GeoArch

Report 2008/13

Evaluation of archaeometallurgical residues from the M74 Completion: WP5, The Govan Ironworks Foundry

Dr Tim Young
11th August 2008

Evaluation of archaeometallurgical residues from the M74 Completion: WP5, The Govan Ironworks Foundry

Dr T.P. Young

Abstract

The report provides an assessment of potential for the archaeometallurgical residues sampled at the Govan Ironworks Foundry (Work Package 5 on the M74 Completion).The assessment has been broadly conducted according to the MAP2 principles and this report contains recommendations for those samples to be taken forward to further analysis, with details and justification of the recommended analysis. Although a wide range of processes are represented with the foundry works, the truncation of the stratigraphy and the large scale of the operation mean that usage contexts were either not produced or are not preserved. Once waste materials were moved across the site for disposal, it becomes very difficult, if not impossible to link deposits of residues with their originating processes and structures. Accordingly, despite the large size of this site, only a relatively modest programme of detailed analysis is proposed here.

71 of the samples taken from WP5 were assessed; 12 from the Lower English buildings were assessed because they had been identified as metallurgical by the store managers in Edinburgh, but were not prioritised by the archaeologists and will not proceed to analysis; 59 samples assessed from the foundry were largely at the recommendation of the excavator. Of those 59, 5 samples were not available for assessment. 20 samples were selected (on a problem-oriented basis) for taking forward for further investigation, including 2 of the samples which were not available for the assessment (but which have subsequently been located).

The assemblage from the Govan Ironworks comprises several distinct components. Firstly there are deposits, mainly of blast furnace slag, although areas of burnt coal shale (from coke making and/or from the steam boilers?) and refining (presumably puddling) slags also occur, which were employed as make-up of the area upon which the Govan Ironworks Foundry was built.

Secondly, some areas around the moulding shop have occurrences of slag which may be associated with the melting furnaces. Structural evidence suggests the presences of both reverbatory and cupola furnaces; detailed investigation of the melting furnace slags to attempt to identify the two processes should be one aim of the analysis phase. The moulding shop sand bed is another residue associated with the casting process.

A third group is formed of residues from the hot working of iron. These residues were primarily microresidues with both spheroidal and flake hammerscale. These were recovered not only from the hearths in the buildings recorded as the smithy and boiler shop, but also from the late Structure 14, where particularly large and thick flake hammerscale occurred and interpretation of the processes operating in Structure 14 should be a major aim of the analysis phase.

The fourth set of residues comprises waste from the finishing of the castings. The finishing shop produced rather few deposits, but one sunken feature contained swarf.

A fifth group of residues are perhaps not strictly metallurgical. This group includes fuel residues of various types. These include materials (mainly soot and vitrified brick) sampled from the hot gas flues. None of this group has been listed for additional analysis since they would not be appropriate for addressing the identified questions. The group also includes burnt and unburnt coal from variety of locations around the site. Finally the group also includes coke from the area of the coking kilns.

Contents

Methods

All investigated materials were examined visually, using a low-powered binocular microscope where necessary. All significant materials were summarily described and recorded to a database (Table 1).

As an evaluation, the materials were not subjected to any high-magnification optical inspection, nor to any other form of instrumental analysis. The identifications of materials in this report are therefore necessarily limited and must be regarded as provisional.

The assessment involved 71 samples, mainly selected according to priorities identified by the archaeological project officer (Sophie Nicol), of which 5 samples were not available for inspection (probably temporarily mislaid in the division of samples between Glasgow and Edinburgh stores).

12 of the samples that had been prepared for the assessment by the Edinburgh staff were from the Lower English Buildings. Most of these were fuel residues and potentially domestic rather than industrial

In this report, where reference is made to structure by name (e.g. the turning shop), this is in reference to the descriptions given to those buildings on the 1857 1st Edition Ordnance Survey, which is not necessarily indicative of the actual usage of the structure at any particular time.

Results

The archaeometallurgical residues sampled on this site may be divided into broad several categories, here listed in order of the *chaîne operatoire*:-

1. Iron Smelting: the residues from the blast furnaces (themselves outside the excavated area of the ironworks) occur widely on the foundry site, principally as make-up or levelling deposits. These occur across the entire site and are dominated by tips of blast furnace slag, although they are intermingled with fuel (coal) residues and refining slags in some areas.

The blast furnace slags are very variable, but typically with pale crystalline forms, of varying degrees of vesicularity and density, associated with glassy slags, mainly of a bluish colour.

Such slags can be broadly interpreted as the waste materials from a hot-blast blast furnace.

2. Iron refining: a lesser quantity of iron refining slags is also present in the make-up, possibly associated with a rebuild of the cupola furnaces. Iron refining is the process of turning the raw pig iron from the blast furnaces into wrought iron. Wrought iron can be formed into shape by forging or rolling – and would have been the raw material employed in most activities in the boiler shop and smithy (see hot working residues below). No details of the variety of puddling undertaken at Govan are currently available. Iron refining would have been carried out in the malleable works, to the north of the investigated area.

3. Iron melting for foundry work: various slag deposits and apparent floor build-ups around the moulding shop area are believed to be residues from the melting furnaces. The slags are variable, with brown glassy slag and a dense pale crystalline slag apparently being the two commonest textures. Structural evidence suggests that both cupolas and reverbatory furnaces were present, but at present it is not possible to assign the slags to either furnace type.

Most of the probable melting slags are broken into fairly small pieces, but one pit in the moulding shop contained blocks of a large dense flow.

In addition to the slags, the residues from iron casting also include the foundry sands themselves, The deposit of foundry sand within the moulding shop was locally over 4m deep; samples can be analysed to examine the nature of the used casting sand

4. Hot working residues: the hot forming of wrought iron by forging and/or rolling is mainly represented by fines – mainly flake hammerscale. This is the result of the oxidation of the surface of the hot iron, with the resultant oxide-rich scale falling from the iron as it cools or is worked. Lesser amounts of spheroidal hammerscale are present; this is the spatter formed when wrought iron is compressed, particularly during forge welding, with slag droplets being expelled from the iron and chilling in the air.

The hot working residues are found in negative features in three structures – those labelled the smithy and boiler shop on the 1857 map, and the later Structure 14 in the west of the site. The fines deposits in the smithy and boiler shop are contained with sunken bases to firebrick structures, which are interpreted as forge hearths. The most likely interpretation of these structures is that they are the bases of waist-level hearths floored with iron plates supported on the brick stub walls. The sunken interiors, and the external iron cladding on one example from the smithy, are likely to be attempts to control rising damp. In this interpretation the residues contained within the brick bases must have percolated through gaps in the structure, so form a somewhat modified rather in-situ assemblage.

Differences are visible between the assemblages from the different buildings, with those from Structure 14 being formed of particular large pieces of thick scale. This difference is worthy of careful investigation – for it suggests heavier work was undertaken in Structure 14 – perhaps either the preparation of large forgings, or rolling, or even possibly a small refining works. The most likely furnace location in Structure 14 was unfortunately entirely robbed out.

The boiler shop shows two brick hearth bases of rather complicated, multi-chambered design – presumably to support a wide hearth. The northern chamber (below the tuyère?) of each hearth contained fuel (coal)

residues, but no scale according to visual inspection (2086, 2088). In contrast, one of the two simpler bases in the smithy produced quantities (2060) of scale, although the other had a similar fuel-dominated assemblage (2133).

5. Finishing of ferrous castings: swarf from a finishing process was recovered from a brick-built pit in the turning shop. Similar residues do not appear to have been recovered from the finishing shop.

6. Fuel residues: residues from the burning of coal, including burnt coal shale, coke, coal dust and clinker, occur widely across the site. Such materials are rarely found in association with a particular process. Coke was found in large quantities around the coking kilns.

It is likely that some of the coal burning residues are associated with some of the hot-working of iron, but much is likely to be derived from the firing of the works' boilers (although with the foundry complex the boilers appear to have employed waste heat).

Evaluation of potential

The archaeometallurgical residues from the Govan Ironworks Foundry ought to be able to provide considerable insight into mid-19th century foundry practices, because they represent construction at a point sometime fairly soon after 1837 (when the main section of the ironworks was built), a relatively short period of subsequent use and then abandonment of the foundry site before 1892.

The potential of the assemblage is limited, however, by the depth of truncation of the archaeological deposits below foundry floor level and by the principle that in large works there is little opportunity for residues to accumulate near their point of origin, for the large amounts of residue generated mean that efficient off-site disposal mechanisms must operate. None-the-less, residue assemblages from the moulding shop area will be able to shed some light on the activities which were undertaken therein.

The residue assemblages are able to address particular local issues; in particular, aspects of the hot working of iron for which the residues may provide the major physical evidence for the nature of the activities. It is to be hoped that analysis of slags from the early make-up layer will provide evidence for the nature of iron-making at Govan Ironworks in the late 1830s/early 1840s; a period for which some aspects of output were provided by Scrivenor (1854).

A list of samples which are recommended to form the basis for the investigations in the Analysis Phase is provided in Table 2. The technical questions that can be addressed through investigation of the residues are varied dependent upon the materials themselves:

1. Iron smelting (*blast furnace) slags*: chemical analysis to determine the nature of the flux and possibly the yield.
Samples 2048, 2053, 2120, 2124

2. Iron refining slags: documentation of the refining slags may lead to an interpretation of the puddling process involved.
Samples 2117, 2147

3. Iron melting slags: residues from cupolas and reverbatory furnaces from this period have not yet been documented.
Samples 2042, 2047, 2076
4. Residues from the hot-working of iron: analysis of the micro-residues should help to clarify the nature of the processes involved within the various buildings
Samples 2060, 2086, 2088, 2133, 2137, 2144

5. Residues from the finishing of ferrous castings: the machine swarf may be able to shed light on then nature of the machining undertaken as well as providing direct evidence for the particular type(s) of iron involved.
Sample 2123

6. Fuel residues: the chemistry of the fuel residues will assist with the interpretation of the iron working fines in (5).
Samples 2086, 2088

7. Floor samples: these may assist with interpretation of the nature of structures where in-situ accumulations occur.
Samples 2061, 2152, ?(from 22283)

8. Foundry moulding sand: analysis will clarify the nature of the sand, possibly identify the additives and also indentify the contaminants from use.
Sample 2121

References

Scrivenor, H. 1854 . *History of the iron trade.* 2nd Ed. London

Summary Catalogue

sample	*context*	*Notes*	*Location notes*
LEB			
2003	20539	brownish deposit dominated by burnt shale fragments, some amalgamated by crude clinkery deposits, but mainly isolated debris	
2004	20542	for environmental	
2005	20733	dark deposit, some stone and brick fragments and a little sand, dominated by coal ranging up to several 10s of mm	
2006	20564	for environmental	
2007	20804	dark deposit, some stone and sand but dominated by coal fines	
2011	20561	red sandy deposit, with stones and a few slag fragments	
2012	20632	brownish soil containing pale blast furnace-type slags but in very small flows. Several pieces show very flat surfaces with right angle re-entrant angles - suggest formation in contact with something. Also contains a block of amorphous iron	
2014	21018	coal burning resides - small clinker blebs and shale and coal. No large clinker blocks	
2018	20096	yellow brown gravelly soil	
2020	20211	brownish rubble deposit with wide variety of slag stone and brick clasts	
2024	21093	black deposit, appears to be dominated by coal dust and fragments. Locally a little sandy, and has decomposed mortar? And brick fragments	
2024	21093	black deposit apparently large amounts of coal fines. Also has small amounts of probable flake hammerscale in coarse and bubbly pieces. Also has small spheroids - some white - which might be fuel residues rather than scale	
2025	21093	apparently fine grained fuel waste - small clinker blebs and many micro-spheroids in black fine matrix	
Foundry			
2031	22068	two deeply and very smoothly vitrified bricks	
2033	22007	black fine matrix bearing comminuted slag debris, also has brick fragments and stone debris	
2034	22198	brick with slagged surface	
2037	22046	Glasgow?	make up for boiler shop
2039	22300	sample has three large pieces of dark glassy slag, one tending to dark and crystalline, one brick with slight maroon surface layer, 1 dark coloured wall slag	make -up layer?
2040	22383	brick samples with strong slagging going around the right angle	
2042		large, but fairly low-density bear-like block	in moulding shop - many blocks of this in a pit - ?a broken-up flow, near N wall
2044	22499	sandy brown soil with occasional shale and brick fragments at least one Fe object	
2047	22286	collection from surface in str16, slag include greenish glassy blast furnace slag, dense dark granular, fired bricks etc	moulding shop
2048	22543	small nubs of pale blast furnace-type slag. Fairly homogeneous collection. Pale vesicular	make up, towards n of site, str20
2052	22635	brownish soil with abundant fresh mudstone fragments, but dominated by rusty concretionary masses - suggests corrosion of iron debris - but iron seems to have gone. Also several iron nails and coiled piece of iron wire.	
2053	22061	coarse blast furnace type of slag deposit. Several distinct slag types - stony blast furnace type, which is surprisingly dense, and which grades into a blue glassy surface. Also a black glass with a wrinkled flow surface, which grades downwards into a highly vesicular material. Also a few pieces of forge slag - a slightly flowed clinker bearing abundant shale debris.	good makeup for yard surface

sample	context	Notes	Location notes
2054	22239	dominated by brownish shale residues. Also has some clinker blebs and probably small spheroids too. Some possible coke fragments	
2059	22411	brown soil with variable casts including scale fragments and sag debris. Some of it is cemented into this sheets - but these are dominantly fine grained.	
2060	22726	dominated by fuel residues - both coal and clinker. But black matrix is rich in hammerscale, both flake and spheroidal. Window glass (thin)	small smithy hearth
2061	22139	coarse sandy/gritty concreted floor layer. Very few real slag inclusions	small late building, Se of pattern shop use unknown
2069	22319	blast furnace-type slag. Brown-blue dense even glasses with conchoidal fracture. Pale crystalline slags, often rather more vesicular and lower density.	
2075	22803	mixed debris in fine dark matrix - includes several large iron rich concretions, blast furnace slag and brick	in turning shop lathe? pit
2076	22803	rusty but mainly non magnetic dense, one edge looks like corroded iron. Looks like a puddle - but iron or slag or mixture? Single large block	in turning shop lathe? pit
2080	22077	silty coal fines occasionally cemented around decayed iron, but mainly friable	railway past smithy
2083	22790	dark greyish brown sandy soil with small slag fragments. Some coherent fragments suggest a bedded deposit with orange brown sandy clay layers between the dominant dark	
2086	22363	coke, coal and occasional small clinker piece	smithy hearth, in boiler shop
2088	22512	coke blocks and coal debris	smithy hearth, in boiler shop
2089	22070	not opened - strong hydrocarbon small	
2090	22456	highly corroded material, possibly iron sheeting c20-25mm thick with sediment, mainly sand but with a little coke and scale adhering to one side. Actively corroding and weeping	
2093	22938	large sample of good coke fragments from kilns	coke from kilns
2096	22936	mainly coke fragments, some dense clinker, some attached to coal piece, dense magnetic slag fragment, matrix has some scale (f and s) including some strange thick variety with ropey surface	
2106	23071	friable but substantial clinker blocks, with shale fragments - in black matrix of uncertain nature - stored in water	
2113	22570	black mud bearing quartz granules, large coal and coal\hale fragments, plus small brick fragments	
2114	22336	bricks with granular black growth on surface - looks like manganese oxide - although presumably not	
2117	22769	large blocks of refining slags Good ropey flows	associated with rebuild of area around cupolas?
2117	22769	mainly refining slags, also some coal lumps, plus clinkery fragments	ditto
2119	20213	organic rich material, but dominated by fine fired coal shale debris	
2120	22969	brownish clayey sand mixed with lots of coal fines. Larger clasts are mainly blast furnace-type slags - including white crystalline types through to large pieces of brown glass	makeup
2121	22422	black fine sand, occasional clasts of sandstone, ironstone and rusted iron nails?	moulding shop deep bed >4m
2123	22945	wood rich deposit, black ,locally rusted and concreted. Slag contained is really flint conchoidally-fracturing glass, mainly cream, but locally more bluish and swirled	sample for swarf
2124	23119	coarse blocks of blast furnace-type slag. Variable flow size. Dominantly white and stony with frequent coke inclusions and dimpled coke-rich base. Some pieces quite dense, others more vesicular, but no really low density types.	makeup
2127	23127	reddened deposit from near duct	
2133	22806	black deposit dominated by coal/coke fines. Some lumps of greyish clay included	fill of hearth in S end of smithy
2133	22806	mainly coal debris, but a few pale vesicular slag fragments, lump of brown clay, plenty of spheroids.	ditto
2136	23148	Glasgow?	Structure14 flue

sample	*context*	*Notes*	*Location notes*
2137	23150	dark deposit, also containing some brown clay, very rich in flake hammerscale. One large accretionary mass suggests that some iron ay be present too. Slag flats and blisters also rarely present.	Structure 14 W end of site - late building
2138	23213	bricks, rather degraded, wet ones looking rather soft where broken, some sandy material between bricks, Vitrified surface shows etching, with chert pebbles standing proud of surface. Fabric reduced near this surface, both other wise pale pink. Very fine grained with rounded chert gravel inclusions	
2140	23025	Glasgow?	
2141	22425	soot	
2142	22425	soft pliable material - presumably essentially soot	
2144	23149	deposit formed almost entirely of very thick flake hammerscale, a few nubs of fresh coal	Str14 W end of site - late building
2145	23203	dark grey (mainly) slag sheet - has even flow surface. Internally shows relicts of small chert pebbles indicating this is a wall-slag block	T shaped flue feature in NW
2146	23203	like 2145 - but clearly essentially failed bricks	T shaped flue feature in NW
2147	22336	Glasgow?	Flow from flue near furnace
2148	23229	soot	
2149	23230	soot	
2150	23055	soot	
2151	22004	tarmac laid on base of classic late blast furnace slag, pale frothy and ropy textures	
2152	22067	large block of very hard laminated concreted layer resting on fragments of glassy blast furnace-type slag up to 80mm across. Floor has lots of gravel grade material, both natural stone and slag	
2203	20539	Fuel residue. Some of the burnt shale fragments are really quite large and delicate	
?	20609	pale bricks - no metallurgical residues	Robber cut near “chimney”, end of turning shop
?	22082	dark clayey soil with stones, bracken fragments, coal shale material (unburnt)	
?	22580	large blocks of highly vesicular pale blast furnace-type slag	Make up below structure 12
?	22283	Glasgow?	"floor" in moulding shop
?	22881	square headed bolt wit hex nut c150mm long, large slab of curved iron c15mm thick, granular corrosion, ?ladle fragment	Deposit near tank finishing shop

Table 1: Summary description of samples by container (i.e. Some samples may be represented by more than one container). Sample numbers in bold with shaded background indicate samples prioritised by the field archaeologists. Samples described as “Glasgow?” are currently missing from the archive in Edinburgh and may still be in Glasgow, although some samples are believed to have been lost. LEB = Lower English Buildings.

Samples proposed for further investigation

sample	*context*	*description*	*material of interest*	*location*	*objective*
2042	22421	large block, fragment of a large slag flow	melting furnace slag?	pit in moulding shop	interpret this melting furnace (?) slag
2047	22286	greenish glassy and dense dark granular slags	melting furnace slag?	surface of moulding shop	identify melting furnace slags
2048	22543	small nubs of pale blast furnace-type slag	blast furnace slags	make-up from N of site, near Structure 13	describe representative blast furnace slag make-up
2053	22061	coarse blast furnace type of slag deposit.	blast furnace slags	make-up from yard surface	describe representative blast furnace slag make-up
2060	22726	fuel residues rich in hammerscale	hot working fines	smithy hearth in N of smithy	describe and interpret
2061	22139	coarse sandy/gritty concreted floor layer.	floor	gritty floor of building SE of pattern shop	identify floor use
2076	22803	large puddle-like block possibly both slag and iron	melting furnace slag?	finishing shop	identify
2086	22363	coke, coal and occasional small clinker piece	Fuel residues	Boiler shop, hearth base	describe and interpret
2088	22512	coke blocks and coal debris	Fuel residues	Boiler shop hearth base	describe and interpret
2117	22769	large blocks of refining slags	refining slag	make-up from area of rebuilt cupolas	describe representative refining slags
2120	22969	variable make-up with blast furnace slags	blast furnace slags	make-up with wide variety of blast furnace slags	describe representative blast furnace slag make-up
2121	22422	black fine sand	used moulding sand	moulding shop - black sand	describe nature of sand bed
2123	22945	black wood rich concreted deposit from pit	swarf	fill of wood-lined pit in turning shop	sample swarf and identify metal and finishing process
2124	23119	coarse blocks of blast furnace-type slag.	blast furnace slags	coarse blast furnace slag make-up	describe representative blast furnace slag make-up
2133	22806	mainly coal debris, with many spheroids.	hot working fines	hearth in S of smithy	describe and interpret
2137	23150	dark deposit very rich in flake hammerscale.	hot working fines	pit in Structure 14	describe and interpret
2144	23149	thick flake hammerscale	hot working fines	machine base in Structure 14	describe and interpret
2147	22336	not yet seen	iron?	within gas flue	describe and interpret
2152	22067	laminated concreted layer resting on blast furnace-type slag	floor	concreted floor from finishing shop	identify floor use
?	22283	not yet seen	floor	"floor" in moulding shop	describe and interpret

Table 2. Samples from WP5 for which further investigation during the analysis phase is suggested.

GeoArch

geoarchaeological, archaeometallurgical & geophysical investigations

54 Heol y Cadno,
Thornhill,
Cardiff,
CF14 9DY.

Mobile: 07802 413704
Fax: 08700 547366
E-Mail: Tim.Young@GeoArch.co.uk
Web: www.GeoArch.co.uk