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Assessment of materials from Haverfordwest Priory

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Abstract

The investigated materials comprised a total of approximately 23kg (133 pieces plus some fine debris). The material included pyrotechnological residues from a wide range of contexts, but the focus was some 19kg of residues associated with a post-medieval smithy.

The assemblage from contexts associated with the smithy included 18.2kg of smithing slags, mostly deriving from smithing hearth cakes (SHCs), 140g of clinker that might also be smithing slag, 416g of vitrified stone from the hearth structure and 180g of fragmented concretions formed around small pieces of iron.

There were fourteen SHCs that were more-or-less complete, ranging in weight from 208g to 1715g, with a mean of 730g. The largest of these may possibly not be a simple SHC, in which case the SHCs would be 13 in number, ranging from 208g to 1385g, with a mean of 654g. Most of the SHCs showed evidence for the incorporation of large fragments of coal shale, indicating a rather poor-quality fuel. The high shale content of the fuel may, at least in part, explain the relatively high weights recorded for the SHCs. The SHCs were mostly internally prilly, with abundant clasts of coked coal, leading to the cakes being rather friable.

The largest slag mass (2128g) from the smithy comprised a lower substantial curved slag sheet with a smooth blown top, formed in contact with the hearth wall, that may have formed in the hearth over more than one work period.

Two of the SHCs displayed partial impressions of tuyères on their rear faces. These suggested the use of an iron tuyère, probably of cast iron, of which the tip had an external radius of approximately 65mm and a bore of 27mm at the front (which was eccentrically placed slightly above the centre of the face). Two highly vitrified stone fragments probably derived from the wall containing the tuyère and the strength of their erosion probably means the tuyère was not set within a wider cast iron plate, but directly within the stonework.

There were very few pieces of iron present to provide any evidence for the nature of the product. The evidence from the size of the SHCs, both in terms of dimensions and weights, suggests that the forge hearth was of reasonably large size and the work periods sufficiently 'lossy' as to indicate the forge was working on larger items and not simply undertaking, for instance, farrier work.

Residues from elsewhere within the excavations include a range of mostly dark glassy materials and vitrified rocks, commonly found with a coating of lime or embedded in lime mortar. These are interpreted as residues from lime-burning and occur as individual piece from up to fifteen contexts. Finds of clinker away from the smithy are less certainly attributable to iron working and may include residues from the burning of coal for other purposes. A single small fragment of ceramic (brick?) coated in slag that exhibits copper corrosion products is likely to have been derived from a crucible furnace working copper alloys.

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Methods

All materials were examined visually, using a low-powered binocular microscope where required. The catalogue of submitted material is presented in Table 1. The material has not been submitted to any form of instrumental analysis.

This assessment was conducted in February 2023 and was commissioned by Sian Rees.

Results

Iron smithing slags

Contexts associated with the post-medieval smithy yielded 18.2kg of smithing slags, mostly deriving from smithing hearth cakes (SHCs). SHCs form within the forge hearth in front of the tuyère or blowhole from the reaction between iron and iron oxide lost from the work piece and the fuel ash. They would typically be cleared from hearth by the smith between work periods.

There were fourteen SHCs that were more-or-less complete, ranging from 208g to 1715g, with a mean weight of 730g and a total weight of 10.2kg (approximately 56% of the recovered smithing slags).

The largest of these is somewhat irregular in shape and may possibly, like the slag mass with a weight of 2128g (discussed further below), not be a simple SHC, in which case the SHCs would be thirteen in number, ranging from 208g to 1385g, with a mean of 654g.

Most of the SHCs showed abundant evidence for the incorporation of large fragments of coal shale, indicating a rather poor-quality fuel. The size of these fragments (sometimes in excess of 50mm) also suggests the use of a coarse fuel particle size. The high shale content of the fuel may, at least in part, explain the relatively high weights recorded for the SHCs. The SHCs were mostly internally prilly, with abundant clasts of coked coal, which leads to the cakes being rather friable. Coal appears to have been the dominant fuel employed in Wales for smithing after approximately the 13th century.

The friable texture of the slag is typical of that of coal-fuelled hearth employing an iron tuyère. Such a hearth lacks the major input of silica from the ceramic of the earth wall (in hearths with a simple blowhole in a ceramic wall) or from a ceramic tuyère; the iron tuyere allows the hearth structure to be outside the hot-zone, so it does not melt and contribute to slag formation. With this source absent, slag is formed solely from the inorganic component of the fuel (known as the ash) and iron lost from the workpiece. Coal shale is typically very aluminous, making the slags generated relatively viscous. The generation of small viscous flows from the reaction leads to a prilly slag that tends not to coalesce into a compact slag puddle.

The largest slag mass (2128g) from the smithy comprised a lower substantial curved slag sheet, formed in contact with the hearth wall, which has a smooth blown top. The degree of melting of this slag and its large size suggest that may have formed in the hearth over more than one work period. The upper friable slag of this piece may represent slag generated during the last phase of hearth use before clearance. This potentially complex origin means that this piece is excluded from consideration of SHC sizes.

Two of the SHCs displayed partial impressions of tuyères on their rear faces., The tuyère tip had an external radius of approximately 65mm and a bore of 27mm at the front face (where it was eccentrically placed slightly above the centre of the face, at least in one of the examples) - although the rounded angles of the contact suggest these measurements would vary slightly immediately back from the face (i.e. the overall diameter could be slightly greater and bore slight less). The annular part of the tip in contact with the slag had a smooth convex surface. These features suggest the use of an iron tuyère, probably but not certainly, of cast iron.

Hearth materials

Two highly vitrified stone fragments from the smithy area were probably derived from the hearth wall containing the tuyère. One (from context (1301); a 200g piece of red siltstone) shows a high degree of erosion with the front face inclined back at 50° to the axis of the stone and a slag coating containing several small plates of stone, suggestive of a packing. The strength of the erosion probably means that the tuyère was not set within a wider cast iron plate, but directly within the stonework, so that this piece was in contact with the hot-zone of the hearth above the level of the blast.

A second fragment (from context (1308)) was of a 216g piece of coarse quartzite, also strongly heat-affected and with one edge worn back and slag coated but showing slightly less apparent erosion than the first.

The high degree of erosion. Particularly on the piece from context (1301)) probably indicates that the stones were set at a level above that of the tuyère, where the hot-zone would have expanded towards the hearth wall.

Fragments such as these would not necessarily derive from demolition of the earth, but could be the result of regular maintenance.

A 432g sandstone slab with adhering residues from (1301) demonstrated post-depositional accretion of the

residues to the stone by secondary iron oxides and is not indicative of a structural role in the smithy.

Glassy residues associated with lime

Greenish glassy residues were recovered from contexts (42), (715), (1755), (2435) and (3014). The last two were partially coated in lime mortar. The glasses are commonly darker in the interior than they are on the surface and several show devitrification spherules. These materials are interpreted to be of a calcium-rich glass formed during lime burning. They represent a reaction between the lime and a siliceous material, perhaps a sandstone in the kiln wall or accidentally incorporated in the charge.

Glassy slags of a much darker colour than the first group were found in contexts (521), (1330), (1367) and (1387). All of these were found with associated lime mortar. This group is interpreted as having a similar origin to the first, but to be formed from reaction of the lime with a less purely siliceous lithic material.

Context (1345) produced a fragment of somewhat similar dark glass, but in a more complex, porous form. This piece may simply be a more fluid component from the smithing slags, rather than sharing an origin with the other pieces in this group.

Vitrified stones

Partially melted lithic materials were recovered from contexts (51), (78), (114), (1955), (2250) and (3001). There are two potential origins for this material, firstly a similar origin in lime burning to the materials above, when pieces of other rocks were accidentally incorporated within the limestone charge and secondly when other rocks were accidentally incorporated alongside coal into a hearth (perhaps of the limekiln, but also possibly a metallurgical hearth or other high temperature coal-burning hearth).

Other materials

The assemblage included four examples of ‘exploded’ concretions from iron objects. The largest of these (from context (1432)) was a complexly-folded sheet iron object, perhaps a vessel. The other three (from contexts (1313), (1328) and (1333)) were from the area of the smithy and may represent pieces of iron lost during working. That from context (1313) was a tiny fragment of iron, that from (1328) was thin sheet iron and that from (1333) was again from a small, possibly angular, fragment.

A large (808g) dense rounded concretionary lump from context (1724) has a very crudely SHC-like shape but no core to the concretion is exposed to confirm or exclude this possibility.

A single small fragment (from context (1882)) of ceramic (brick?) coated in slag that exhibits copper corrosion products is likely to have been derived from a furnace or hearth (perhaps a crucible furnace) working copper alloys.

Other materials within the collection included some fragments of coal and some pieces of natural rock, particularly a fine-grained conglomerate with an iron-rich cement.

Interpretation

Iron smithing

The iron working residues indicate the working of iron in a coal-fuelled hearth. The fuel contained a high proportion of shale ‘dirt’. The hearth was blown through an iron tuyère, which was probably set into a stone hearth wall, rather than being mounted through a cast iron plate (e.g. as described by Moxon, 1703, but following his first edition of 1677).

The SHCs are moderately large, but there are few well-described post-medieval coal-fuelled assemblages with which to compare them. There is a body of analysed coal-fuelled smithing slags of Roman age, but these were formed in hearths with a ceramic wall/tuyère.

The large size of the SHCs in the present assemblage is partly because of the dirty fuel, but there is still a significant amount of iron in each SHC, so the tasks being undertaken in each work period involved the loss of a few hundred grams of iron. The work was therefore not that of a simple farrier for instance, but something involving the processing of larger quantities of iron, and most likely the denser SHCs at least were generated during ‘lossy’ processes that probably included welding and other higher temperature activities.

The assemblage does not permit any comment on the scale of the operation, since the residues recovered were mainly associated directly with the smithy, they will not represent the main focus of waste deposition.

The nature of the materials, and the locations in which they were recovered, does little to help elucidate the layout of the smithy. In typical post-medieval smithies, the forge hearth is separated from the bellows by a short wall that both protects the bellows and commonly acts as one support for hood or chimney. The most common arrangement (for a right-handed smith) is to have the bellows to the left of the hearth (with the stub wall between) and with an exterior wall running behind both, to support the chimney. The hearth is typically set well away from a door, to make it easier to observe the colour (temperature) of the metal. In this case, there is little to guide a reconstruction of the arrangement, but the obvious location for the forge hearth would be against the south wall. The combined length of the bellows and the hearth would probably be approximately 4m, so they would easily have been accommodated here. It is possible that the infilled doorway in the southern wall may have been used in the installation, either to hold the timber framing for the bellows supports or perhaps as a route for the construction of the chimney.

Unfortunately, the later digging of pits [1327] and [1367]) may have removed all trace of the footings for the hearth and the supports for the bellows. If the above suggestion for the layout is correct, then the bellows would have been against the eastern part of the southern wall and the anvil within the body of the western part of the room.

Further work

No further investigation of the materials is recommended.

References

MOXON, J.,1703. *Mechanik exercise or the doctrine of handy works*. 412pp.

YOUNG, T.P. 2018. Archaeometallurgical residues from Cleevelands, Bishop's Cleeve, Gloucestershire. *GeoArch Report 2018/12*, 95pp.

Table 1. Catalogue of materials from Haverfordwest Priory submitted for investigation, grouped by box and context. Assm = assemblage of small pieces/dust, SHC = smithing hearth cake

Context	Item wt.	Item no.	Item notes
box 300			
1301	200	1	burnt red siltstone with eroded curved face at around 50° to axis of stone
1301	1165	1	160x120x80mm, dense plano-convex SHC, top rises slightly forward, dense, rear shows impression of curved surface of tuyère tip, external 65mm internal 35mm
	1715	1	large crudely plano-convex mass of friable open-textured slag, 160x230x80mm (bowl 50mm), very large friable SHC, possibly slightly incomplete
	950	1	110x170x85mm (bowl 70mm), slightly biconvex well-formed SHC with raised smoothish top, base very granular, friable
	894	1	120x160x95mm (bowl 65mm), porous SHC, top smooth but dimpled, base prilly and friable
	432	1	sandstone block with concreted dark smithy floor material. Coal dust, coke, sand, possible slag, all in secondary iron mineralisation
1302	540	1	120x100x80mm, friable block from a large SHC
	306	1	85x90x50mm, small plano-convex SHC with broadly dimpled top and more finely dimpled base
	80	1	stone
	92	1	60x70x30mm, wedge shaped piece with dimpled surface, probably a detached fragment from a larger mass
	14	1	lobate slag over large coke fragments
	1060	1	170x130x100mm block of open-textured porous slag, way up and completeness uncertain
box 301			
1305	1810	1	mass 240x160x100mm; curving slab of smooth-topped slag 30-50mm thick, internally glassy and dense, attached to this is 130x150x50mm more open porous slag, with large coked clasts and voids
	318	6	fragments broken from above
1308	826	1	SHC, internally prilly with abundant coked inclusions, plano-convex except for shale slab sticking out of top at a high angle, 160x130x70mm plus shale clast which rises 35mm
	208	1	100x125x50mm, plano-convex SHC, smooth top with protruding shale clasts,
	202	1	ball of SHC material, 70x105x60mm, rolled up SHC, unclear if complete
	208	3	fragment of SHC material, openly prilly with abundant coke
1308	472	1	very neat concavo-convex SHC with bowl shaped base, 130x115x50mm, with 50x70mm and 20mm deep depression in centre
	352	1	slab of SHC material, probably almost whole mass formed possibly on inclined surface
	228	1	possibly slightly rolled lump of SHC material, probably not a complete SHC

1308	286	1	100x115x50mm (35mm bowl), thin neat plano-convex SHC, base smooth, top flat smooth and dimpled
	48	1	sub-cuboidal block with highly lustrous surface with abundant vesicles, probably cored on shale fragment
	1385	1	190x140x100mm (bowl 60 mm), bowl neat, rather triangular in plan, biconvex, dimpled top to bowl overlain by similar material extending up an extra 40mm
	236	1	very irregular block of open slag, rich in shale fragments, just possibly an SHC, but probably only a fragment
	434	1	95x160x60mm, open textured SHC, approximately semi-circular in plan
	146	1	lateral fragment of very open-textured SHC, rich in coked clasts
1308	216	1	burnt stone with vitrified surface, markedly slagged surface over rounded corner. Stone is a quartzitic sandstone, disaggregating polygonal grains
box 345			
1311	552	4	2 large slag fragments - one from curved sheet the other an almost complete small SHC (242g) and two smaller fragments
1312	34.78	7	clinker/clinkery slag fragments
1313	432	12	fragments of clinkery iron slag
	16.32	5	black glass in blebs, drawn out lengths and prills
	9.29	3	exploded small iron fragment
1314	770	1	105x130x80mm (bowl 50mm), 65mm diameter imprint of tuyère, eccentric 27mm bore, 28mm above base, very dense SHC, fragmental - but this impression is enhanced by accreted fragmental material
	184	1	rather fragmental SHC fragment
1322	54.71	4	glass blebby clinkery slags
	10.57	1	decalcified stone fragment, appears to have quartz-rich vein, possibly as inclusion in slag?
1328	442	1	100x120x65mm (bowl 50mm) neat SHC with some dimpled slag piled on dimpled planar top, base has neat smooth dimpled slag surface
	304	3	clinkery iron slag fragments
	72	assm	exploded fragments of concretion containing sheet iron
1330	30	1	finger like slag flow of dark glass with blue surface bloom (cf black grape), pale lime adhering
	26	1	clinker on reddish shale fragment
1333	900	1	elongate mass with nearly curved basal contact surface, top very irregular raised slightly lobate clinkery slags, 220x130x90mm
	102	assm	debris apparently from concretion of smithy floor material around small iron fragment

1336	340	1	central section from a smallish SHC, clinkery slag, porous
	74	1	fragment of clinkery iron slag
1338	104	19	small fragments of clinkery slag, some bleb like some dominated by coke, but all similar to components of the unconsolidated SHCs
1345	8.6	1	black vesicular glass in porous mass, some sand possibly integrated in one face
1367	26.12	1	partially devitrified dark, almost black glass with adhering lime mortar
	4.49	1	low density clinker fragment
1371	208	2	dense iron slag fragments, weathered, coke/shale inclusions
1387	82	1	complex flowed mass of dark glass (black with hint of blue) coated in lime mortar
box 376			
42	12.15	1	small fragment of pale green slag with abundant sub-spherical vesicles. Around some vesicles the slag is more completely glassy, pale green
51	5.53	1	rather variegated fuel ash slag fragment - orange core, reddish exterior locally white on outside, probably bloated fragment of coal shale origin?
	108	1	fine-grained sandstone slab, partially melted, variable grey and reddish glaze over surfaces
78	108	1	partially melted (almost totally melted) slab, probably originally stone, dark glass with specks, surface, dark green and tan colours with adhering lime
114	58	1	curved slab of vesicular grey material c18mm thick, voids flattened parallel to overall form, lime attached to outside. Slab could be ceramic, but most likely stone
320	36.13	1	natural ferricrete with small, mostly angular lithic clasts set in dark ferruginous silt/fine sand matrix
521	6.97	1	dark translucent glass in rounded bleb, 22x16x8mm, sandy mortar attached to piece
715	44	1	dark variegated vesicular glass in elongate viscous lobe with light green/khaki surface, with attached lime
1000	120	2	material grades between crystalline clinker with moulds bearing coke and a cleaner khaki glass in possible flow lobes.
1432	416	2	concretionary material containing mineralised folded iron sheet. Original morphology unclear, folded multiple times within each block, larger piece 160x90mm, unclear how smaller piece abuts

1447	36	1	glassy slag with large rounded voids and some probable coke particles
1474	106	1	very large slab of coal shale with clinker coating
1475	52	1	clinker-coated bloated shale fragment
1550	386	1	ferricrete - fine natural conglomerate in rounded mass. Mixture of angular and rounded clasts
1555	196	1	large rounded piece of vesicular 'bloated stone', dark greenish vesicular slag, some lime coatings on surfaces and in voids, tan coloured smooth external glaze
1708	808	1	100x130x75mm, rounded slightly rusty appearing concretionary mass, crudely plano-convex, so most likely to be SHC but core not visible
1724	58	1	dark clinker containing clasts of red sandstone altering to variegated vesicular fuel ash pieces
1755	36	2	broken nub of green glass, with white devitrification spherules
1882	21.52	1	margin of brick with coarse quartz temper, overlain by dark grey slag with multiple points of secondary copper minerals
1955	76	1	dark rich glass locally very slightly maroon on surface, lime, in a form suggesting coating of a stone, gaps in glaze hint at contacts with other stones
2250	114	1	fine grain sandstone showing partial melting, part of piece shows bloating, raising and disrupting the external thin clear green glaze
2435	46	1	very dark green partially devitrified glass, grading into lime mortar with coal fragments
2506	428	3	natural ferricrete, fine conglomerate of particles to approximately 5mm set in ferruginous matrix - locally dark and fresh, mostly yellow brown, particles both round and angular lithics
3001	26.82	1	small fragment of fine sandstone (?) with a multi-coloured translucent superficial glaze, varying from clear -green-violet- yellow- violet.
3014	6.44	1	small fragment of glass in lime mortar, glass is variably devitrifying, mostly very dark green, locally marron on surface and in one area grades into more opaque blue vesicular slag
3015	14.41	1	coal
3551	14.97	1	coal

Table 2: summary of distribution of material classes by context. Weights in g.

Context	Context notes	SHC	clinker	hearth	green/ black glass	vitrified stone	iron	conc ?slag	Cu slag	coal	natural
42	Rubble layer to E and NE of N transept				12						
51						114					
78	Post diss rubble in crossing and S side of N transept					108					
114	Stone and mortar footings in alcove in N transept					58					
320	Upper fill of graves 319										36
521	Monastic make-up layer near garden wall S of presbytery				7						
715	Fill of post-Diss pit E of presbytery				44						
1000	Fill of Pit 106		120								
1301	Topsoil nave above smithy	4724		200							432
1302	Soil below topsoil above smithy	2012									80
1305	Same as 1301	2128									
1308	Layer and fill of hollow below 1305, within smithy on north side	4983	48	216							
1311	Pile of slag and ash (with stones / oyster shell) on N side of smithy	552									
1312	Thin black layer on floor of smithy	35									
1313	Post Diss rubble, N side of nave	448					9				
1314	Dump of black soil and ash similar to 1311/1308	954									
1322	Stone, slate/crushed mortar layer – levelling up of rubble for smithy construction		65								
1328	Fil of pit within smithy, S side, against nave wall	746					72				
1330	Rubble/soil layer – possibly base layer for smithy construction		26		30						
1333	Black fill of pit 1332, deriving from smithy activity	900					102				
1336	Lower fill of pit, below 1328	414									
1339	Charcoal fil of scoop 1338, rounded bottom	104									
1345	Fill of posthole 1344, associated with smithy activity				9						
1367	Fill of pit 1366, in SW corner of nave		4		26						
1371	Rubble in nave	208									
1387	Post-med blocking of nave SW doorway, associated with smithy activity				82						
1432	Disturbed rubble, NW cloister						416				
1447	Upper fill cloister drain NW section, contaminated by Rahbula excavation		36								
1474	Same as 1447		106								
1475	Same as 1475		52								
1550	Diss layer contaminated by pit fill 106, N transept										386
1555	Same as 1550		196								
1708								808			
1724			58								
1755	robber trench in Upper fill N cloister walk				36						
1882	slate layer over S cloister walk								22		
1955	Post Diss rubble by riverside					76					
2250	Fill of centre cloister garden feature					114					
2435	rubble layer below collapse E of chapter house /slype				46						
2506	Disturbed (by Clapham) upper fill of grave 2505										428
3001	Topsoil Site F					27					
3014	Slate/mortar collapse mid west of Site F (south)				6						
3015	Same as 3014									14	
3551	Late rubble									15	

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