

# GeoArch

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Proposal for analysis of  
archaeometallurgical residues from  
Culmstock Road, Hemyock

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## Assessment Methods

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

The material in the site archive (Table 1) is a hand-picked collection of material, mostly collected from a large slag dump, estimated to contain several tonnes of slag, with a lesser amount from the adjacent cut features.

This project was commissioned by Naomi Payne, of AC Archaeology.

This report presents the case for a programme of further analysis of the bloomery iron smelting slag assemblage from Culmstock Road, Hemyock, Devon. The assemblage is currently undated. The report is not a formal assessment of the assemblage.

## Analytical Proposal

### General:

The assemblage comprises a coherent suite of residues from the bloomery smelting of iron. Slag morphology indicates that this was undertaken in a non-slag tapping furnace, of the type known as a slagpit furnace, because the slag produced during a smelt accumulates in a pit below the base of the furnace shaft.

Slagpit furnaces were employed in Britain as the main variety of furnace in the Iron Age, becoming largely replaced by various other furnace types around the period of the Roman invasion. After the Roman period

the slagpit furnace was again employed, possibly reintroduced to Britain from both the west, where the type had continued in use in Ireland, and from the east, where similar furnaces had been employed outside the Roman Empire in Denmark and adjacent areas.

A high priority of the post-excavation programme should be to acquire high-quality dates from the site.

The purpose of the analysis would be two-fold:

- Detailed investigation of the residues would enhance the description and understanding of the technology. This particularly important as the significance of the difference between examples of slagpit furnaces in both space and time is not well-understood. This is exemplified by the variation between the evidence from this site (as currently understood) and sites at Churchills Farm (also in Hemyock; Young 2103) and Burlescombe (Reed *et al.* 2006).
- The chemical analyses of the residues should allow construction of a mass-balance description of the reaction (using the techniques of Thomas & Young 1999a and b). This approach allows some estimate of quantification of the smelting process, allowing an estimate of yield and permitting some modelling of the overall assemblage in terms of production.

The technical analysis of the residues should be accompanied by a thorough review of the nature of the metallurgical structures so that the residues may be related to their originating furnaces/hearths.

### Method Statement:

Selected samples will be 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. Polished blocks for investigation optically and on the SEM are prepared in the Earth Science Department, The Open University. Electron microscopy will be undertaken on the LEO S360 analytical electron microscope in the School of Earth and Ocean Sciences, Cardiff University. Microanalysis will be undertaken using the system's Oxford Instruments INCA ENERGY energy-dispersive x-ray analysis system (EDX).

Chemical analysis will be undertaken using two techniques. The major elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, and P) will be 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) will be undertaken using a sample in solution on the ThermoElemental X-series Inductively-Coupled Plasma Mass Spectrometer (ICP-MS) in the School of Earth and Ocean Sciences, Cardiff University (this also generates lower quality results for Fe, Mn, Ti, P that are used mainly for QA purposes).

#### **Sample Selection:**

The assemblage to be investigated comprises materials hand-picked from the excavation in the field. These have been catalogued (Table 1) and a series of representative materials identified (Table 2). Sampling has deliberately avoided the large 'furnace bottom' masses which are to be left intact,

In order to interpret the residues as an assemblage the analytical campaign needs to incorporate samples of furnace lining and ore, as well as a broad selection of the different classes of slag. In order to test variation, at just a minimum level, wherever possible more than one sample of each type should be investigated. Unless there are specific reasons so to do, we do not normally investigate the furnace lining samples by SEM (there chemical contribution to the reaction is the main motivation for their investigation, rather than their ceramic properties).

The suggested programme of analysis therefore comprises (Table 2):

1. Chemical analysis of two furnace lining pieces.
2. Chemical and microstructural analysis of two ore specimens.
3. Chemical and microstructural analysis of six slag specimens (burr region x2, slag bowl margin x2, dense flow slag, basal slag puddle).

#### **Costing:**

At current prices the full chemical analyses are £100 and the microstructural investigations are £200 each. Reporting and management is £300 per day.

Total cost for analysis is  $10 * £100$  plus  $8 * £200 =$   
 $£1000 + £1600 = £2600$   
 Reporting/data processing: 4 days = £1200  
 Total cost £3800

#### **Notes:**

These costings are valid for 12 months. GeoArch is not currently registered for VAT, so VAT is not chargeable on the above amounts. However, it is possible that GeoArch will be required to register during the period of validity of the quote, in which case VAT would become chargeable on part of the above costs.

## References

- REED, S.J., JULEFF, G. & BAYER, O.J. 2006. Three late Saxon iron-smelting furnaces at Burlescombe, Devon. *Proceedings of the Devon Archaeological Society*, **64**, 71-122.
- THOMAS, G.R. & YOUNG, T.P. 1999a. A graphical method to determine furnace efficiency and lining contribution to Romano-British bloomery iron-making slags (Bristol Channel Orefield, UK). *In*: YOUNG, S.M.M., BUDD, P.D., IXER, R.A. and POLLARD, A.M. (eds). *Metals in Antiquity*, British Archaeological Reports International Series, **792**, 223-226. Archaeopress, Oxford.
- THOMAS G.R. & YOUNG, T.P. 1999b. Bloomery furnace mass balance and efficiency. *In*: POLLARD, A.M. (ed) *Geoarchaeology: exploration, environments, resources*, Geological Society of London, Special Publication, 165, 155-164.
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Table 1: summary catalogue of archaeometallurgical residues and associated materials from Culmstock Road, Hemyock, by bag.

Context	Context note	Weight	Number	Notes	Sample
4	spread of iron smelting debris	1070	1	dense flow, rather like poorly developed tapslag, but with wood impressions on all faces, including passing at high angle through the flow-lobed surface. Top crudely flow-lobed in broad lobes with variably smooth/rough surfaces, outer margin formed of rounded lobes, suggesting top of slag fill in pit, with inclined non-wetted surface below, inclined at 60 degrees, before being lost in fuel moulds, 70mm thick	
		1100	1	dense margin of FB; well-formed non-wetted lobate surface, terminating ?upwards in narrow lobate edge, some lobes of tapslag like material on presumed top, even with some slight maroon colour; abundant moderately large fuel moulds internally, some small and round, most larger and angular	
		910	1	slab from wall of bowl, with steeper (60 degree upper part shallowing to c.45 degrees, 50-70mm below top). Upper part of section finely granular in appearance, overlying moulds are separated by very thin horizontal lobes, outer layer shows very thin dark brittle sheets, possibly extending behind face of visible clay lining.	
		410	1	very dense, dark, brittle flow slag, with outer non-wetted lobate surface very well developed, curving downwards from 60 to 45 degrees. Upper face is probably a very large non-wetted fuel contact. Slag is internally highly vesicular in places with bladed crystals in others	
		5100	1	220x190x130mm irregular block of rather variable slag, locally with well-formed but small internal prills, passes a mass of more granular-appearing slag and charcoal debris.	
		348	1	planar slab of oxidised and vitrified lining with well-formed buried vitrified surface, 120x90x38mm, earlier face buried up to 25mm below later	HCR1
		424	1	overhanging (?) reduced-fired vitrified furnace wall, dark glazed grey ceramic passes in 80mm . Wall contains at least 4 internal vitrified surfaces, with laminated clay between, over up to 50mm. Front face is pad of rusty lining slag - could be just below blowhole, although no hint of oxidation.	
		430	1	block of reduced-fired clay with multiple internal surfaces, whose stratigraphy appears to match piece above, but no join found,	
		554	1	dense flow slag mass, with rather poorly-developed non-wetted wall contact. Large irregular voids after fuel, has small possible ore clast, and face near one end shows some reddening	
		326	1	block of possibly roasted, low-grade ore, has thin dark goethite skins around patches of red, ruddy, clay	HCR3
		538	1	irregular block of very dense, very dark, flow slag, with large wood impressions, including roundwood c30mm diameter as well as angular pieces	
		448	1	irregular lobate slag mass, resembling lip of bowl described above, slightly rusty broad lobes on top with abundant large wood clasts, lower face is a strangely convex lobate surface - possibly from contact with a large wood block	
		2850	1	large curving 'along-wall' block of dense flow slag with large wood moulds. Curvature suggest pit of c.450mm diameter at this height. Wood up to 160mm x 40mm, 270mm length of outer face seen, by 150mm wide - although orientation is not clear	
		846	1	large mass with crudely lobate surface (viscous flow?), part of which is secondarily haematized; wood to over 100 mm long and greater than 50x30mm section; probably from lip of bowl with 45 degree inclined margin	
		376	1	arcuate mass from near burr with layer of well-formed dark flow lobes 35mm thick, extending into wall by up to 50mm behind front face, front face mainly slightly glazed but deeply vitrified ceramic; burr formed along shaft/pit join perhaps?	HCR5

Context	Context note	Weight	Number	Notes	Sample
		1170	1	probable large burr fragment, but front face is completely accreted in fine rusty material with organics, so detail not known	
		368	1	plano-convex mass of microprilly slag with large grey clay inclusion on base; superficially resembles SHC, but probably a fragment of bowl crust, 90x80x40mm; base very dark, shiny, non-wetted prills; top irregular; slag grey, vesicular, with other brown glassy inclusions that may also be wall fragments	
		236	1	angular fragment of FB with coarsely-crystalline slag and well-formed large wood moulds	
		1945	1	large slab of slag from pit wall, well-formed outer face with some indurated clay attached; inner face dirty, not well seen, rather irregular slag with small charcoal moulds	
		1135	1	large block of complex flow slag with wood moulds, including slag casts of moulds; all rather fragmented; prills typically quite small except near convex outer face; very large wood moulds with cracking, including a strange one which is rounded and bowl-like 60x80mm preserved	
		2320	1	large block from margin of FB bowl; 130mm deep fragment with edge suggestive of c.400mm diameter; margin shows dense crust to 30mm at top thinning downwards; side inclined at c60mm but flattening downwards; wood to 130x40x30mm, much of which is inclined down the side; upper part of outside with regular lobed horizontal non-wetted lines, becoming simple and smoother downwards; base of piece becomes more finely prilly and friable.	HCR6
		3550	1	large block of prilly FB - variable between well-formed prilly areas and somewhat more chaotic with fine charcoal; a few impressions of wood, but not well developed; orientation of block uncertain.	
		2480	1	large FB block, irregular and orientation difficult to ascertain, but appears to include rod-like mass of downward flows penetrating down outside an inclined wood slab, 100x100x50mm or larger; lots of good moulds including many of curved split round c30mm diameter	HCR7
		2235	1	large FB block, outside shows well-formed prills, with just a hint of grass in places possibly, wood moulds are large - possibly including faces of some large diameter roundwood; all good flow slag	
		1705	1	large FB block with good moulds, including up to 40mm diameter roundwood (possibly split in half); wood with large cracks; outer face well developed prills mostly, become more planar at one end; material 90mm thick off outer face, orientation uncertain	
		1245	1	very dense dark slag flowing around very large wood moulds, angular >50x40mm, rounded >60x30mm	
		636	1	large FB fragment with coarsely lobate lip; extending at very shallow angle in thin sheet with prilly loose base and compact smooth top with fuel impressions; if this part of top is an overall wood impression (not certain) then it is >100x30x90mm	
		214	1	slab of vitrified lining, with variable but oxidised rear, up to 25mm of lining slag on face.	
		762	1	fragment of exceptionally dense tapslag-like puddle with broad dark flow lobes up to 60mm across; very long internal crystals, little vesicularity, basal lobes very dark, metallic sheen; wood impressions present, but slightly coarse because of the large non-wetted lobe size.	HCR8
		1415	1	very dense mass of flow slag with multiple very large wood moulds; mixture of quite large prills and smaller ones; dense, black, almost metallic lustre; probably >130mm thick; multiple wood pieces >120mm long	
		1110	1	irregular block of FB passing from more friable material with dished surface, passing into material with larger wood moulds; orientation uncertain	

Context	Context note	Weight	Number	Notes	Sample
		1010	1	block from FB margin, with characteristic lobes as in other pieces, as also seen before shows around 5 horizontal lobe layers on non-wetted margin, above more rough but planar material; curious form of base may suggest dislocation of crust fragment upwards when material around still fluid	HCR9
		966	1	block of low-density yellow brown goethitic/limonite iron ore, grey massive texture with yellow-coated voids	HCR4
		5285	1	double burr structure, superimposed, with planar front margin, forming margin to deep plano-convex bowl side; upper face of which has dimpled/whispy texture; internally massive, but becomes charcoal rich on distal base; reminiscent of form of burr on piece from c77; chord c. 330mm across with burr extending out 140mm,(or 360mm across extending back 180mm depending on which bit of burr is back); maximum crust thickness 60mm; 50mm wide on planar top as seen; 140mm deep	HCR10
		1215	1	angular block of friable slag, rich in large wood fragments and debris (including some still carbonaceous material)	
		650	1	dense flow slag with external lobes and internal large wood fragments, including thin planar lobes; very dense	
		296	1	reduced-fired lining slags, with some partial refacing; rear starts to go reddish in one margin; unaltered clay to rear seems to show significant organic temper.	HCR2
		350	1	small irregular rusty mass of charcoal -rich slag	
		642	1	irregular mass of dark very dense slag of smoothly lobate form; appears to be an essentially isolated mass, base prilly; possibly from distal edge of base of mass?	
17	sample23	2465	1	all fragments of ceramic bracketing layers rich in crushed slags and with some denser flows, backing ceramic variable indurated	
	total for sample 23 = 9468g	568	1		
		518	1		
		530	1		
		742	1		
		662	1		
		416	1		
		174	1		
		594	1		
		514	1		
		2285	1		
17	sample 22	c23kg	1	burr area of cake with surviving blowing wall and lower part of blowhole. 230x420mm wide and 210 deep. Back of burr to front of blowhole 140mm (40mm grey reduced, then straight margin, then 100mm oxidised-fired clay). Tip of blowhole 55mm in front of wall below, 55mm above rough top of mass which is 150mm thick; open recess below blowhole is 280mm wide; to the side of blowhole non-wetted black slag extends all the way to rear of burr- not clear if this is intrusive or a former margin; blowhole founded on straight margin; overall at least 4 up to 40mm thick relinings, with front relining approximately 60mm in front of blowhole	

Context	Context note	Weight	Number	Notes	Sample
48	f27	3150 324 550	1 (3) 1 1	370mm wide, 220 mm tall almost planar wall, with centrally thickened slag layer and rusty clots; reduced-fired fragment as above (both pieces show a relining event), maximum overall thickness is 70mm thick. concavo-convex lump of dense prilly slag, 110x90x60mm, probably FB rather than SHC fragment	
50	sample 13	2580 1165 66	1 (4) 6 1	fragments of planar (just one end marginally oxidised) reduced-fired wall, 310x210mm, with evidence for 1 relining further fragments of similar wall, but joins could not be found small fragment of low density friable charcoal-rich slag	
74	cut 26	7400 2790 1750 6945	1 1 1 (4) 1	large burr, with microprilly slag against relined reduced fired lining - highly indurated irregular block of slag rich in fine charcoal, prills poorly developed similar morphology of just very slightly dished relined planar wall to earlier wall, very slight reddening one end, central area of more glass and rusty blebs large block of finely prilly charcoal rich slag; outer face shows charcoal , but also some striated areas - just possibly a trace of grass -but might also be crushed charcoal texture.	
77	fill of furnace 14	13kg	1	one end of burr is marked by large slag tube passing down wall - 50x35mm oval section.	

Table 2: List of samples selected for analysis. All selected samples from c4.

Sample	Weight	Type	Notes
HCR1	348	Clay	planar slab of oxidised and vitrified lining with well-formed buried vitrified surface, 120x90x38mm, earlier face buried up to 25mm below later
HCR2	296	Clay	reduced-fired lining slags, with some partial refacing; rear starts to go reddish in one margin; unaltered clay to rear seems to show significant organic temper.
HCR3	326	Ore	block of possibly roasted, low-grade ore, has thin dark goethite skins around patches of red, ruddly, clay
HCR4	966	Ore	block of low-density yellow brown goethitic/limonite iron ore, grey massive texture with yellow-coated voids
HCR5	376	Slag	arcuate mass from near burr with layer of well-formed dark flow lobes 35mm thick, extending into wall by up to 50mm behind front face, front face mainly slightly glazed but deeply vitrified ceramic; burr formed along shaft/pit join perhaps?
HCR6	2320	Slag	large block from margin of FB bowl; 130mm deep fragment with edge suggestive of c.400mm diameter; margin shows dense crust to 30mm at top thinning downwards; side inclined at c60mm but flattening downwards; wood to 130x40x30mm, much of which is inclined down the side; upper part of outside with regular lobed horizontal non-wetted lines, becoming simple and smoother downwards; base of piece becomes more finely prilly and friable.
HCR7	2480	Slag	large FB block, irregular and orientation difficult to ascertain, but appears to include rod-like mass of downward flows penetrating down outside an inclined wood slab, 100x100x50mm or larger; lots of good moulds including many of curved split round c30mm diameter
HCR8	762	Slag	fragment of exceptionally dense tapslag-like puddle with broad dark flow lobes up to 60mm across; very long internal crystals, little vesicularity, basal lobes very dark, metallic sheen; wood impressions present, but slightly coarse because of the large non-wetted lobe size.
HCR9	1010	Slag	block from FB margin, with characteristic lobes as in other pieces, as also seen before shows around 5 horizontal lobe layers on non-wetted margin, above more rough but planar material; curious form of base may suggest dislocation of crust fragment upwards when material around still fluid
HCR10	5285	Slag	double burr structure, superimposed, with planar front margin, forming margin to deep plano-convex bowl side; upper face of which has dimpled/whispy texture; internally massive, but becomes charcoal rich on distal base; reminiscent of form of burr on piece from c77; chord c. 330mm across with burr extending out 140mm,(or 360mm across extending back 180mm depending on which bit of burr is back); maximum crust thickness 60mm; 50mm wide on planar top as seen; 140mm deep



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