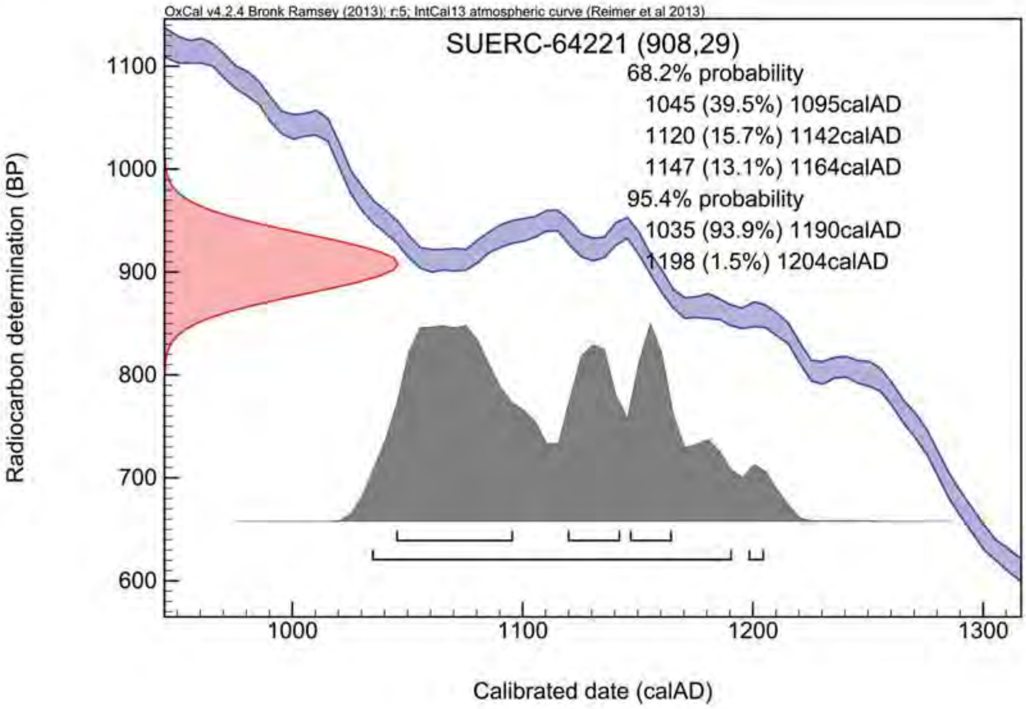
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code	SUERC-64222 (GU39273)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	G2246 Hen Gastell
Context Reference	2023 - burnt stone deposit
Sample Reference	G2246 HG/16
Material	Charred plant remains : Hazel nut shell fragments
$\delta^{13}C$ relative to VPDB	-24.0 ‰
Radiocarbon Age BP	919 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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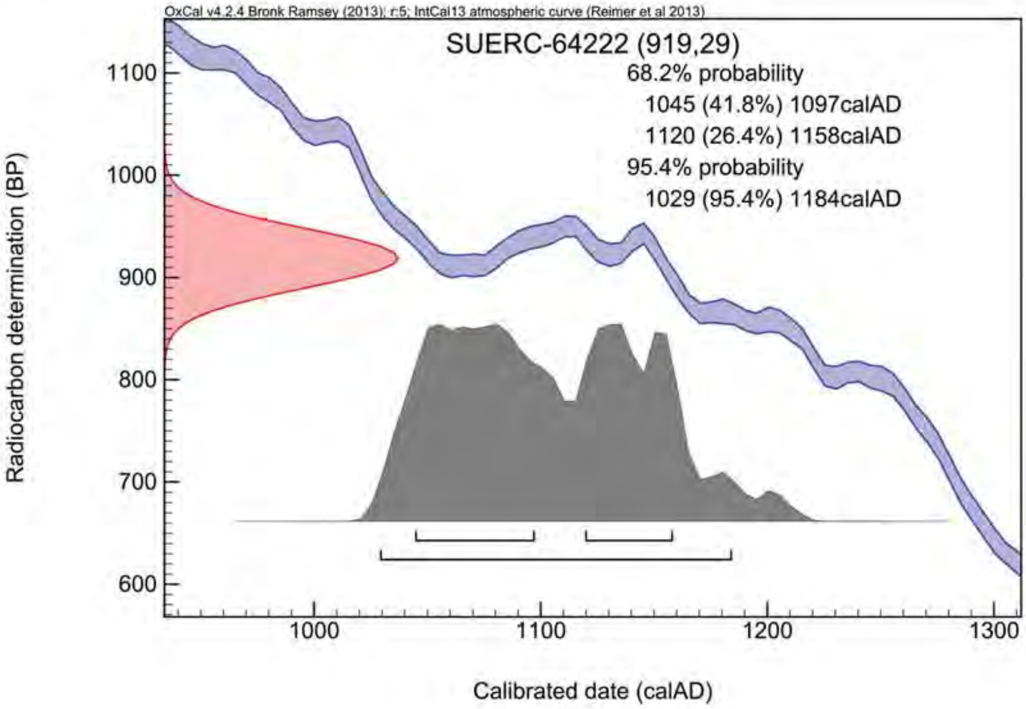
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code	SUERC-64226 (GU39274)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	G2246 Hen Gastell
Context Reference	2069 - fill of post-pipe in posthole [2068]
Sample Reference	G2246 HG/31
Material	Charred plant remains : Hazel nut shell fragmnts
$\delta^{13}C$ relative to VPDB	-28.2 ‰
Radiocarbon Age BP	922 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

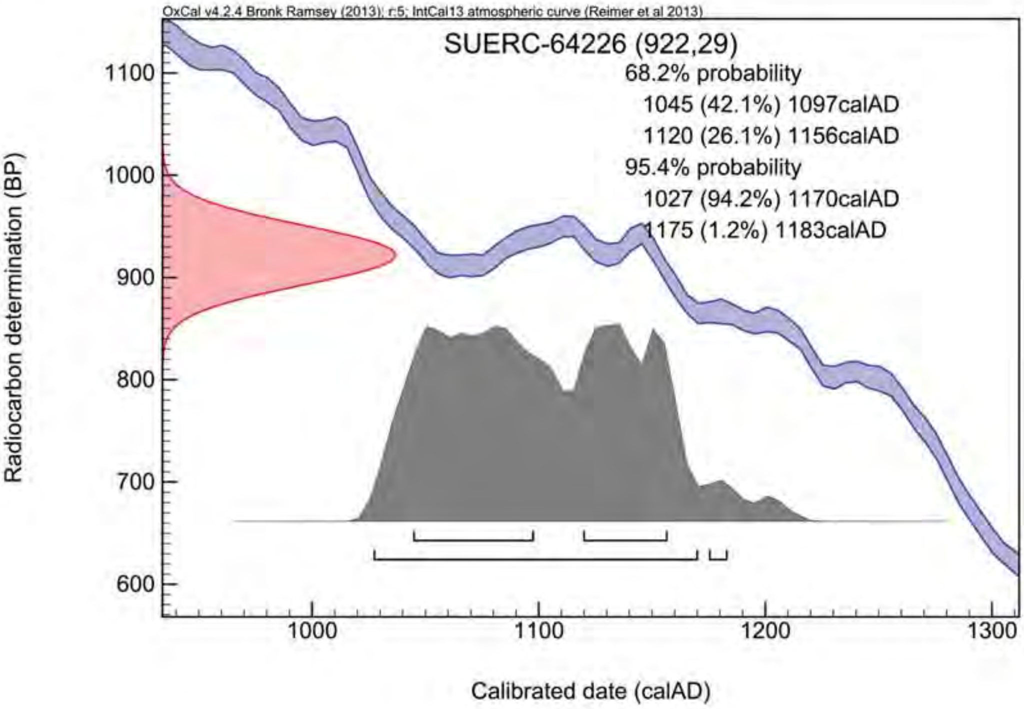
Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email Gordon.Cook@glasgow.ac.uk or telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code	SUERC-64227 (GU39275)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	G2246 Hen Gastell
Context Reference	2070 - packing deposit in posthole [2068]
Sample Reference	G2246 HG/20
Material	Charred plant remains : Hazel nut shell fragments
$\delta^{13}C$ relative to VPDB	-25.7 ‰
Radiocarbon Age BP	883 ± 27

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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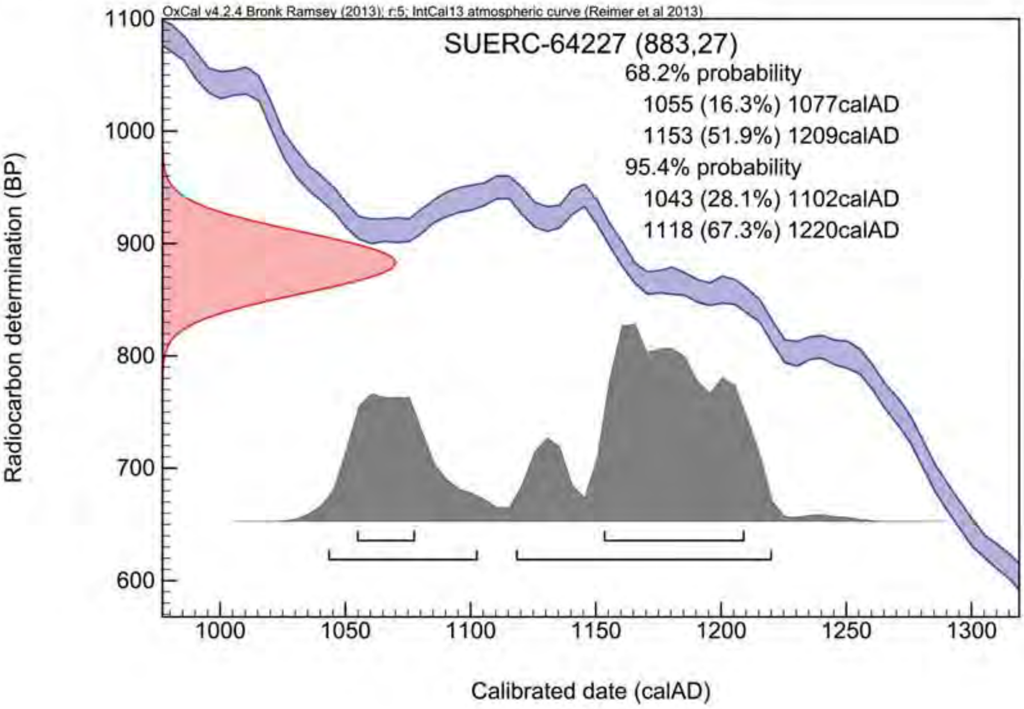
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code SUERC-64228 (GU39276)

Submitter Jane Kenney
Gwynedd Archaeological Trust
Craig Beuno, Ffordd y Garth
Bangor
Gwynedd LL57 2RT

Site Reference G2246 Hen Gastell
Context Reference 2082 - burnt layer under bank
Sample Reference G2246 HG/28

Material Charred plant remains : Hazel nut shell fragments

$\delta^{13}C$ relative to VPDB -26.4 ‰

Radiocarbon Age BP 929 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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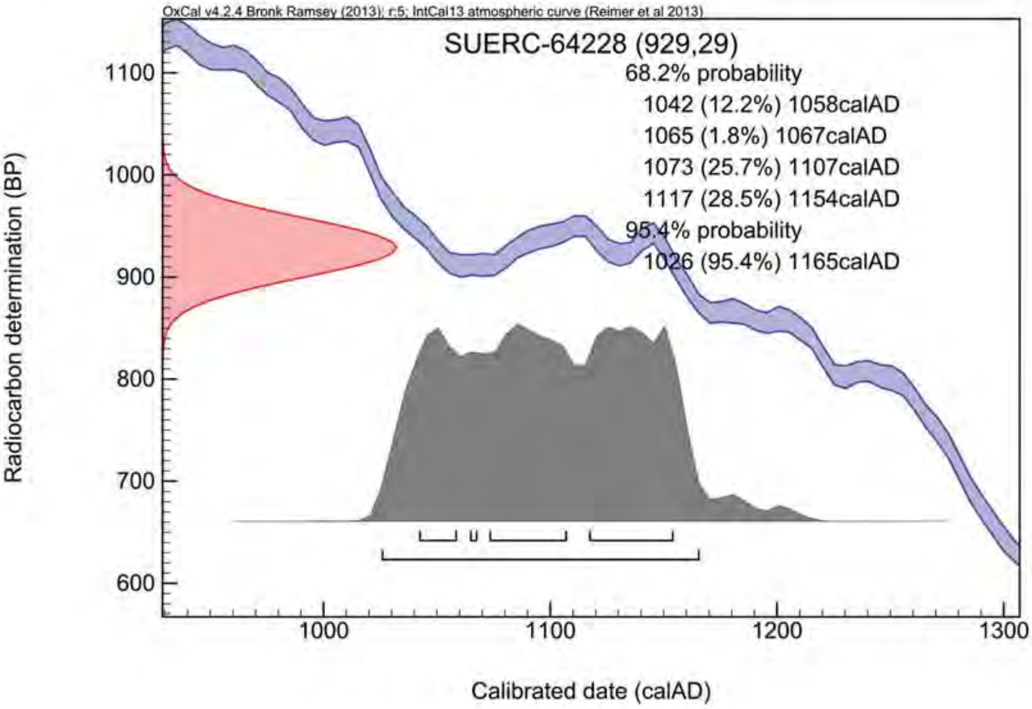
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code	SUERC-64229 (GU39277)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	G2246 Hen Gastell
Context Reference	2082 - burnt layer under bank
Sample Reference	G2246 HG/41
Material	Charred plant remains : Cereal grains (unidentifiable)
$\delta^{13}C$ relative to VPDB	-23.8 ‰
Radiocarbon Age BP	925 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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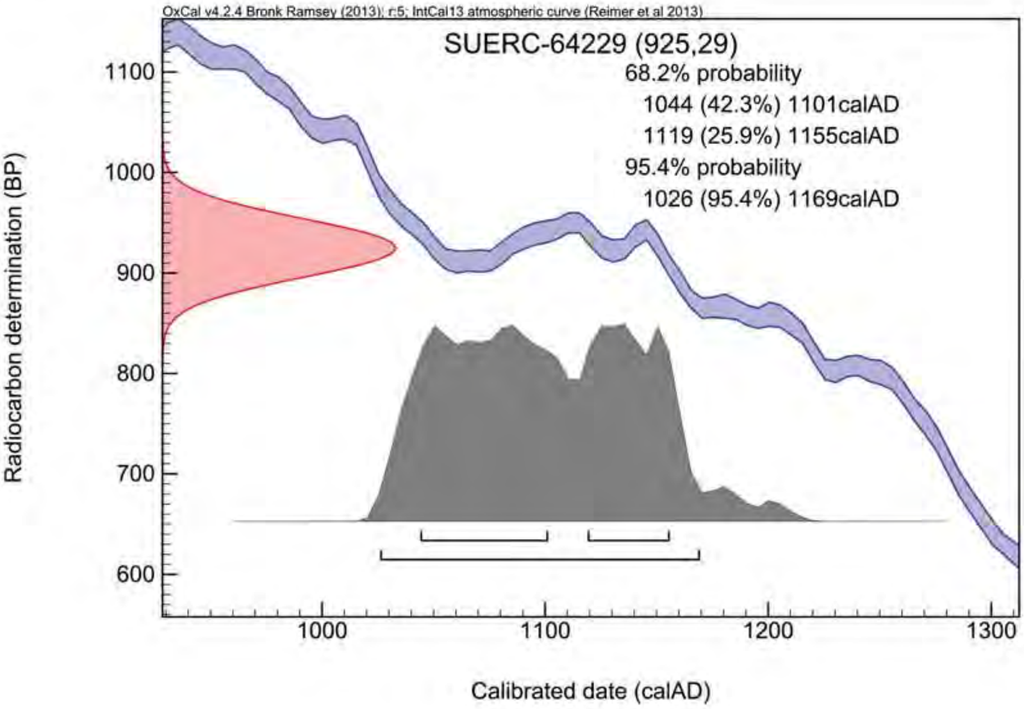
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code SUERC-64230 (GU39278)

Submitter Jane Kenney
Gwynedd Archaeological Trust
Craig Beuno, Ffordd y Garth
Bangor
Gwynedd LL57 2RT

Site Reference G2246 Hen Gastell
Context Reference 2093 - packing deposit in posthole [2092]
Sample Reference G2246 HG/34

Material Charred plant remains : Hazel nut shell fragments

$\delta^{13}C$ relative to VPDB -25.8 ‰

Radiocarbon Age BP 890 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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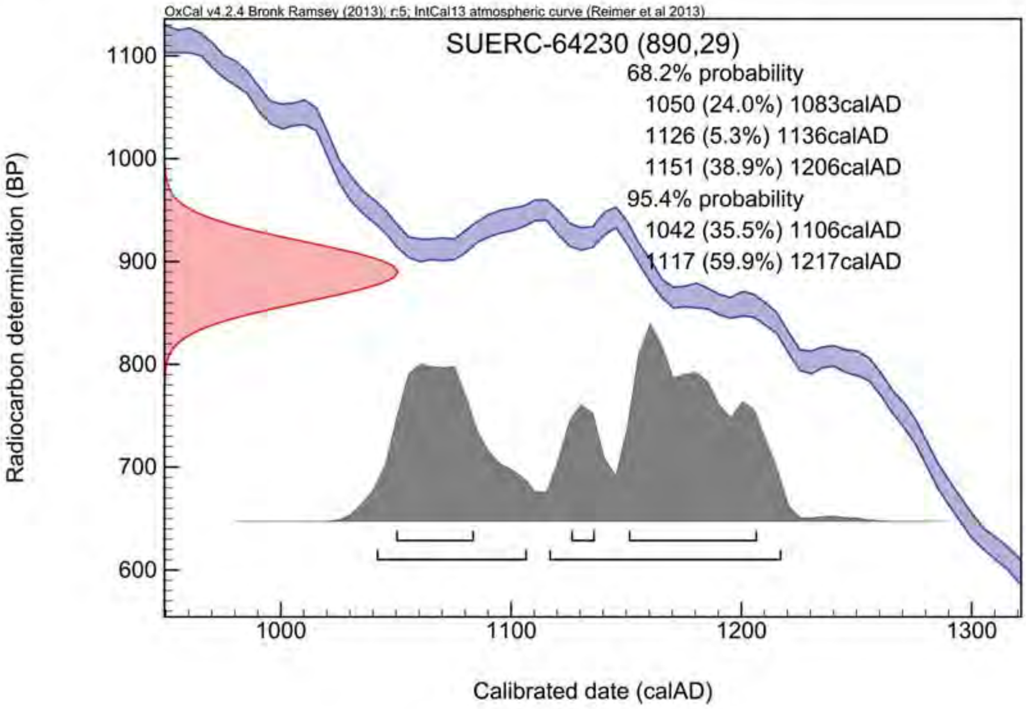
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code SUERC-64231 (GU39279)

Submitter Jane Kenney
Gwynedd Archaeological Trust
Craig Beuno, Ffordd y Garth
Bangor
Gwynedd LL57 2RT

Site Reference G2246 Hen Gastell
Context Reference 2097 - fill of post-pipe in posthole [2092]
Sample Reference G2246 HG/38

Material Charred plant remains : Hazel nut shell fragments

$\delta^{13}C$ relative to VPDB -27.1 ‰

Radiocarbon Age BP 865 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

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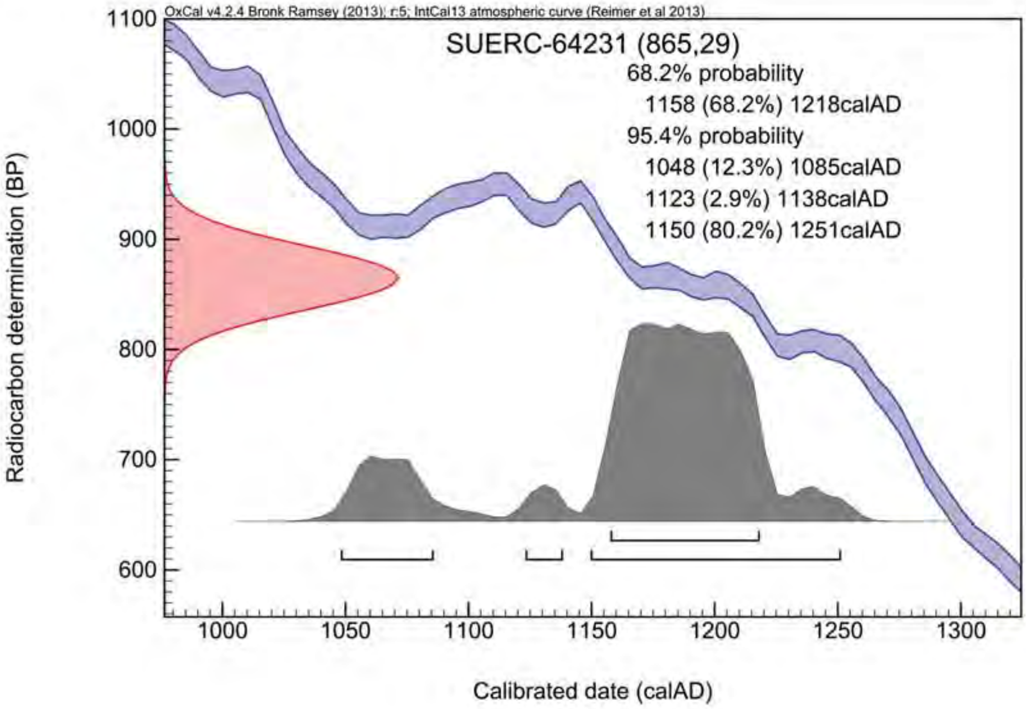
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

University of Glasgow

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code	SUERC-64232 (GU39280)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	G2246 Hen Gastell
Context Reference	2098 - clay deposit in metal-working pit [2078]
Sample Reference	G2246 HG/32
Material	Charred plant remains : Hazel nut shell fragments
$\delta^{13}C$ relative to VPDB	-24.8 ‰
Radiocarbon Age BP	958 ± 27

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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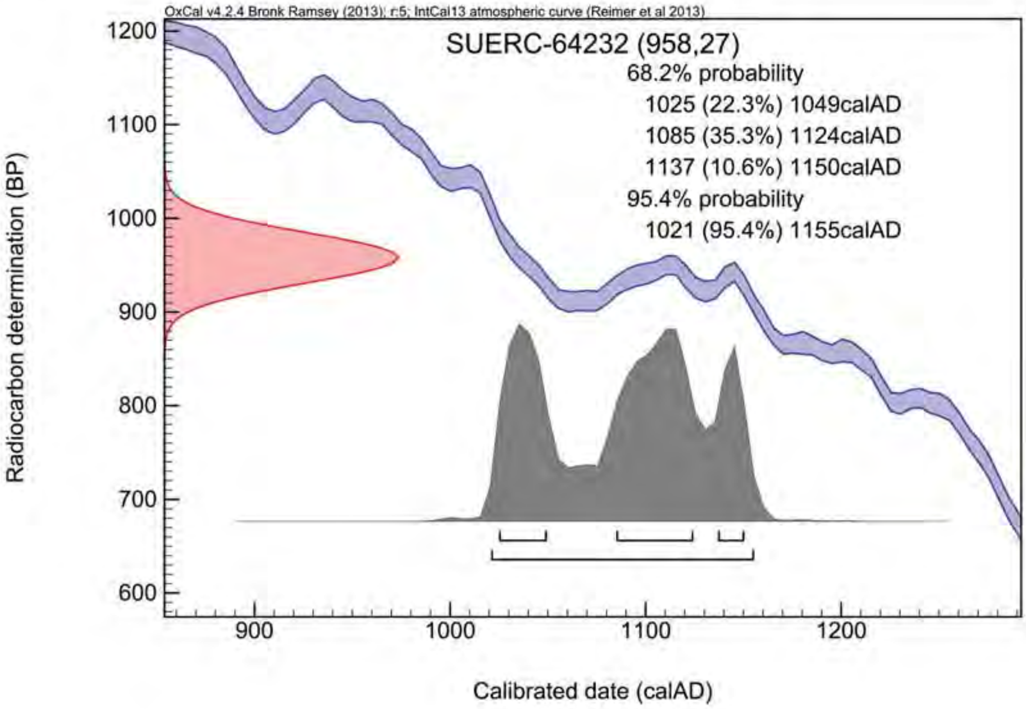
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

09 December 2015

Laboratory Code	SUERC-64236 (GU39281)
Submitter	Jane Kenney Gwynedd Archaeological Trust Craig Beuno, Ffordd y Garth Bangor Gwynedd LL57 2RT
Site Reference	G2246 Hen Gastell
Context Reference	2099 - burnt layer in metal-working pit [2078]
Sample Reference	G2246 HG/33
Material	Charred plant remains : Cereal grains (unidentifiable)
$\delta^{13}C$ relative to VPDB	-23.8 ‰
Radiocarbon Age BP	960 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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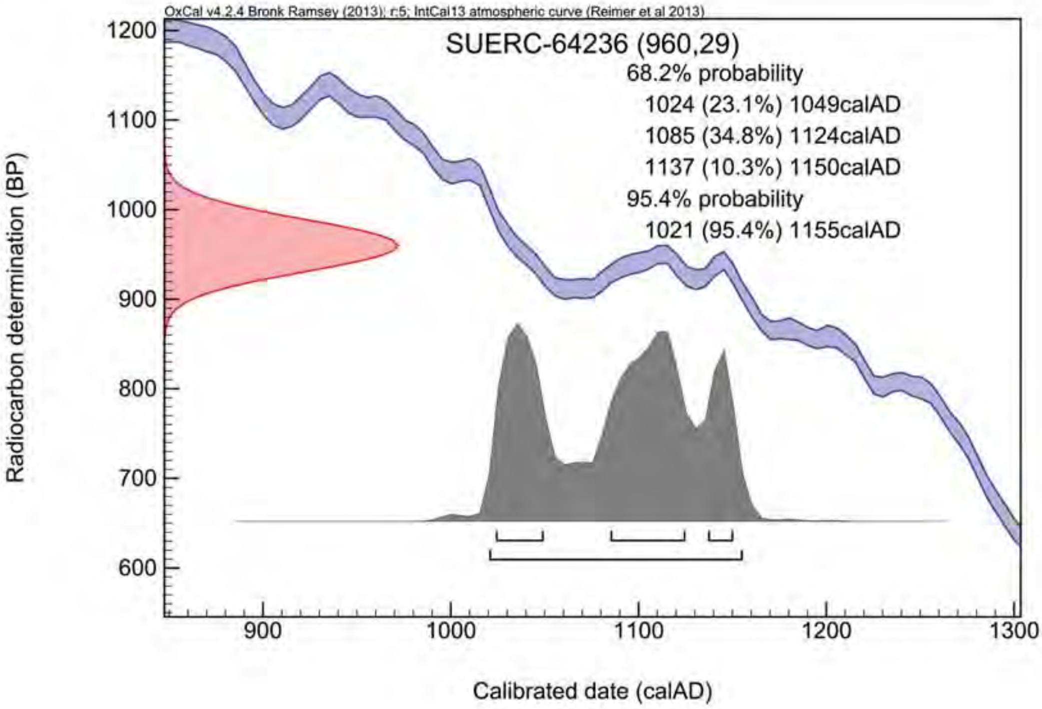
Conventional age and calibration age ranges calculated by :- E Dunbar Date :- 09/12/2015

Checked and signed off by :- P. Naysmith Date :- 09/12/2015

University of Glasgow

Calibration Plot



Llywodraeth Cymru
Welsh Government

Gwynedd Archaeological Trust
Ymddiriedolaeth Archaeolegol Gwynedd

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