GeoArch

Report 2026/02

Assessment of archaeometallurgical residues from Penygroes Quarry (PQ/24/SME)

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28th January 2026

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Abstract

This excavation produced evidence for sparse assemblages of ironworking residues with the fills of several cut features. In some cases, these included small quantities of macroresidues, but most produced only small quantities of microresidues (hammerscale).

It is possible that the sparse assemblages of microresidues are intrusive (by percolation or worm action) from a small quantity of forge waste spread over the ground surface, rather than the pits themselves being contemporary with the activity. Macroresidues too large for intrusion this way only occurred within two features.

The residues are indicative of blacksmithing but might be of any age from Iron Age to modern.

A post-medieval ditch produced a small amount of reside from the burning of coal, perhaps as waste from the use of steam-powered agricultural equipment.

Many contexts produced evidence for natural superficial Fe-Mn mineralisation (bog iron ore and wad). This is of interest because iron smelting sites in the region have largely not produced evidence of the ores employed. There is no indication the ores were employed for any economic purpose on this site.

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Methods

Background

This assessment was commissioned by Rhiannon Philp of Archaeology Wales. The materials described and assessed here arise from excavations undertaken on land at Penygroes Quarry, Gwynedd (site code PQ/24/SME)).

Assessment

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

Results

General

The total submitted assemblage weighed 2.44kg (161 fragments plus 25g of microscopic sieved residues).

The collection includes 13 macroscopic fragments of probable iron slags with a total weight of 232g and 21 pieces (total 14g) of fuel ash slags (FAS). There were 9 pieces (3.5g) of coke and clinker. In addition, there were 8 fragments of concretionary of which 5 fragments were probably formed around pieces of iron. The most abundant class of material in the collection was, however, pieces of lithologies formed by supergene Fe-Mn enrichment, with a total of 81 pieces weighing 843g.

Eight samples of fine magnetic separates were submitted. Five of these samples contained low levels of hammerscale, with one containing moderately high levels of hammerscale.

Details

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

Iron slag: the largest fragment of iron slag was an angular fragment weighing 142g (context (1092)). This had a surface coating of secondary concretion, obscuring all surface details. The overall morphology of the piece would perhaps suggest that it was a fragment of smithing hearth cake (SHC).

The same context produced two other fragments, one (28g) a small fragment from the base of a slag mass with a finely prilly/dimpled base and large internal vesicles. Such a piece is likely also to be a fragment from a SHC. The other (28g) also had a dimpled base, but was formed of elongate, rather irregular, flow lobes with a maroon upper surface. The origin of this piece is less certain. The morphology resembles some of the poorly-flowed tapslags from early medieval iron smelting sites in the area (e.g. Young 2025), but such morphologies may sometimes arise during smithing too.

A rather similar fragment (7.9g; context (1119)), also shows a somewhat maroon surface and is poorly flow lobed, but has a slightly waxy lustre. These features might suggest that it is clinker, rather than true slag, but inclusions of fuel trapped between its basal prills appear to be charcoal not coal.

All the iron slag fragments were too small for any meaningful comment on their textures or likely origin.

Hammerscale: six samples yield small quantities of flake hammerscale (FHS). Only two samples produced reasonably certain examples of spheroidal hammerscale (SHS). Spheroidal particles occurred in two other samples, but their surface colours and textures suggested that they were slag droplets rather than SHS.

Fuel ash slag (FAS): low density, friable, vesicular FAS in small slightly lobate particles, was represented by an assemblage of 15 particles (4.3g) from context (1091), 6 pieces coated in concretion from context (1159) (9.9g, much of which was the adhering material rather than FAS itself).

Coke/Clinker: clinker can be considered as a specific form of fuel ash slag, formed from the inorganic residue of burning coal, with coke being the organic residue from the partial combustion of coal.

The only moderately-sized coke particle observed was from context (1124) (even so, it was only 2.4g). Smaller particles from other contexts are less securely identified. The partial combustion of organic matter from other sources may also produced coked lithologies, and discrimination is not possible on small particles. Similarly small fragments of clinker are only

identified with some qualification – discrimination from other forms of slag is based solely on the rather unreliable criteria of colour and lustre, because other textural indicators are not always visible on small particles.

Concretions/iron: context (1092) contained four concretions showing the characteristic cracking associated with the weathering of metallic iron. Obe piece, the largest, was broken in two, to reveal a piece of sheet iron with an irregularly curved outline measuring 75 x 38 x 2mm.

A similar small concretion was observed from contexts (1159).

Contexts (1115) and (1161) each produced a tiny concretion fragment contain small fragments of charcoal.

Fe-Mn mineralisation: most of the investigated samples, and many of the hand collected pieces, were natural Fe-Mn deposits. These varied across the spectrum from materials that appeared as simple manganese wad, through to pieces of hard bog iron ore. Many pieces were likely to be somewhere in between compositionally. It is not possible to determine the significance of the materials from small pieces – something that is lithologically equivalent to a bog iron ore might just be described as an Fe-Mn crust, if it is only thin.

The frequency of the materials is however interesting. The occurrence of such deposits is implied by the early medieval iron smelting sites at Penrhyn Quarry and at Cefn Graianog, but little or no ore was recovered during excavations on those sites.

Some of the very small dense iron oxide particles may perhaps be tiny oxidised pyrite nodules rather than supergene Fe-Mn enrichments.

Distribution

The various materials derive from a variety of types of context (*: denotes a context with no pieces of pyrotechnological residue > 1g):

Post medieval ditch [1005] – coke and clinker
Post medieval ditch [1118] – clinker?

Spread (1036)/(1091)* – FAS
Spread (1092) – iron artefacts, smithing slag, possible smelting slag, some FAS

Posthole [1112]* – tiny slag fragment
Posthole [1131]* – natural only
Posthole [1160]* – slag and charcoal-bearing concretion

Possible cremation pit [1096]* – FHS and SHS
Possible cremation pit [1123]* – coke?
Possible cremation pit [1176]* – rare FHS

Pit [1094]* – rich FHS in top, some in lower fill
Pit [1114]* – spheroid of slag/clinker, dimpled slag
Pit [1116]* – FHS and SHS
Pit [1158] – slag, FAS rare FHS

Of these contexts only spread (1092) and pit [1158] produced fragments of debris from metalworking that weighed more than 1g.

Spread (1092) lies within cut [1079]. The features containing microresidues all lie within an area of approximately 5m (EW) by 4m (NS) immediately to the west of this. Microresidues are absent from samples from all the other features to the N and to the S, but occur in the majority of cut features in this restricted area. With the addition of the are of the macroresidues from the spread (1092), the total area of distribution of the ironworking residues is approximately 10m x 5m (defined by the green pecked line on Figure 1).

Interpretation

The collection probably comprises several distinct elements:

- Sparse quantities of coke and clinker, residues from the burning of coal. With the exception of one tiny piece of ‘coke’ (potentially from the burning of a different type class of organic material), these are represented only in the post-medieval ditches.

- Small quantities of macroscopic residues from ironworking (blacksmithing). These are only present in the fill of pits [1158] and [1089], These probably represent genuine deposits of these materials.

- Assemblages of microresidues, including hammerscale and fine slag debris. These occur in most cut features over an area of 4m x 3m to the west of [1085] surrounding [1158]. These assemblages are sparse apart from the from [1094] (just 1m S of [1158]. These assemblages are (with the possible exception of that from [1094]) perhaps suggestive of the contamination of the fills of cut features by microresidues percolating downwards through the soil profile from an overlying deposit, rather than being the direct sites of accumulation.

The limited extent of both the potential surviving deposits of ironworking residues and the probably intrusive microresidues, suggests an originally small amount of smithing residue spread over a small area (perhaps 10m x 4m in total).

Although the transport of slag from source to dump is common, it is less common to see the deliberate transport of forge fines (fuel waste and hammerscale) apart from the dumping of ‘ash’ to improve a soil. Therefore, it would seem likely that this was the site of the ironworking, even if there are no surviving burnt features.

The ironworking residues are too few to provide much evidence for age. The smithing assemblages do not appear to contain coke or clinker and any evidence for fuel consistently points towards charcoal. Charcoal was commonly employed throughout the history of ironworking from the Iron Age to the present day, even alongside the use of coal when/where that was available.

The presence of the microresidues in features on both sides of the post-medieval ditch might suggest (on the assumption those features are not cut into the ditch) that the scattered microresidues were emplaced before the ditch was dug. The lack of ironworking residues within the samples from the ditches would circumstantially support this relative dating.

Discussion

Following the arguments presented above, there may be grounds for considering whether the deposition of the ironworking residues into [1085] and [1158] and across the adjacent ground surface forms a quite distinct process from the formation of the majority of the underlying pits and postholes. Although the two might be related, they are not necessarily so.

Although blacksmithing does not usually occur in agricultural settings without other settlement activity, it is not unknown. Potential contexts include smithing associated with mobile artisans (e.g. 'tinkers') and smithing directly associated with agricultural activities such as field forges for sharpening scythes during harvesting.

Further work

Although the existence of Fe-Mn 'ores' on this site is of great interest, there is no convincing evidence that they were being smelted on the site. Such ores are likely to be similar to those being smelted on nearby sites, such as Cefn Graianog (McNicol 2016, Young2015a, 2015b) and Penrhyn Quarry, Bethesda (Kenney, 2024; Young 2025). Their occurrence here is noteworthy, but their further investigation would not contribute to understanding of this site – and would therefore probably not be justifiable.

No further work is therefore recommended, on the current understanding of the archaeological context.

If significant archaeological questions arose about the character of the ironworking following completion of the programme of scientific dating, then that recommendation could be revisited.

Glossary

Bog iron ore: a rather loosely defined term for a superficial iron ore formed with a host sediment, typically associated with bogs, but may include ores on floodplains and other settings.

Clinker: the partially melted inorganic residue from the burning of coal

Coke: the partially melted organic residue, typically from the burning of coal, but similar materials may be formed from other organic substrates (such as food residues)

Fuel ash slag: a partially melted silicate material, that has melted under the fluxing influence of alkali and alkaline earth elements derived from the fuel (and sometimes the substrate). May form from the action of heat on soil, small stones and hearth ceramics.

Hammerscale: scale forms from the oxidation of iron when heated. It may fall from the iron substrate because of development of a melted zone at the interface between scale and iron, or through fracture when the iron is struck and deformed by the smith. Such scale formed during blacksmithing is termed flake hammerscale (FHS). If the iron is sufficiently hot, often particularly when a silica flux has been thrown on the iron, the scale may melt. When struck by the smith (e.g. during the closing of a weld) the melt may be squeezed out at high speed and chill in flight to form spheroidal hammerscale (SHS)

Wad**:** a rock, typically rather soft, formed dominantly of dark manganese minerals, usually hydrated oxides and hydroxides. Typically formed in superficial environments.

Figure caption

Figure 1: Distribution of contexts with and without evidence for ironworking. The evidence appears to be constrained to within the pecked green line.

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All GeoArch reports are available for download from: https://www.geoarch.co.uk/report%20library/

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

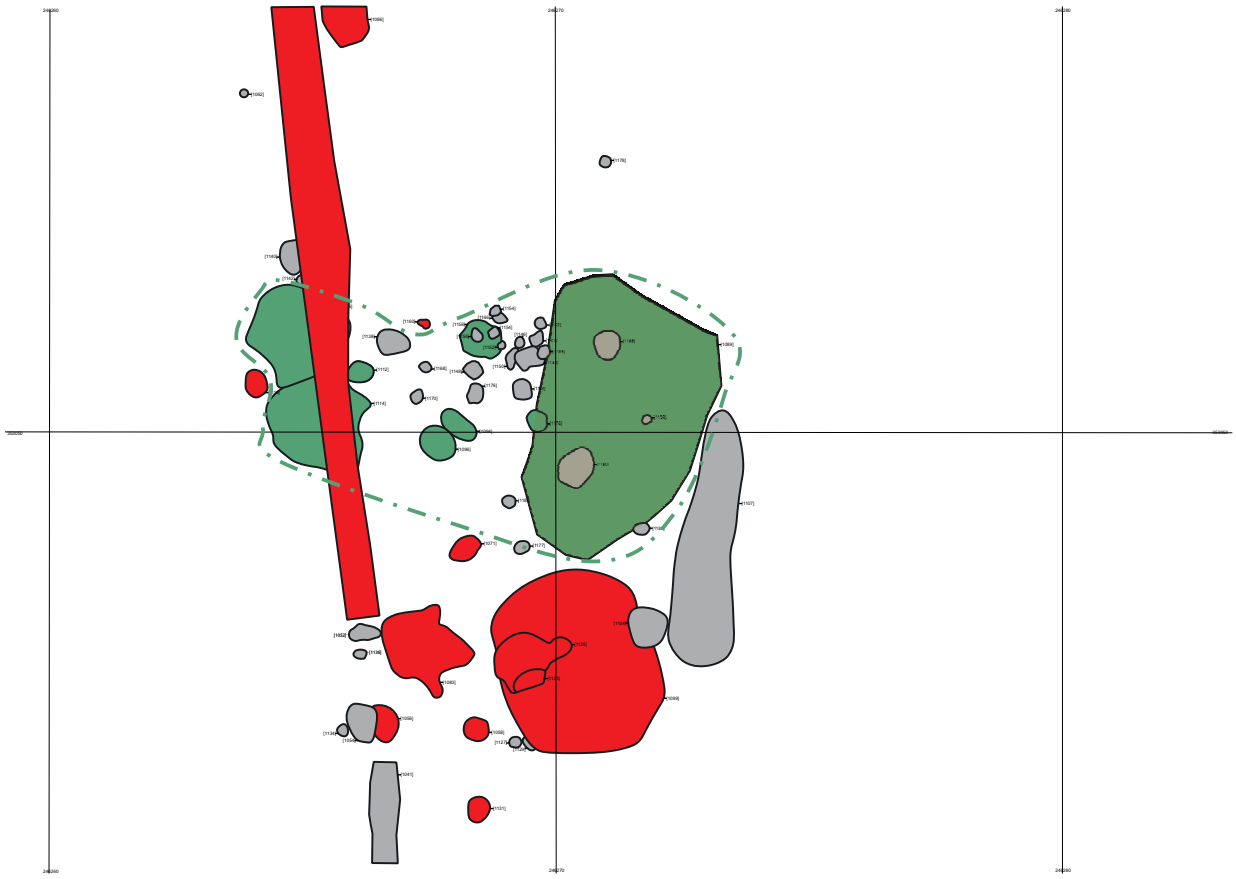
Context	Sample	S wt	I wt	I no	notes
1091			15	4.3	pale FAS with slight green/blue tint, reflecting internal colour. One piece has small pink lithic grain, but no other inclusions observed
1092		361	38	2	single piece of sheet iron with recent fracture, mineralised and accreted, iron piece is 75x38x2mm
			119	3	more equant concretions on iron, showing first signs of fragmentation
			8	1	small rounded concretion, possibly with manganiferous cement
			142	1	somewhat accreted irregular block, core is probably, but not certainly slag, with shape suggesting a possible smithing slag
			2.5	1	small chip of probable bog iron ore
			28	1	flow lobed slag, probably a tapped smelting slag fragment, base shows dimples, top slightly maroon; not from a substantial cake
			28	1	fragment of dense slag, broken top is vesicular, base shows lobes and dimples; uncertain origin
1132			1	777	pale shale fragments cemented by low density manganese wad
slag from samples					
1006	<1>	0.36	0.25	6	coke
			0.8	2	glassy fragments of slag/clinker
1091	<31>		17.8	4	probably a single fragmented piece, low density manganese wad
			1	2	yellowish rock with harder brown veins and surfaces, complex, void-rich, bog iron ore?
			0.9	1	very corroded and worn lobed slag fragment - potentially a smelting slag but too small for certain ID
1092	<30>		4	assm	fuel ash slag in small fragments
1098	<20>	1.1	<.01	1	slag spheroid
			0.28	8	tiny fragments of dense Fe-Mn minerals with attached brown-red material - possible heated ore?
			0.42	9	brown dense Fe-Mn materials, probably bog iron ore, but weathered slag cannot be excluded for some
			0.06	2	dense Fe-Mn mineral with some weathering, possibly oxidised sulphides
			0.14	1	shiny material with glass-like fracture, morphology resembles slag, but possibly rottenstone
			0.09	3	dark granular materials, Mn-rich concretion?
1113	<22>	1.1	0.6	1	deeply dimpled iron slag fragment
			0.6	2	low grade bog iron ore/concretion fragments
1115	<27>		0.78	21	fragments from yellow to black, soft Fe-Mn crust material, denser sheets within are dark suggesting Mn dominant
			0.08	1	small fragment of microprilly, dimpled slag
			0.05	1	oxidised sulphide?
			0.07	1	soft ferruginous concretion with charcoal

1119	<23>		7.9	1	complexly lobed lag fragment with slightly maroon surface and slightly waxy lustre, rather clinker like, but the fuel dimpled base retains fragments apparently of charcoal, so most likely a true flowed slag
1124	<06>		2.4	1	coke
1159	<33>	77	6.7	1	partially exploding ferruginous concretion on iron
			13	1	concretion on low density highly vesicular slag, parle internal maroon exterior, probably an iron slag
			9.9	6	concretion on friable pale FAS
			6.3	3	vesicular dark iron slag in angular fragments
			7	10	dark granular material - probably manganese bearing concretions
			3.4	2	dark granular material with some charcoal, probably Mn concreted with moderately large peds/spheroids
			21.4	8	hard materials with waxy lustre, probably hard Mn-Fe ores
			2.2	1	flat harder concretion, could be on a low flow lobe or an iron fragment
			7.1	assm	smaller fragments
1161	<32>	6.8	0.74	2	bog iron ore fragments, delicate films of fibrous ore mineral between more ochreous zones
			5.1	2	slightly prilly slag fragments in thin accretionary films with quartz grains
			0.9	1	soft ferruginous concretion with charcoal fragments
1177	<34>	1.9	1.2	2	hard materials with waxy lustre, probably hard Mn-Fe ores
			0.7	2	hard dense sheets coated in red granular material - roasted iron ore?

magnetic residues with hammerscale

1036	<4>	1.49	assm	stone, traces of possible slag
1095	<18>	2.44	assm	stone, but rich in FHS and slag debris
1098	<20>	1.02	assm	stone, but both FHS and SHS present
1109	<19>	3.41	assm	mostly stone, with some FHS, pale slag spheroids, slag films,
1115	<27>	<	assm	single c2mm spheroid with slightly maroon surface, well formed
1117	<25>	7.95	assm	mostly stone, moderately rich in FHS, rare probable SHS, reddened grains that may be roasted ore?
1159	<33>	7.11	assm	rather Fe rich residue but only low levels of FHS amongst the stone
1177	<34>	1.53	assm	mostly stone, very rare FHS

Figure 1



Extent of sampled contexts without ironworking residues

Extent of sampled contexts without ironworking residues

Extent of contexts not sampled, but without macroscopic ironworking residues

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