7.6.1.4 Tarbat slag report

Cecily Spall with Catherine Mortimer

1.0 INTRODUCTION

A total of *c*.590kg of slag was recovered from excavation across Sector 1 and 2 between 1994 and 2007. The assemblage recovered up to 2004 was assessed rapidly by Dawn MacLaren and Gemma Cruikshanks, National Museums Scotland in 2006 and slags associated with smelting and smithing were identified and full cataloguing was recommended. A further three seasons of excavation also produced slag and vitrified material and the entire assemblage was subsequently catalogued in 2011-12.

2.0 SUMMARY OF ASSEMBLAGE

2.1 Recovery method

No on-site sub-sampling regime was implemented during fieldwork and the assemblage represents all slags excavated, collected either by hand (3-D positioned or recovered by feature) or recovered by the site soil sampling strategy. For a full description of the strategy see Data Structure Reports; in summary, deposits were bulk sampled for coarse-sieving (100% or min.100l whichever was the greater) and further samples passed through a Sirāf tank (1mm mesh; min.10l or 100% if associated with metallurgical processes) capturing smaller grade slag and micro-slags which were collected by scanning a magnet through dry flotation residues sieved to 2mm and 500micron grade.

2.2 Recording methodology

The Tarbat material was identified visually and sorted into type, weighed, measured where appropriate and as far as possible identified as belonging to one of the following categories:

dense slag (ds); ferruginous concretion with hammerscale (fc); flake or spheroidal hammerscale (hs); fuelash slag (fs); smithing hearth bottom (shb); *tap slag (ts); tuyère (ty); undiagnostic iron-working slag (uis)*; *vitrified furnace lining (vfl)*.

Hearth bottoms/slag cakes were measured (diam. or length and width x thickness) and weighed, or where incomplete the diameter and/or the percentage of the whole represented were estimated allowing the weight to be estimated. The *shb* dimensions were then tabulated to allow comparison of dimensions in relation to mass and density. Assemblages of hammerscale were scanned visually and estimates of the ratio of flake to spheroidal hammerscale recorded (noted as f:s in the catalogue). Good examples of smithing hearth bottoms illustrating the range of sizes, tap slag, hammerscale, vitrified furnace lining with evidence for tuyère holes and diagnostic tuyère fragments were selected for photographic recording and illustration.

2.3 Reconstructing metallurgical processes

Iron-working begins with the bloomery process of *smelting* ore to win an iron bloom, followed by *primary smithing* whereby the slag-rich, spongy bloom is consolidated into a billet by hammering, followed by *secondary smithing* of a billet into objects. The first two stages happen at one site and are immediately sequential, while secondary smithing, i.e. the production of wrought objects from consolidated billets, can take place at a later stage and at a different site along with the maintenance and repair of items and recycling of scrap. Each stage requires a range of resources and in turn produces a range of waste products, some diagnostic allowing these metallurgical stages to be identified in overview.

Smelting produces diagnostic tap or rake slag, the former being a liquid 'gangue' of non-iron minerals, primarily silicates, released in a liquid state from the furnace shaft through a tapping arch in the furnace base or allowed to pool at the base producing dense slag cakes. Tap slag was identified within the assemblage by its characteristic blue-black appearance probably indicative of high manganese content and its flowing surface morphology and vesicular structure. Tap slag is relatively brittle and at Tarbat was often recovered in angular fragments which conjoined within context groups. Raked slag is the product of the gangue being manually removed from the furnace shaft while still hot and plastic, although none was identified among the Tarbat residues.

Smelting slag cakes are plano- or concavo-convex in form and can sometimes be differentiated from smithing hearth bottoms on morphological grounds as they tend to be less vesicular or denser and can have run surfaces similar to tap slag. Where the distinction can be made visually identification has been reinforced by comparing mean density (McDonnell 1994, 230). Morphologically, differentiation between these types of slag at Tarbat was difficult. Tap slag was recorded on the surface of plano-convex and concavo-convex or bowl-shaped slag cakes but very rarely. Differentiation within the Tarbat assemblage was attempted by calculating density of all the slag cakes (*shbs*). Volume was calculated using πr^2 or πab (a=half length, b= half width) x thickness; density was then calculated by $m/v=g/cm^3$. Unfortunately, distinct cohorts were not identified with density ranging across a spectrum from 0.3 to 2.3 with rare outliers. Comparison with data from Howe where the mean density of smelting cakes and smithing hearth bottoms was recorded (here using the above calculation) as $1.7g/cm^3$ and $1.3g/cm^3$ suggests that both types of slag cakes are in fact present in all periods at Tarbat, but actual the point of departure between the two is not clear within the recorded data.

Primary smithing produces amorphous smithing slags and large thick flake hammerscale and high relative percentages of spheroidal hammerscale. Flake hammerscale is formed by oxides dislodged from the surface of hot iron by hammering both during consolidation of a bloom and during secondary smithing; spheroidal hammerscale is formed when molten droplets of oxides are expelled under pressure and harden in the air during primary smithing of a bloom and during fire welding (McDonnell 1984; 1986a; Starley 1995).

Secondary smithing also produces flake and spheroidal hammerscale, amorphous smithing slag and smithing hearth bottoms (*shbs*) which are characteristically plano- or concavo-convex in form. Compositionally, they are primarily fayalitic (iron silicates). In a couple of instances double *shbs*, one formed on top of the other, were recorded indicating two episodes of smithing had taken place before removal of the slag cake from the smithing hearth. Where pieces of slag were clearly derived from a fragmented *shb* it was catalogued as dense slag; these were recorded frequently since *shbs* are characteristically brittle and easily shattered (Bachman 1982, 5). Where recorded the make-up tended to be vesicular throughout. Ferruginous concretions – *fc* – were recorded characterised by brightly coloured rust deposits and hammerscale could sometimes be discerned within the make-up. These are considered to be smaller grade smithing residues including amorphous slag and hammerscale which have become fused into a single mass by post-depositional processes but may represent the floor surfaces of iron-working areas.

Recent studies using high-speed film have confirmed that spheroidal hammerscale can be the result of molten oxides expelled during the closing of a fire weld (Dungworth and Wilkes 2009; McDonnell 1986a, 146; Young 2011). A range of spheroidal microslags, some known as combustion spheres, can also be produced during primary smithing by accidental burning of the iron when over heated; these can only be differentiated from spheroidal hammerscale by microscopic examination, but it has been assumed that the Tarbat spheroidal scale is indicative of fire welding techniques.

All stages of iron-working can produce residues which are not diagnostic of smithing stages or other high temperature processes. Vitrified furnace lining (*vhl*) has a characteristic appearance of a black to grey vitrified, glassy interior and brightly coloured (red to orange) oxidised exterior with grey cinder margins. *Vhl* is not necessarily diagnostic of any stage or iron-working or actually metal-working *per se*. Nevertheless the material was sometimes noted adhering to the edge of slag cakes and was almost exclusively recovered from features and deposits which also yielded other iron-working residues. Blowing holes for tuyères were frequently recogniseable in the Tarbat examples demonstrating as a minimum that the hearth linings derived from a structure which required concentrated oxygen input and therefore probably not domestic in nature.

Other material was more broadly indicative of high-temperature processes not necessarily connected with iron-working including a quantity of 'fuelash slag' sometimes recorded at other sites as 'cinder'.

3.0 CATALOGUE

3.1 Overview of the assemblage

Sector 1 produced an assemblage of *c*.21kg of slag and by contrast Sector 2 produced *c*.560kg being the focus for craft-working throughout all periods (Table 1). A catalogue was compiled during recording and forms part of the online archive for the project (OLA).

Table 1 Summary of slag by sector and intervention

Sector	Int.	Weight (kg)
1	11	20.82
	25	0.53
	Total	21.35
2	8	17.11
	14	263.40
	24	269.10

	26	19.19
	Total	568.80
	Grand total	**590.15**

Most bloomery and smithing sites normally produce less than 200kgs of slags (McDonnell 1989, 1991; Photos-Jones 2006, 137; 2010a) and the Tarbat assemblage can be considered to be substantial, one of the largest recovered in Scotland. Comparison with other sites, including multi-period sites and from urban and rural locations, confirms the comparatively sizeable assemblage (Table 2).

Table 2 Slag quantities from sites in Britain and Ireland

Site	**Quantity of slags**	**Period** (Tarbat equivalent period)
Coppergate, York	248kg	Roman, Anglo-Scan to medieval (McDonnell 1992)(3/4)
Fishergate, York	220kg	Roman, Anglo-Saxon to medieval (McDonnell 1993)(2-4) Roman, Anglo-Saxon to medieval (Mortimer 2005)(2-4)
Walmgate, York	138kg	medieval and late-medieval (MacNab 2003)(4)
St Andrewgate, York	95kg	medieval and late medieval (Mortimer 2004)(4)
Eilean Donan Castle, Ross-shire	120kg	medieval (Mortimer 2009; Starley 2010)(4)
Killickaweeny, Co. Westmeath	86kg	9th to 10th century (Photos Jones 2010b)(3)
Hoddom, Dumfriesshire	250kg	10th to 12th century (Photos-Jones 2006)
Brough of Birsay	14kg	8th to 12th century (McDonnell 1986b)(2/3)
Dornoch, Sutherland	12kg	8th to 15th century (Coleman and Photos-Jones 2008)(2/3)
Johnstone I, Co.Westmeath	2000kg	6th to 16th century (Photos Jones 2010a)(1-4)
Lowpark, Co. Mayo	1372kg	early medieval (Wallace 2010)(2/3)
Seafield, Inverness	9kg	Iron Age (Heald, McDonnell and Mack 2011)(0)

4.0 METALLURGICAL ACTIVITY BY PERIOD

The data recorded are presented in Table 3 by period and metallurgical process.

The majority of material derived from late Period 4 deposits (15th to 16th century) and included slags indicative of both iron smelting and smithing (73%). A possible smelting hearth and the stance of a smiddy were identified in the field. Overall, much less material derived from deposits and features of Period 1 to 3 (6th to 11th century)(3%; 11%; 14%), but iron smithing was identified in all these periods with a relative emphasis on this activity during Period 3 along with some evidence for smelting.

Table 3 Summary of assemblage and activity by period

Activity	**Classification**	**Weight by period (kg)**

		Period 1	Period 2	Period 3	Period 4	Total
Smelting	tap slag	-	0.13	1.29	4.31	5.73
Smithing	smithing hearth bottom	2.82	12.38	19.98	192.13	227.31
	dense slag	3.91	5.50	25.69	107.97	143.08
	hammerscale	-	0.01	0.88	0.06	0.94
	ferruginous concretion with h'scale	-	0.14	1.83	2.86	4.83
Undiag.	undiagnostic ironworking slag	2.64	9.73	56.18	115.24	183.80
Metallurgical/ high temperature process	vitrified hearth/furnace lining	-	0.12	3.07	7.28	10.47
	fuelash slag	0.02	3.68	8.65	0.86	13.20
Grand total		**18.79**	**63.38**	**82.17**	**430.71**	**590.15**

4.1 Period 1

A group of Period 1 features yielded small quantities of smithing slags (*ds*, *uis* and *shbs*). Several features which produced these slags belonged to Structure 11 or lay close-by. Structure 11 hearth 14-24/F535, gully 14-24/F547 and adjacent slag-filled pit 14-24/F560 yielded just over 2.3kg of undiagnostic iron-smithing and dense slag which indicates that secondary smithing was probably being undertaken in the building. Other slags recovered from Period 1 backfills and layers included four smithing hearth bottoms (14-24/F435, C3529 and C3177).

4.2 Period 2

More than half of the iron-working slags recovered from Sector 1 derived from Period 2 deposits and frequently from features belonging to Structure 1 (*c*.11kgs). The range of slags indicates secondary smithing was being undertaken in the building or nearby, although the quantity recovered does not indicate intensive activity. The make-up of the assemblage from nearby Period 2 features reflects that recovered from features belonging to Structure 1 and the assemblage recovered from the building has therefore been assigned to Period 2 occupation. Features from within Structure 1 (11/F49, F53, F65, F114, F130, F135, F138, F147, F390, F408, F426, F429, F472 and F484) produced about 1kg of slags, primarily fragments of dense slag and undiagnostic smithing slag along with four incidences of flake hammerscale recorded in small quantities and a smithing hearth bottom. Nearby Period 2 deposits trapped in the sinking fills of Period 1 ditch 11/F176=25/F179 produced over 4.5kg of slags including dense slag (recorded with adhering vitrified furnace lining), smithing hearth bottoms, vitrified furnace lining and a single possible instance of tap slag, although given that the fragment is isolated and small it most probably represents fayalitic run slag from smithing given the make-up of the associated assemblage. Nearby Period 2 features 11/F34 and 11/F401 produced 5.6kgs of slags including five smithing hearth bottoms and vitrified furnace lining.

Within Sector 2 just over 12kg of slags were recovered from Period 2 features and deposits. Too little was recovered from Period 1 for the Period 2 assemblage to be considered residual indicating that smithing activity continued. The slags were recovered from secondary deposits and the locus for the activity was not identified with only 4.4g of flake hammerscale recovered. Fuelash slag was frequently recorded (3.5kg) and may relate to a range of high temperature craft-working and domestic processes and to the fire destruction of structures which marks the end of the period.

Slags recovered from Period 2 deposits and features included seven *shbs*, *ds*, *uss* and *vfl*; again small occurrences of possible tap slag were recorded although fayalitic run slag is a more likely identification.

Slags were recovered from the backfill of the Period 2 enclosure ditch (8/F36) where the feature was sampled within Intervention 8, but these are assigned to Period 4 activity; elsewhere the feature is levelled early in Period 4.

4.3 Period 3

A more significant component of the assemblage (109kg) was recovered from deposits of Period 3 origin, notably including from primary metal-working dumps. The assemblage was restricted to Sector 2 and indicated that both iron smelting and smithing was being undertaken.

A total of nearly 3kgs of *ts* was recorded from Period 3 strata indicating that smelting was being undertaken, although none could be associated with specific features. A similar quantity of *vfl* was also recorded along with 0.8kg of *ty* fragments including a single, complete tuyère (24/7116) recovered from deposits which made up the Period 3 metal-working terrace. The tuyère may be related to small, clay-built non-ferrous metal-working hearths which characterise the Period 3 metal-working complex.

The period also produced the most hammerscale (876g), accounted for largely by a single deposit from a pit (14-24/F288 C1667) which was extremely rich in hammerscale producing (0.61kg). The quantity and ratio of 1:10 spheroidal to flake *hs* signals fire-welding was taking place nearby, although no features directly associated with iron-working were identified.

The Period 3 assemblage comprised *c*.20kgs of *shbs* and *c*.26kgs of *ds*, some of which is likely to represent shattered *shbs* along with 56kgs of *uss*. A notably large *shb* was recorded measuring 240mm l x 200m w x 80mm t and weighing 3.1kgs. The cake may represent a large smelting furnace base or indicate that large objects were being smithed. Comparison of the mean mass and dimensions of all Period 3 cakes with those recorded on other early medieval sites indicates that the Tarbat cakes are significantly larger overall (Table 4).

Table 4 Mean mass and diameter of slag cakes from early medieval sites in Britain

Site	**Mean mass**	**Standard Dev.**	**Mean diam.**	**Standard Dev.**
Tarbat n=25	991g	747	132mm	35
Coppergate (McDonnell 1992, 475) n=163	385g	304	95mm	30

Fishergate (McDonnell 1993, 1225) n=46	460g	265	100mm	20
Wharram Percy (McDonnell 2000, 156) n=22	369g	-	95mm	-
Brough of Birsay (McDonnell 1986b, 201) n=21	158g		57mm	-

Period 3 also produced the greatest quantity of fuelash slag (over 8.5kgs). This material generally consisted of very lightweight vitrified material, predominantly with a high silica content where this could be discerned. The deposits which yielded quantities of the material could largely be identified with the primary burning horizon at the site suggesting the origin of the material could have been the site-wide conflagration which destroyed Structure 9 and affected upstanding features across the northern part of Sector 2.

4.4 Period 4

The majority of the material was recovered from deposits of Period 4 origin. The material was recovered from secondary soil layers which characterise the period across Sector 2 and also from isolated deposits traps, such as the late fills of Period 3 ditches and hollows created by subsiding Period 2 feature fills. The material was distributed fairly widely across the infilled monastic pool and within a concentrated area identified as the floor of a medieval smiddy associated with the remains of drystone walls. Unfortunately the smithy was identified during post-excavation and no recovery of microslags in the field was undertaken.

Evidence for smelting took the form of a single possible smelting hearth (14-24/F11) and was recorded as a stone-lined shallow pit measuring *c*.0.6m in diameter. A total of 1.5kgs of *ts* was recovered from the feature along with 0.65kgs of *uis* and 0.20kg of *vfl*. Other evidence for smelting was recorded in the form of 1.25kgs of tap slag and a slag cake with tap slag on its surface.

Evidence for secondary smithing was dominated by a smithy identified as an open-fronted stone-built structure measuring 9m x 10m in plan abutting a stone-walled enclosure. The walls enclosed a large spread of concreted slag which included patches of *in situ* burning and some lenses of discolouration from copper-alloy perhaps from brazing. Slag recovered from this deposit (14-24/F109) and from nearby features included 13 *shbs* including two double *shbs*, along with 6.6kg of ds. Hammerscale was recorded from associated slag spread 14-24/C1496. The wall core of an adjacent wall was filled with complete *shbs* (14-24/F189) while 32 others were recovered from a nearby spread of rubbly hardcore (14-24/C1326).

Examples of excavated smithies are few and comparable rural smithies include a 14th and 15th century examples from Goltho and Burton Dassett. The dimensions of the Tarbat smiddy are broadly comparable with the structures identified at these two sites (Goltho 8m x 4m; Burton Dassett 14 x 15m)(McDonnell 2000, 165).

Again the size and weight of the Period 4 *shbs* are exceptionally large and compare well with an assemblage of *shbs* recovered from Eilean Donan Castle (Table 5). The *shbs* from Eilean Donan are associated with a late medieval episode of smithing of large iron items; a hearth filled with slags was radiocarbon-dated to 1450-1640AD (95%)(Starley 2010). Items smithed at Tarbat are also likely to have been sizeable and, although speculative may have included the manufacture of arms. Evidence for late medieval clan-based ironworking has been detected at Highland sites and is thought to have been stimulated by inter-clan warfare and conflict (Atkinson 2003).

Table 5 Mean mass and diameter of slag cakes from medieval sites in the Highlands

Site	**Mean mass**	**Standard dev.**	**Mean diameter**	**Standard dev.**
Tarbat n=77	1242	682	132	28
Eilean Donan Castle (Starley 2010) n=39	1165g	723	139	28

4.4.1 Iron sources

The iron smelted at Tarbat during Period 3 and late Period 4 was almost certainly won from roasted bog ore. Alternative sources of iron ore from geological strata - carbonate, haematite and limonite - are not found nearby (Tylecote 1986, 124-5). The underlying solid geology of iron-oxide-rich Old Red Sandstone coupled with the wet, boggy conditions of parts of the site from the Iron Age onwards would probably present ideal conditions for bog ore formation.

Iron smelting was identified across the firth at salvage excavations within the historic core of Dornoch in deposits of 8th to 15th-century date from which fragments of bog ore were positively identified (Colemand and Photos-Jones 2008, 13-15). A study of iron ore exploitation in the Highlands concluded that prior to the 17th century small-scale iron smelting won ore from regenerative bog deposits (Photos-Jones *et al* 1998).

References

Atkinson, J. 2003. 'Late Medieval Bloomery Sites: Settlement and Industry in the Scottish Highlands', in S. Govan (ed), pp35-44

Bachman, H. 1982. The Identification of Slags from Archaeological Sites, *Institute of Archaeology, Occasional Publication No.6*

Ballin-Smith, B. (ed) 1994. Howe: four millennia of Orkney Prehistory, Excavations 1972-82, Society of Antiquaries of Scotland Monograph Series No 9 (Edinburgh)

Carlin, N., Clarke, L. and Walsh, F. 2010. *The Archaeology of Life and Death in the Boyne Floodplain: The Linear Landscape of the M4, Kinnegad-Enfield-Kilcock motorway*, NRA Scheme Monographs 2

Coleman, R. and Photos-Jones, E. 2008. Early medieval settlement and ironworking in Dornoch, Sutherland: excavations at The Meadows Business Park, *Scottish Archaeological Internet Report* 28

Cressey, M. and Anderson, S. 2011. A Late Prehistoric Settlement and Metalworking Site at Seafield West, near Inverness, Highland, *Scottish Archaeological Internet Report* 47

Dungworth, D. and Wilkes, R. 2009. 'Understanding hammerscale: the use of high-speed film and electron microscopy', *Historical Metallurgy* 43(1): 33-46

Gillespie, R.F. and Kerrigan, G. 2010. *Of Troughs and Tuyères: the archaeology of the N5 Charlestown Bypass*, NRA Scheme Monographs 6

Govan, S. (ed) 2003. Medieval or Later Rural Settlement in Scotland: 10 Years On (Historic Scotland)

Photos Jones, E., Atkinson, J.A., Hall, A.J. and Banks, I. 1998. 'The bloomery mounds of the Scottish Highlands, Part 1: the archaeological background', *Historic Metallurgy* 32(1): 15-32

Heald, A., McDonnell, G.J. and Mack, I. 2011. in M. Cressey and S. Anderson 2011, pp 20-24

Hunter, J.R. 1986. Rescue excavations on the Brough of Birsay 1974-82, *Society of Antiquaries of Scotland Monograph Series*, No.4

Lowe, C. 2006. *Excavations at Hoddom, Dumfriesshire* (Society of Antiquaries of Scotland)

McDonnell, G.J. 1984. 'The study of early smithing residues', in B.G. Scott and H. Cleere (eds), pp 47-52

McDonnell, G.J. 1986a. The classification of early ironworking slags (unpublished PhD thesis, Aston University)

McDonnell, G.J. 1986b. 'Iron and Ironworking with technological discussion and analyses', in J.R. Hunter 1986, pp 198-203

McDonnell, G.J. 1989. 'Iron and its alloys in the fifth to eleventh centuries AD in England', *World Archaeology* 20: 373-82

McDonnell, G.J. 1991. 'The classification of slags from Launceston Castle, Cornwall', *Ancient Monuments Laboratory Report* 125/91

McDonnell, G.J. 1992. 'The ironworking residues', in P.J. Ottaway 1992, pp 476-485

McDonnell, G.J. 1993. 'Ironworking residues', in Rogers, N.S.H. 1993, pp1224-28

McDonnell, G.J. 1994. 'The Slag', in B. Ballin-Smith, pp 228-234

McDonnell, G.J. 2000. 'The Ironworking Evidence', in P.A. Stamper and R.A. Croft (eds) 2000, pp 155-166

Mortimer, C. 2005. 'Assessment of metalworking wastes', in C.A. Spall and N.J.Toop (eds) Excavations at Blue Bridge Lane and Fishergate House, York

Mortimer, C. 2009. 'Assessment of Metal-working debris from Eilean Donan Castle, Ross-shire' (unpublished technical report)

Ottaway, P.J. 1992. Anglo-Scandinavian Ironwork from Coppergate, *The Archaeology of York*, The Small Finds 17/6

Photos-Jones, E. 2006. 'Metallurgical waste', in C. Lowe. 2006, pp137-144

Photos Jones, E. 2010a. ‘Johnstown 1, Metallurgical waste’, in N. Carlin, L. Clarke and F. Walsh

Photos Jones, E. 2010b. ‘Killickaweeny 1, Metallurgical waste’, in N. Carlin, L. Clarke and F. Walsh

Scott, B.G. and Cleere. H. 1984. *Crafts of the Blacksmith* (Belfast)

Spall, C.A. and Toop, N.J. 2005. Excavations at Blue Bridge Lane and Fishergate House, www.archaeologicalplanningconsultancy.co.uk/mono/001

Starley, D, 1995. ‘Hammerscale’, Historical Metallurgy Society Datasheet 10

Starley, D. 2010. ‘Assessment of Metal-working debris from Eilean Donan Castle, Ross-shire’ (unpublished technical report)

Rogers, N.S.H. 1993. Anglian and Other Finds from 45-54 Fishergate, *The Archaeology of York*, The Small Finds, 17/9

Stamper P.A. and Croft R.A. 2000. *Wharram, A study of Settlement on the Wolds*, 7, The South Manor Area, (York University Archaeological Reports 10)

Tylecote, R.F. 1986. *The Prehistory of Metallurgy in the British Isles* (London: Institute of Metals)

Wallace, A. 2010. ‘Appendix VIIIb: Metallurgical Residues from Lowpark’, in R.F. Gillespie and A. Kerrigan

Young, T. 2011. ‘Some preliminary observations on hammerscale and its implications for understanding welding’, Historical Metallurgy 45(1): **-**