

## Iron-working in medieval Perth: a case of town and country?

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### ABSTRACT

*The established view of urban medieval iron-working in Scotland is that urban smiths depended on rural bloomeries for the supply of processed raw materials. This view is challenged on the basis of chemical/mineralogical analyses of industrial waste from several urban medieval excavations in and around the town of Perth. Archaeological evidence and the composition of iron-working debris in Perth suggests that the town smiths may not have been dependent on rural supply, but practised primary extraction themselves, thus controlling all aspects of output and development in the iron-working industry from perhaps as early as the 13th century. This paper is funded by Historic Scotland and forms part of ongoing research on the Scottish Bloomeries Project.*

### INTRODUCTION

The excavation of medieval urban settlements has been for the last 20 years a consistent feature of archaeological research in Scotland. A wealth of information is emerging about all aspects of the social and economic organization of the burghs during the medieval and post-medieval periods. Among the sites excavated a number show clear evidence of metal-working activities with associated artefacts and industrial debris (both ferrous and non-ferrous). These include excavations in Inverness (Wordsworth 1982), Perth (eg Holdsworth 1987; Bowler *et al* 1995; Cox 1996) and Edinburgh Castle (Driscoll & Yeoman 1997), to mention only a few. Forges and smithies are generally assumed to have been the locus of production of this industrial waste, despite the fact that some of this material seems on visual examination to have been derived from primary processes, like smelting.

Of all Scottish burghs, Perth has attracted most attention over the last 20 years with the 'largest and greatest number of excavations' (Holdsworth 1987, 13) and its development during the medieval period has been described in several publications (eg Simpson & Stevenson 1982; Spearman *et al* 1988). Industrial waste was retrieved from a number of excavated sites within the town, and from contexts ranging in date from the 12th to the 16th centuries. This paper cites examples from several excavations both in the town and its hinterland, but focuses on three sites, in particular, which have produced evidence for hearths ascribed to industrial rather than

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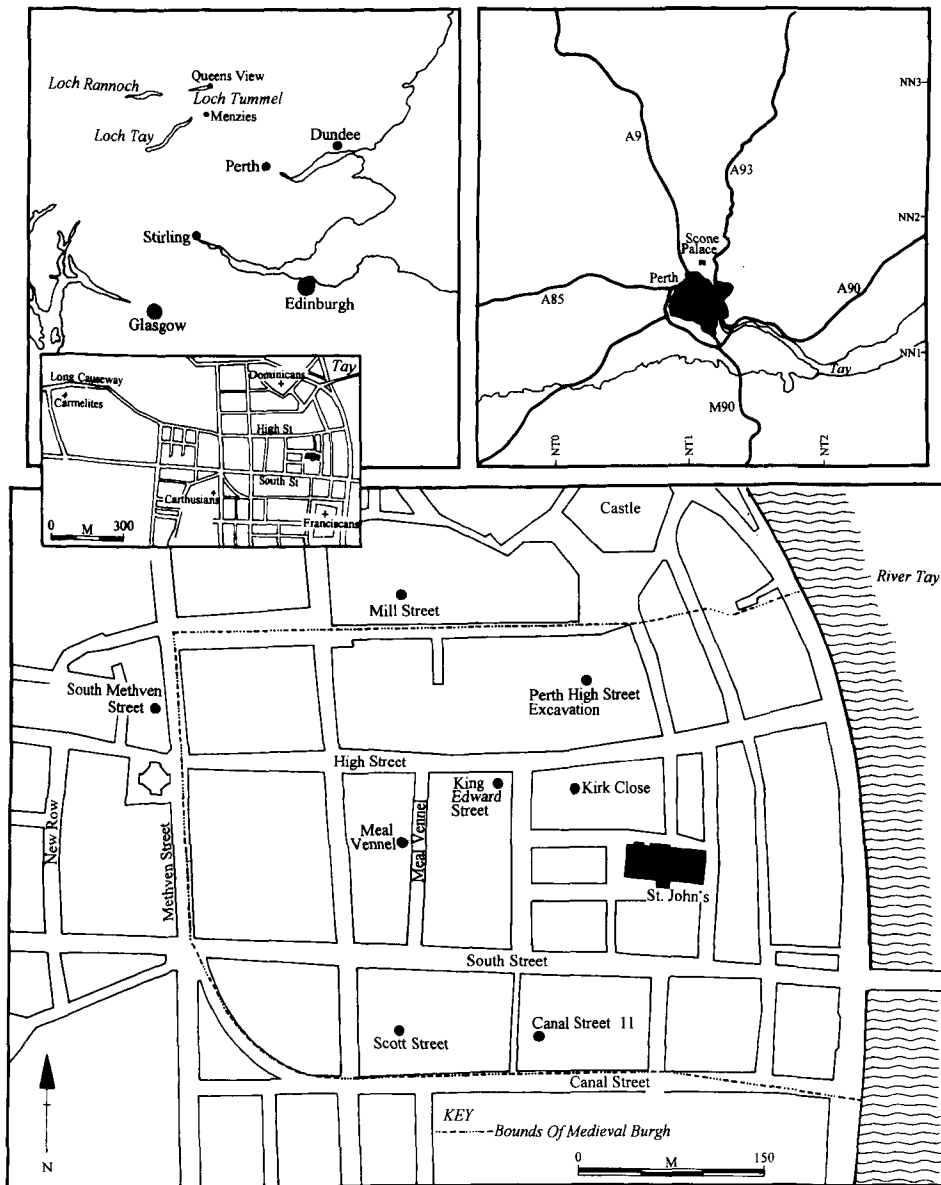
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domestic functions, as well as industrial debris. These are King Edward Street (Clark & Blanchard 1995), Canal Street II (Spearman 1987a) and Meal Vennel (Cox 1996) (illus 1). The aim is to elucidate the chemical/mineralogical composition of the iron-related metallurgical debris in order to assess whether primary processes were indeed practised within the boundaries of medieval Perth. The conclusions drawn from these analyses may have wider implications for the relationship of the medieval burgh with its rural hinterland. This question of 'town and country' cannot simply be resolved on the basis of the organization of the metal-working industry, yet aspects of this industry can offer an insight into that relationship since the countryside was the 'natural' provider of the raw materials, including iron ore and charcoal, and perhaps — as assumed until now — the raw metal as well. If Perth did manufacture its own raw metal, the implication is that the town controlled access to the natural resources, or that there was an established network of trade for their procurement. Alternatively, the town would have existed in a state of constant dependency on small manufacturers of raw metal, the rural smiths who operated numerous Highland bloomeries. The industrial waste from these rural sites is already the subject of an ongoing research project involving survey, excavation and analyses (Atkinson & Photos-Jones 1997; Photos-Jones *et al* 1998), but urban production also needs to be analytically examined. To tackle these questions the following four points need to be considered: the documentary evidence associated with the early burgh and the development of trades and manufactures; the archaeological evidence associated with the excavation of the three locations in Perth; the analytical investigation of the industrial waste from the same three locations in the context of the examination (Harrison 1996) of a large number of artefacts (knives) recovered from Meal Vennel; and the analytical investigation of similar material from rural areas in Perthshire and on monastic settlements around Perth.

#### TRADE AND MANUFACTURING IN THE EARLY BURGH

Perth was one of the earliest burghs in Scotland to be chartered by the Crown, being inaugurated by David I sometime between 1124 and 1127 (Pryde 1965, 4). It has been suggested that its earliest development was around the Watergate area, but the town soon expanded and by the 14th century it encompassed the area bounded by Canal Street, Mill Street and Methven Street, with the River Tay to the east (Bowler *et al* 1995, 927–9) (illus 1). The history of Perth's defences is not fully understood, but by this time it is likely that they comprised a substantial stone wall or bank within a wet ditch (*ibid*).

The wealth of the burgh during the medieval period was based on trade and the production of goods or, in the formula of Simpson & Stevenson (1982, 1), 'Perth owes its origin and subsequent prosperity to trade.' Trade implies the presence of a manufacturing sector; this can be manifested both by the material goods (pottery, metals, etc) but, more importantly, by industrial waste derived from manufacturing processes. Excavations in Perth have yielded undeniable artefactual evidence of trade and manufacturing, in the shape of objects of iron or copper alloys and lead-based or precious metal artefacts, and industrial waste has been recovered both from workshops/hearths as well as from middens/waste heaps. Chemical/mineralogical analyses offer a different perspective on these materials. Knives, for instance, are ubiquitous utensils in the medieval world and are often listed as imports or among the goods paid by Scottish merchants for their release from English captivity (Ewan 1990, 87). Recent analysis of medieval knife blades from Meal Vennel revealed a high quality of smithing but also suggested the likelihood that the blades were made from local ores (Harrison 1996).



ILLUS 1 Plan of medieval Perth with (inset, top left) locations of some rural bloomeries. (Based on the Ordnance Survey © Crown copyright)

The history of crafts and urban industries in medieval Scotland has recently been assessed as problematic due to the restrictions imposed by documentary sources which mainly focus on large-scale cash crops and seldom refer to smaller-scale craft production (Spearman 1988, 134). This is also true of the documents which survive for Perth. Typically, for example, William the Lion's charter of 1205 cites tradable goods such as hides, cloth, wool and timber (Reg Regum Scot ii, 430-2). Although these trade goods remain a feature of the documentary record

throughout the medieval and post-medieval periods, the sources also record an increasing diversity of goods in the economic life of the burgh. There is little information in the early sources on the trade or production of ferrous goods, though locksmiths were in trade in both Aberdeen and Perth by the 13th century (Ewan 1990, 34) and in the early 13th century 'William the helmet maker was granted a place in Perth in exchange for an annual rent of two iron helmets' (Simpson & Stevenson 1982, 4; Reg Regum Scot ii, 471–2). These glimpses imply that a wide range of services was available to the burghers and the probability that the production of iron goods was under way by this point within the burgh appears to be confirmed by the archaeological record, from both artefactual and metallurgical remains. By the 16th century, ferrous and non-ferrous metalworking were important components of a number of related crafts which had attained guild status, combining a wide range of trades under the umbrella term 'Hammermen'. The Incorporation of Hammermen was one of the largest guilds in Perth and included blacksmiths, plumbers, armourers, gunsmiths, brass and pewter workers, silver and gold smiths; its foundation date is unknown, but the guild was certainly active between 1518 and 1568 (Hunt 1889; Simpson & Stevenson 1982, 5; Verschuur 1987, 36–54).

Although the fabrication aspect of the metals industry is well represented in medieval Perth, it has generally been assumed that the 'winning and smelting of metals took place in the countryside, the unsmithed products being supplied to the burghs' (Yeoman 1995, 76). The reference here, of course, is to iron and possibly lead, but could perhaps be extended to copper, silver and gold. Documentary sources attest that iron was imported from Spain, Sweden and Flanders (Ditchburn 1988, 168; Stevenson 1988, 193) and the traditional explanation offered by early writers (eg Froissart [1385], quoted in Brown 1891, 11) was that Scottish iron ore was not good enough for the production of quality goods. Trade balance sheets between Sweden and Scotland from the 1570s to the 1630s certainly corroborate this (Whyte 1995, 272), but the validity of the argument remains to be tested scientifically. The critical question here is not whether iron objects were manufactured in Perth, but rather whether iron metal was produced — smelted from the ore in a process called the bloomery — within the bounds of the medieval town. Clear evidence for metal-working hearths/furnaces is paramount to this question, but this evidence has not been forthcoming. Neither are there any surviving or recorded place-names referring to metalsmiths of one type or another (such as the examples of Smithyrow in Aberdeen or Coppergate in York) to indicate that a centre for such activities existed in Perth. The information presented to date is conflicting. Ewan (1990, 26) suggests that smithies would have been located along the waterfront in Perth, while the documentary sources and limited evidence from excavations indicate that there was a concentration of smiths' workshops around the western side of Meal Vennel from at least the early 1600s (Cox 1996, 736). In either case, there is no archaeological evidence to date for structures to support primary production of iron within the medieval town. The lack of recorded evidence led Spearman (1988, 144) to conclude that 'it is clear from this iron-working waste that iron ore was not smelted in the towns. The origin of all the iron used in the towns is unknown but it included bloomery iron in an unsmithed state and probably scrap and imported iron. The most probable source for the former was the many moorland bloomeries of Scotland which utilised bog-iron.'

Spearman's 'mountain bloomeries' refers to the numerous bloomery mounds scattered throughout the Highlands (the National Monuments Record of Scotland lists over 150 known sites and the number is rising as awareness of them increases). In the bloomery process, which gave its name to the furnace, the lump of iron produced is never molten, but is reduced from its oxide ore while still in the solid state. By 'bloomery iron in an unsmithed state', Spearman refers to the consolidated piece of solid iron, largely free of associated slag, called the smithed bloom or

billet. The metal produced contains varying amounts of carbon, extending from wrought iron (0.01%C) to high carbon steel (1.8%C), in addition to or instead of other possible inclusions such as phosphorus.

The work of Aitken (1970) in the mid 1960s brought to light the number of upland bloomeries in Perthshire and elsewhere in the Highlands. Although he principally undertook to record the sites, thus building on existing work by MacAdam (1887), Aitken also carried out a number of excavations, with examples at Upper Dall and Grundd na Darachan, at Loch Rannoch. The bloomery mounds are usually small (about 5 m long and up to 1 m high) and consist of broken fragments of dense, blue-black 'tap' or other slag, lying in proximity to furnace remains. For the majority of these mounds the date is yet to be determined. This form of small-scale industrial activity appears to have been conducted throughout the Highlands, with concentrations of mounds in areas as widely spread as the Cowal peninsula in Argyll, the Ardnamurchan peninsula in Lochabar, Loch Maree in Wester Ross and Loch Rannoch in Perthshire (Photos-Jones *et al* 1998). Geophysical prospection and excavation at two Highland bloomery sites in the Cowal peninsula have shown that the remains of furnaces and working floors — presumably for bloom smithing — are usually found in the immediate vicinity of these mounds, with varying states of preservation (Atkinson & Photos-Jones, forthcoming). These furnaces and their associated remains bear testimony to an iron 'industry' built on self-reliance, given the ruggedness of the landscape, the remoteness of its settlements and the extremes of its climate, but also built on the abundance of natural resources in charcoal and ore.

These Highland bloomeries could well have been the source of the raw metal for many urban medieval centres. In Scotland there is a considerable diversity in the available sources of iron ore. Iron seepages and encrustations abound on Scottish soil, together with clayband and blackband ironstones, magnetite schists (banded iron formations) and pyritic schists (Hall & Photos-Jones, forthcoming). Given the ubiquitous association of iron seepages and encrustations with 'red' burns, it is unlikely that access to these resources would have been wholly restricted to rural communities (although access to woodland and hence charcoal might have been restricted, the towns relying more heavily on peat and coal) and although no bloomery furnaces have yet come to light in Perth, this in itself is not absolute evidence that they did not exist in the town. Admittedly, where excavation has recorded structures in association with industrial waste, those structures are thought to have related to smithing of iron, rather than its production (eg Meal Vennel: Cox 1996). However, the combined area of excavations to date in Perth is a small proportion of the total area of the medieval town. Furthermore, the investigation of bloomery mounds and associated features has only recently become the subject of sustained archaeological effort (see Photos-Jones *et al* 1998). Given these two factors, bloomery structures may yet be identified by further fieldwork in the town.

Pending the discovery of an *in situ* bloomery, the argument in favour of primary processing in medieval Perth must be advanced with caution, but can be developed to some degree at least by chemical/mineralogical analysis of samples of industrial debris from excavations in the town itself and in its rural hinterland.

## SAMPLES ANALYSIS

A total of 49 samples of industrial debris was examined. Of these, 46 were obtained from Perth Museum (this almost constitutes the museum's entire collection; see Table 1); in addition, three samples were supplied by Adrian Cox from excavations at Meal Vennel by the Scottish Urban Archaeological Trust (SUAT). All were examined macroscopically and 87% were subjected to

TABLE I  
The samples — excavation contexts and museum accession numbers

Site	Site Code	Context	Sample	Period	Century	Museum No
<i>Blackfriars</i>	3A	162	24	—	14–15th	—
		219	30	—	14–15th	—
		101	36	—	14–15th	—
		55	38	—	14–15th	—
		68	40	—	14–15th	—
<i>Canal Street II</i>	PEG81	2347	20	III	13–14th	Q0381
		2322	31	VI	14–15th	Q0670
		2150	33	VII	16th	Q0366
		2130	34	VI	14–15th	Q0060
		2347	35	III	13–14th	Q0382
		2345	41	III	13–14th	Q0454
		2052	42	—	—	—
<i>Castle Menzies</i>	—	—	11	—	—	Q120
		—	11	—	—	1995.1
<i>Easter Bleaton Hill</i>	—	—	10	—	—	1995.999.1
		—	6	—	—	1995.999.1
		—	7	—	—	1995.999.2
<i>High Street</i>	PEX15	200	12	—	—	Q051
		200	16	—	—	R058
		400	18	—	—	Q177
		401	4	—	—	R248
		700	8	—	—	Q096
<i>King Edward Street</i>	PEJ82	1000C	1	I	12th	Q175
		1380	2	I	12th	Q268
		1351	21	I	12th	—
		1431	23	I	12th	Q272
		E.EXT.	27	I	12th	Q238
		1402	43	I	12th	Q274
		A4	45	I	12th	Q186
<i>Kinnoull Street</i>	2A	slag1	22	—	post–1559	—
		slag3	28	—	post–1559	—
<i>Kirk Close</i>	PED79	2034	14	V	14th	Q258
<i>Meal Vennel</i>	PEL83	—	15	—	—	Q256
		4210	47	VII	16th	SUAT
		4032	48	VII	16th	SUAT
		2013	49	VII	16th	SUAT
<i>Methven Street</i>	PEH79	100/200	13	IV	18–19th	Q018
<i>Mill Street (Boots)</i>	PEF	516	17	V	15th	Q098
		242	17	VI	16–17th	Q168
		452	26	VI	16–17th	Q027
		425	29	VII	17–18th	Q044
		211	3	VI	16–17th	Q155
		175	32	VI	16–17th	Q138
		475	44	V	15th	Q061
<i>Queens View</i>	—	—	5	—	—	—
<i>St Anne's Lane</i>	PA75	—	9	—	—	—
<i>Whitefriars</i>	PEK82	104	25	—	post–1559	Q120
		104	37	—	post–1559	Q090
		104	39	—	post–1559	—

metallographic examination and/or chemical analysis with the energy dispersive analyser unit of the scanning electron microscope (SEM-EDAX). Metallographic examination involves the preparation of polished sections and their subsequent examination under the metallographic (reflecting) microscope. Examination with the SEM of the same polished section allows the investigation and subsequent chemical analysis of mineralogically distinct phases — crystalline, glassy or metallic — within these otherwise very complex materials. Phase characterization makes

TABLE 2  
SEM-EDAX area analyses of industrial waste; composition in % weight; nm = not measured

	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	CaO	TiO <sub>2</sub>	MnO	FeO
<i>Glassy Slags (high bloomery?)</i>											
Perth 8	1.31	0.62	8.67	60.19	0.2	nm	2.51	3.29	0.79	0.23	22.18
Perth 11	0.38	0.19	8.65	59.19	0	0	5.42	8.07	0.67	0.22	17.2
Perth 14	2.4	1.39	10.46	57.78	0.29	0.45	2.67	3.21	1.02	0.21	19.52
Perth 31	nm	nm	21.46	49.95	nm	nm	4.94	0.47	2.97	nm	8.12
Perth 28	0.26	0.13	14.4	49.07	0.39	0	0.77	4.32	1.91	5.8	23.05
<i>Meal Vennel</i>											
Perth 47	0.38	1.87	8.68	24.58	0.52	1.56	1.1	2.02	0.73	0.58	58.01
<i>King Edward Street</i>											
Perth 21	0	0.5	7.75	81.72	0.42	nm	2.05	0.94	0.75	0.07	5.62
Perth 23	1.21	1.31	11.88	65.73	0	0.78	3.91	5.28	1.07	0.4	10.43
Perth 27	1.46	0.83	12.13	72.74	0.41	nm	2.6	1.51	0.89	0.19	7.42
Perth 43	1.84	1.35	12.53	60	0	0.7	4.7	2.1	0.81	0.19	15.77
Perth 45	2.15	2.19	8.85	68.95	0	0.78	4	5.92	0.64	0.5	5.17
<i>Rural and Monastic</i>											
Perth 5	1.34	0.25	4.24	5.85	0.3	0.7	0.26	0.47	0	15.42	72.29
Perth 6	1.34	0.84	3.96	23.67	0.2	nm	0.37	1.75	0.53	7.22	59.99
Perth 24	0	0	0	6.97	3.34	0	0	3.11	0	2.33	84.47
Perth 36	0.42	0	13.1	0.74	0.74	0	0.24	0.35	0.45	0.42	68.32
Perth 40	0.62	0	7.94	20.54	0.34	nm	0.67	1.48	0.65	2.52	65.46
Perth 25	0	0	4.74	11.71	0.3	0.7	0.27	0.48	0	18.88	62.69
<i>Canal Street II</i>											
Perth 33	1.15	0.35	5.22	16.33	0.15	0	0.56	1.38	0.3	2.17	72.02
Perth 35	0.48	0.5	8.68	14.7	0.3	0.37	0.23	0.35	0.36	0.37	74.18
<i>Perth 34 area 1</i>											
Perth 34 area 2	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	K <sub>2</sub> O	FeO	CuO	Zn	As	Pb	Sb	Sn	Ag
Perth 34 area 1	1.45	7.76	0	10.02	59.54	2.34	1.42	12.44	0	3.55	0.46
Perth 34 area 2	6.17	30.11	1.84	13.74	29.42	0.55	6.37	10.93	0	0	0
Perth 34 Ag-rich inclusion	0	0	0	8.69	6.66	17.2	8.69	61.72	12.3	0	7.2

possible the establishment of the temperature and conditions prevalent within the furnace, and the raw materials and type of fuel involved. These materials are often the only testimony available to counterbalance the established view (and relevant documentary evidence) that metals were imported rather than manufactured locally. (The method can also be applied to other goods, principally pottery.)

#### BLOOMERIES IN RURAL PERTHSHIRE

Perthshire slags, as indeed most slags associated with Highland bloomeries, are characterized by a high iron content ranging between 60 and 70% FeO in area analysis (3 mm by 4 mm) by SEM-EDAX. In bloomery slags, most of the iron is in the oxide and silicate phases with little evidence of metallic iron inclusions (prills). The main phases include fayalite ( $2\text{FeO}\cdot\text{SiO}_2$ ) (long needles), wustite (FeO) (dendrites fine and coarse) and a silicate-rich interstitial 'glass' which is finely crystalline only when examined at high magnification. Excess alumina deriving from the ore or clay lining (ie c 10% on 'bulk' analysis) can often lead to the formation of angular grains of hercynite, with the relative amounts of each component ranging from 20%  $\text{Al}_2\text{O}_3$  and 70% FeO to 40%  $\text{Al}_2\text{O}_3$  and 45% FeO (illus 2). The presence of this particular phase has been used as one of the criteria for differentiating between smelting and smithing slags in the context of the Scottish bloomeries.

The Perth Museum's collection of industrial waste from rural sites includes material from Queen's View, Loch Tummel (PERTH 5), excavated by the late Margaret Stewart, and from Easter Bleaton Hill (PERTH 6) (M Hall, pers comm). None of the slags appears to be of the tapping variety, although the small size of the dark brown fragments (c 30–50 mm) and the extent to which they have weathered precludes accurate assessment of their original surface texture. The chemical composition of two samples (PERTH 5 & 6) is shown in Table 2.

The Loch Tummel sample (PERTH 5) is characterized by manganese iron oxides and a manganese-rich fayalite (illus 3). The presence of manganese is ubiquitous in almost all sites sampled from the Highlands. In some cases it is as high as 30% (on 'bulk' analysis). On the other hand, phosphorus is generally low, but its presence would not be expected in any case in slag, partitioning instead within the metal. Calcium, potassium and magnesium amounts are also rather low (less than 2–3%) with some trace levels of sodium also present. Therefore, manganese and aluminum appear to 'fingerprint', albeit in a coarse manner, the composition of Highland bloomery slags.

The high manganese component of the Perthshire slags (in combination with the high iron content) would have acted as a flux enabling the slag to be liquid at relatively lower temperatures (c 1100°C). Thus, although large quantities of iron may have been lost while making slag (rather than metallic iron), this loss must be counterbalanced with the fact that good separation between slag and metal was always possible. If ore availability was not a pressing issue, such 'loss' may not have been a point of much concern for the Highland smith.

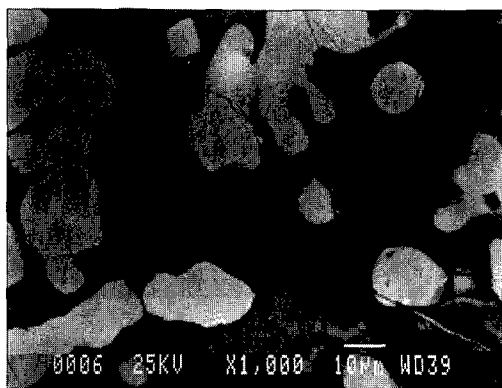
#### MEDIEVAL PERTH

Despite an extensive programme of fieldwork from the mid 1970s onwards, publication of excavations in Perth has been affected by a number of problems, particularly the absence of adequate funding for post-excavation work on projects initiated by the Manpower Services Commission. Although this is now being remedied by Historic Scotland's 'backlog publications' programme (see Barclay & Owen 1995), the number of excavations published in the 1970s/1980s





ILLUS 2 SEM-SE image of PERTH 33, a smelting slag consisting of angular grains of hercynite (dark grey) amid long needles of fayalite, dendrites of wustite and a shiny inclusion of metallic iron (bar = 100  $\mu\text{m}$ )



ILLUS 3 SEM-SE image of PERTH 5 showing manganese-rich wustite (light grey) and fayalite (dark grey) phases (bar = 10  $\mu\text{m}$ )

was limited (eg Blanchard 1983; Holdsworth *et al* 1987; Stones 1989), with some further excavations reaching publication in the recent past (Bowler *et al* 1995; Coleman 1996; Cox 1996; Moloney & Coleman 1997).

Of the published excavations, metallurgical waste has been recovered from South Methven Street, Kirk Close and Canal Street II (Holdsworth *et al* 1987); King Edward Street, Mill Street, Kinnoull Street and Blackfriars House (Bowler *et al* 1995); and Meal Vennel (Cox 1996). This material has been recovered from a variety of contexts, representing both a diversity of features and processes and a wide range of chronological periods. The analytical investigation of these materials indicates both iron-working and copper-working. Although the processing of non-ferrous metals within medieval Perth is clearly of interest, it will not be discussed here, principally because it was identified in only two of the excavations: Canal Street II (see Spearman 1987a for further discussion) and Mill Street. Iron-working debris, on the other hand, occurred in quantities on all of the published sites as well as some which are awaiting publication (eg 1–5 High Street: Holdsworth, forthcoming). This material is not associated with excavated features in many instances, however, and in a number of cases may be redeposited from elsewhere or residual from earlier iron-working episodes. This was clearly the case at South Methven Street and Kirk Close, which led Spearman to conclude that ‘iron working at quite a substantial level was obviously closely associated with the town from early times to produce such ubiquitous debris’ (Spearman 1987b, 157). The recovery of metallurgical waste from insecure contexts is only part of the story, however, and a number of excavations have recovered industrial materials from apparently

secure contexts. It is this material which is of consequence for the present discussion, particularly where a clear association between archaeological features, finds and metallurgical waste occurs.

### *King Edward Street*

At King Edward Street, a series of hearths in Structure 2 yielded quantities of industrial waste which led the excavator to suggest that this was 'an industrial workshop rather than domestic structure' (Clark & Blanchard 1995, 938). The building was ascribed to the earliest phase and was associated with 12th-century Low Countries Grey Ware (*ibid*, 931). Five samples of industrial waste — from a total of seven (Table 1) — were examined chemically and metallographically: PERTH 21, 23, 27, 43 & 45. The results are given in detail by Table 2; significant points are discussed below.

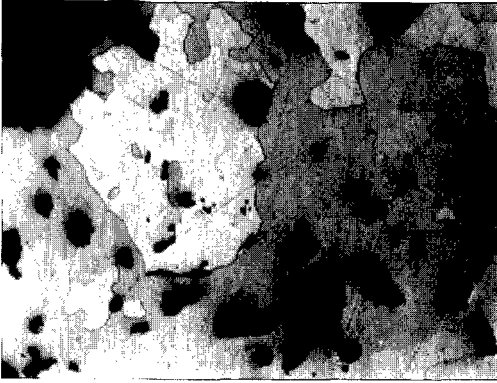
PERTH 21 is a fragment of a thin-walled ceramic crucible, with a smooth exterior surface and a rough interior which has been subjected to high temperature. The gradient in temperature between the interior and the exterior and the dark grey colour of both surfaces suggest that the ceramic has been subjected to reducing conditions and that it was primarily heated from within. It is not possible to deduce the shape and size of the original crucible other than to suggest that it had a wide mouth. Analysis of the fabric revealed an aluminosilicate low in calcium but high in iron. Traces of zinc and chlorine were also recorded. Shell inclusions were also noted suggesting the crucible was an import (R Will, pers comm). This sample may constitute the earliest (12th-century) metallurgical waste from Perth.

PERTH 23, 27, 43 & 45 are all highly vitrified, amorphous, light and very porous (nearly frothy) materials. They comprise high silica with alumina and silicates and no more than c 10% FeO. Iron-titanium-rich phases appear to characterize these materials, the titanium being a soil constituent. In chemical composition (area analysis) they resemble the over-fired ceramic fragment described above (PERTH 21), but typologically they are different. They could have been produced by a reaction between fuel, fuel ash and soil associated with any industrial or domestic hearth. The presence of sulphur in one of the samples (PERTH 43) suggests the possible use of coal as fuel.

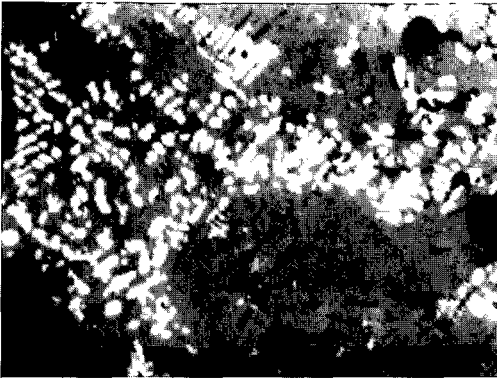
Overall, there is no substantial evidence, in the form of characteristic minor elements and/or mineralogical phases, to ascribe these materials to a metallurgical process. Indeed, these highly vitrified light and frothy materials, rich in alumino-silicates, are a ubiquitous feature of archaeological sites. They are commonly described as 'cramp' in fieldwork reports, but rather than deriving solely from funerary practices — as was once commonly assumed — they can be associated with diverse contexts, whether industrial, agricultural (eg corn-drying installations), domestic or funerary (eg Linga Fold, Orkney: Carter 1997). They are probably the product of a reaction between fuel (and perhaps only seaweed), rather than fuel ash, with the underlying soil. The experimental reconstruction of cramp is currently being undertaken by one of us (EP-J).

### *Canal Street II*

Excavation at Canal Street II recovered a total of 89 clay mould fragments and three crucible fragments, as well as small quantities of ferrous and non-ferrous slag. The moulds and crucibles were chiefly found in contexts associated with pottery of the 13th and 14th centuries; the earlier moulds (Period II & III) may have been for casting fine metal objects, such as jewellery, but most of the later moulds were probably for vessel-casting (Period IV); a significant group of moulds also occurred in 15th-century contexts (Period VI) (Spearman 1987a & 1987b). There was no



ILLUS 4 Optical microscope image of PERTH 46 showing large equiaxial grains of ferrite; black areas denote holes (x 36)

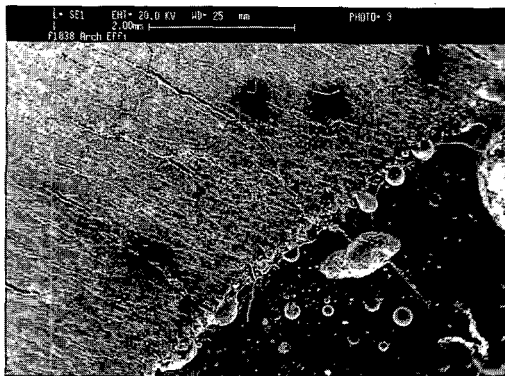


ILLUS 5 Optical microscope image of PERTH 35, showing long compact needles of fayalite (matt grey), dendrites of wustite (white) and shiny small inclusions (no larger than 10 microns in diameter) of iron sulphide dispersed within the fayalite; dark grey corresponds to a glassy phase; black represents pores (x 143)

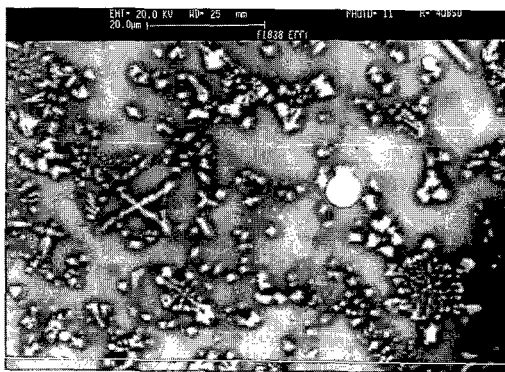
evidence of the hearths or furnaces which would be expected should casting have been undertaken in this area, leading the excavator to observe that ‘it can only be assumed that the working area was outwith the area of excavation’ (*ibid*, 158). A concentration of bloom-working debris, hammer scale and iron nails was recorded on the western end of the site in probable 16th-century features (Period VIII). Although there were no related structures, the excavator could suggest ‘that some ironmaking, probably nail making, had taken place near the site’ (Spearman 1987b, 157).

The samples from Canal Street II are perhaps the most revealing of all the material examined. PERTH 46 is a large piece of smithed bloom (illus 4). Blooms are usually rare on excavated sites and, in that respect, this is an important find. Metallographic investigation showed large equiaxial grains of ferritic structure with only a few areas showing low carbon content; hardness testing gave a value higher than that expected for simple ferrite ( $Hv_{100} = 150$ ) suggesting the possible presence of small amounts of phosphorus. The bloom is quite clean of slag inclusions, most having been removed in the process of consolidation/billet formation. It is different in carbon content from that of another piece of bloom found on a moorland site at Stiddriggs, Dumfriesshire, dated to c 800–1200 (Photos-Jones 1997). The Stiddriggs bloom was primarily high carbon steel, at least in the section sampled from the outer surface, and may have consisted of a steel envelope covering a ferritic core.

Chemically and metallographically, PERTH 46 can be compared with PERTH 33, a bloomery (smelting) slag on the basis of the hercynite phase present and the high manganese content (illus 2). At Canal Street, bloom, smelting and smithing slag coexist on the same site, albeit in different



ILLUS 6 SEM-SE image of PERTH 31 with (left) fragment of coal and (right) fragment of glassy slag (bar = 2 mm)

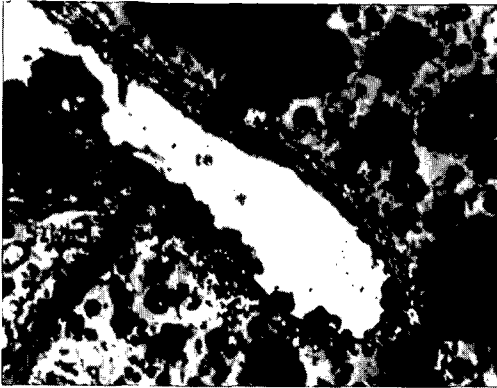


ILLUS 7 SEM-SE image of PERTH 31; the 'glassy' matrix consists of fine iron-rich crystallites with round metallic iron inclusions suggesting that the iron was at some stage molten (bar = 20 µm)

periods. This suggests that iron-smelting was practised in Perth from the 13th to the 16th centuries (Table 1).

PERTH 41 & 35 are identified as probable smithing slags on the basis of their mineralogy (primarily iron oxides in the form of either wustite or magnetite [ $\text{Fe}_3\text{O}_4$ ]). PERTH 35 also shows clear evidence of association with sulphur in the form of iron sulphides (illus 5). Thus, it appears that all three stages — bloomery smelting, bloomery smithing and iron-making with the combined use of charcoal and coal — have been undertaken at Canal Street II. Indeed, PERTH 42 consisted solely of fragments of coal and PERTH 31 was a glassy slag attached to a lump of coal. PERTH 31 (illus 6 & 7) is of particular interest since it shows a piece of coal attached to a piece of slag consisting of a glassy phase with metallic round inclusions. In many parts of medieval Britain coal was used for the smithing of blooms or the mending of artefacts (Dearn & Branigan 1995), but it is rarely, if ever, thought to have been used for the smelting of iron ore, at least in the context of the bloomery furnace. This is because sulphur, present in coal, is deleterious to iron as it makes it brittle when worked in the hot (hot shortness). Coal is used in smelting of ore, but only in the context of the reverberatory furnace where the fuel and ore are kept apart. Yet, given the high alumina content of the slag, PERTH 31 would not normally have been produced by smithing a bloom or mending a tool. This may, therefore, represent a case of smelting with coal. It is impossible to confirm this hypothesis on the basis of one fragment of slag alone and, given the complete absence of relevant installations, the potential use of coal in other than a smithing context must remain an open question for medieval iron-working in Lowlands Scotland.

In PERTH 34, copper-working was also evident at Canal Street II. Copper, lead, arsenic and iron are the main metallic inclusions within this smelting slag (illus 8). However, the presence of



ILLUS 8 Optical microscope image of PERTH 34 showing large grain of copper (white) surrounded by a glassy matrix (x 71)

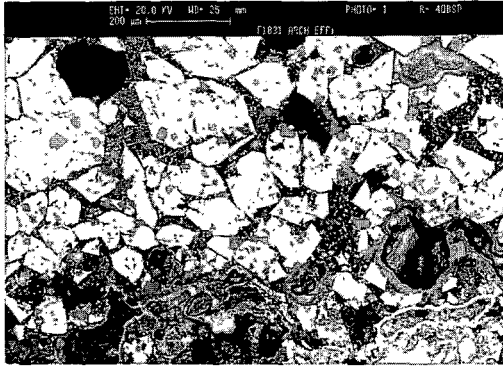
silver within the lead suggests that the slag may have been part of a liquation process whereupon silver was retrieved from silver-rich copper (probably coins) or other argentiferous copper alloys by co-melting with lead. Lead has traditionally been used as a collector of precious metals. Where it occurs in Perth, this practice may reflect adverse economic conditions at particular periods, but should be seen in the context of non-ferrous metal-working in general before any conclusions can be drawn.

### *Meal Vennel*

The work at Meal Vennel (Cox 1986) has been most successful in linking excavated structures to industrial debris and artefactual evidence. Metal-working debris occurred in all phases, extending from the mid 13th to the end of the 17th century, and features recorded in Phase 7 were interpreted as a smithy.

Cox (1996, 815) observed that the Phase 1 corn-drying kiln and metal-working areas in Meal Vennel may have lain outside the boundaries of the town because they represented a fire risk. This is an attractive argument, but it does not explain the proliferation of iron-working within the same area by the 16th century, when Meal Vennel had long been encompassed by the town. The risk of fires originating from metal-working activities is in reality a low one, since strict regulation of the fire within a contained area, a hearth or a furnace, both in terms of temperature and conditions (oxidizing or reducing), is essential to the success of the operation. Furthermore, most urban metal-working quarters in European towns — from classical antiquity (see, for instance, Mattusch 1988) to more recent times — are located within town centres, the craftsmen's workshops usually being densely packed within a particular quarter. If metal-working at Meal Vennel was deemed a fire risk, then surely it would have been discontinued at this site prior to the expansion of the burgh in the 12th century (see illus 1).

The principal importance of the site is in relation to the artefactual and structural evidence. The recovery of two knives in Phase 2 (14th century) extends to 44 knives by Phase 7 (16th century). The high manganese levels identified by Harrison (1996, 777) in 23 of these strongly indicate a local source for the ore and is corroborated by the manganese content of the smelting slag from Canal Street (Table 2). It is not until Phase 7, however, that the first clear traces of a smithy appear, with the discovery of an anvil, forge and ash pit (Cox 1996, 749–51). These features are clearly of importance in relation to the development of an industrial quarter around Meal Vennel. At least half a dozen 16th-century smithies can be identified on this street from



ILLUS 9 SEM-SE image of PERTH 47 consisting of 'broken up' needles of fayalite (light grey), small angular grains of hercynite, fine dendrites of wustite, fine 'wire' of shiny metallic iron (bottom right) and partly reduced/reacted iron ore (bottom left) (bar = 200  $\mu\text{m}$ )



ILLUS 10 SEM-SE image of PERTH 47 consisting of angular grains of hercynite (large dark grey) and 'broken up' needles of fayalite (light grey); coring, or the localized variation in major element concentration, can be seen within the fayalite from the difference in the shade of grey (bar = 50  $\mu\text{m}$ )

entries in the *Rental Books* of the King James VI Hospital (Milne 1891; cited in Cox 1996, 815), justifying the observation by Cox (1996, 816) that the excavated features on this site are 'likely to be representative of the daily workplaces of this artisan community'.

Only three samples from Meal Vennel were analysed. PERTH 47 shows quite clearly the presence of hercynite, fayalite, wustite and interstitial glass. Evidence for metallic formation (illus 9 & 10) as well as unreacted fragments of primary ore suggest primary iron-making. Phosphorus is present while manganese is quite low. PERTH 48 also consisted of a smelting slag while PERTH 49 was a smithing fragment. Fragments of coal were also retrieved (A Cox, pers comm).

#### SMITHING AND RELIGIOUS HOUSES

The Perth smiths may have worked independently at sites like Meal Vennel, but others may have been associated with the houses of the Dominicans or Black Friars on the northern margin of the town (Bowler & Hall 1995), or the Carmelites, or White Friars, located half a mile to the east (Stones 1989) (illus 1). Excavations at both sites recovered iron-working debris, but some of this came from rubble deposits likely to post-date the disestablishment, demolition and robbing of these houses in the late 16th century and beyond (while the samples from Whitefriars post-date demolition layers on that site, the Blackfriars samples are dated to the 14th to 15th centuries: D Hall, pers comm).

Three samples from these sites (PERTH 24, 36 & 40) show clear associations with bloomery iron-making. PERTH 40 is a piece of bloomery slag with small quantities of manganese. The presence of hercynite is also recorded as well as metallic inclusions. Analysis of PERTH 36 revealed

the same phases, but with the additional presence of iron sulphide, usually associated with the use of coal. PERTH 24 included fragments containing both coal and lumps of iron ore, suggesting primary processes. Analysis of PERTH 25 revealed a high manganese slag within an apparently glassy phase. The presence of barium sulphide inclusions suggests that the origin of the material is a smelting slag. PERTH 37 was also rich in manganese and glassy, with no particular crystalline phases evident. Thus, the industrial waste found on these sites suggests the use of manganiferrous ore but also hints at the use of coal in a primary iron-making activity.

#### GLASSY IRON SLAGS

The presence of coal fragments directly or indirectly associated with metallurgical waste brings into question the use of this fuel in other than a smithing context. Of particular interest is the small number of glassy slags with small metallic iron inclusions comprising 13% of the total collection analysed from Perth and its hinterland. These are PERTH 8 (1–5 High Street), 11 (Castle Menzies), 14 (Kirk Close), 28 (Kinnoull Street) and 31 (Canal Street). PERTH 12 (1–5 High Street) is also a potential candidate on the basis of metallography. Unfortunately, most are of unknown date, if not of unknown context as well.

These samples are characterized by a glassy matrix which, however, displays crystallinity at higher magnification. The glassy matrix may include particles of silica (quartz) grains, fractured as a result of heating. Chemically, it consists of silicon, aluminium and iron with an average composition in oxides of 60% SiO<sub>2</sub>, 15% Al<sub>2</sub>O<sub>3</sub> and 15% FeO. The matrix also contains metallic inclusions, all iron, with minor amounts of silica, alumina, manganese, phosphorus and sulphur, or a combination of these. The predominantly round shape of these inclusions suggests that the iron was molten.

Glassy bloomery slag which includes metallic round inclusions of iron can be associated with parts of the bloomery 'gone wrong', where areas of the furnace were hotter than normal and metallic iron melted under localized strongly reducing (ie oxygen-starved) conditions. High-carbon molten iron, or 'cast iron', is known to have been produced in many a bloomery furnace from the Roman period onwards, but these products were normally considered waste. Nevertheless, as the shaft of the furnace in the bloomery was raised from 1 m to 2–3 m, the 'high bloomery' or *stuckhofen* developed, an invention attributed to Central Europe and Styria in particular (Tylecote 1986, 213). Because of the higher shaft it was possible for the ore to remain within the furnace for longer periods of exposure to carbon monoxide produced from the combustion of charcoal. As a result, it was possible to reduce iron oxide to high-carbon iron, either as steel or cast iron.

The method by which steel was produced within these furnaces is described by Rostoker & Bronson (1990, 100):

Stuckhofen were run hotter than usual bloomeries, so that the ore was reduced to cast iron droplets in some zones. Under such conditions manganese oxide is more readily reducible and absorbed by the liquid cast iron. The droplets, when absorbed by the bloom, impart to it both carbon and manganese producing a steel of considerable hardenability.

High bloomeries are thought to have operated in Scotland in the transition period (c early 17th century) between the traditional bloomeries and the charcoal-operated blast furnaces (Atkinson & Photos-Jones 1997).

## DISCUSSION

This paper uses the evidence from scientific analysis of industrial waste from several sites in medieval Perth to challenge the assumption that the 'winning and smelting of metals took place in the countryside, the unsmithed products being supplied to the burghs' (Yeoman 1995, 76). Although smelting slags have previously been identified on the basis of visual examination (tap slag), analytical verification was lacking. Of the sites presented here, only Canal Street II and Meal Vennel show clear signs of metallurgical activities. King Edward Street produced evidence for hearths and high-temperature derived waste, but no direct evidence for metallurgical activity other than, potentially, in PERTH 21.

Evidence from excavations at Meal Vennel combines with documentary evidence to indicate the existence of a metal-working centre in medieval Perth from at least the 16th century and potentially as early as the 14th century. This is paralleled by recent work at Trondheim in Norway where 'intensive iron-smithing and non-ferrous casting took place on a permanent basis between AD 1150 and 1350' (McLees 1996, 134). Although a difference in chronology exists between Meal Vennel and the corresponding Trondheim sites, their location at the edges of medieval burghs and their level of specialization indicate strong similarities in the organization of crafts. Meal Vennel has produced metallurgical waste related to iron smithing, as well as evidence for hearths or forges, and the setting for a stone anvil. Yet two of the samples analysed (PERTH 47 & 48) point to smelting slags. Ideally — should further research funds become available — more analyses on the large collection of industrial materials from this site would confirm this result.

The industrial waste from Canal Street II — though not directly associated with particular hearths — provides greater insight into iron-working and indeed the possible retrieval of precious metals. The evidence for a phosphorus-rich ferritic bloom (PERTH 46) in association with smelting (PERTH 33) and smithing (PERTH 41 & 35) slag represents all three stages in bloom-making. Coal was used for smithing, as iron sulphide inclusions in PERTH 35 suggest, but charcoal must be assumed to have been the fuel for smelting, until more evidence to the contrary is forthcoming. Detailed analysis of slag inclusions within the bloom may yet provide a match between the bloom and the primary and secondary slags but these, of course, have to be of the same period.

The high manganese content of the smelting slag suggests a Highland source, of the 'bog ore' variety (iron seepages or encrustations), but it is proposed here that this would have been widely available to urban and rural smiths alike. Phosphorus would have been present within this sort of ore and would partition within the metal rather than the silicate phase, resulting in phosphoric iron. Thus, in the supply of iron ore, the Perth smiths may not have needed to rely on their rural neighbours. Charcoal could have been bought, but could also have been made by the smiths themselves. For artefacts of everyday use — like the knives analysed by Harrison (1996) — the town smiths could have operated small bloomeries of their own within the town, just as their rural neighbours would have done elsewhere. Carrying the entire bloomery cycle from bloom to artefact within the comfortable and dry confines of a workshop, albeit of a lean-to type (open to three sides), would have been a very suitable arrangement. It would have also allowed the smith to prepare 'made to order' metal — especially in the output of phosphoric iron or iron and steel — for particular purposes. Furthermore, the town smiths' ready access to coal supplies — initially for their smithing — may have allowed them to push forward in experimenting with iron-making techniques, ultimately affording them technical superiority or at least more versatility than their rural counterparts. Indeed, there may have been some consciousness of superiority or artisan's pride at work in driving the need for towns to control all aspects of production as this would clearly be of importance in establishing the guild as a bona fide trade organization.



There is as yet no urban bloomery in evidence; furthermore, the mechanisms for the distribution and redeposition of industrial waste materials are complex and diachronic. Nonetheless, the clear evidence for urban smelting — albeit on a limited scale — sets the question of ‘Town and Country’ in a new perspective. The scientific investigation of iron industrial waste from ‘new’ urban medieval contexts will advance the argument in favour of one or the other.

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## REFERENCES

- Aitken, W G 1970 ‘Excavations of bloomeries in Rannoch, Perthshire and elsewhere’, *Proc Soc Antiq Scot*, 101 (1969–70), 188–203.
- Atkinson, J A & Photos-Jones, E 1997 *Scottish Bloomeries Project Phase 2: the Excavations*. Unpubl Interim Report by Glasgow University Archaeological Research Division/Scottish Analytical Services for Art and Archaeology and Department of Archaeology.
- Atkinson, J A & Photos-Jones, E forthcoming ‘Brave-at-heart: clanship and the work of the Highland smith’. Paper presented to a conference on ‘Metals in Antiquity’, Harvard University (USA), Sept 1997.
- Barclay, G & Owen, O 1995 ‘Historic Scotland’s Backlog Project and the Projects’ Database’, *Proc Soc Antiq Scot*, 125 (1995), 1–8.
- Blanchard, L M 1983 ‘An excavation at 45 Canal Street, Perth, 1978–9’, *Proc Soc Antiq Scot*, 113 (1983), 489–519.
- Bowler, D & Hall, D 1995 ‘Kinnoull Street’, in Bowler, D *et al*, 939–47.
- Bowler, D, Cox, A & Smith, C 1995 ‘Four excavations in Perth, 1979–84’, *Proc Soc Antiq Scot*, 125 (1995), 917–99.
- Brown, P Hume 1891 *Early Travellers in Scotland*. Edinburgh.
- Carter S 1997 ‘Report on the analysis of slags from cremation pyres at Linga Fold’. Unpublished archive report. Headland Archaeology Ltd. Edinburgh.
- Clark, P & Blanchard, L 1995 ‘King Edward Street’, in Bowler, D *et al*, 931–8.
- Coleman, R J 1996 ‘Burgage plots of medieval Perth: the evidence from excavations at Canal Street’, *Proc Soc Antiq Scot*, 126 (1996), 689–732.
- Cox, A 1996 ‘Backland activities in medieval Perth: excavations at Meal Vennel and Scott Street’, *Proc Soc Antiq Scot*, 126 (1996), 733–821.
- Dearn, M & Branigan, K 1995 ‘The use of coal in Roman Britain’, *Antiq J*, 75 (1995), 71–105.
- Ditchburn, D 1988 ‘Trade with northern Europe, 1297–1540’, in Spearman *et al* (eds), 161–79.
- Driscoll, S T & Yeoman, P 1997 *Excavations within Edinburgh Castle in 1988–91*. Edinburgh (= Soc Antiq Scot Monogr Ser, 12).
- Ewan, E 1990 *Townlife in Fourteenth Century Scotland*. Edinburgh.
- Frössart, J 1746 *A Parallel of Times and Events*. London.

- Hall A J & Photos-Jones, E forthcoming 'The bloomery mounds of the Scottish Highlands: Part II. A review of iron mineralisation in relation to the investigation of bloomery iron making in the Scottish Highlands', *J Hist Metallurgy Soc*.
- Harrison, P 1996 'Metallurgy of the Knives', in Cox, A, 776–7.
- Holdsworth, P (ed) 1987 *Excavations in the Medieval Burgh of Perth 1979–1981*. Edinburgh (= Soc Antiq Scot Monogr Ser, 5).
- Hunt, C A 1889 *The Perth Hammermen Book, 1518–1568*. Perth.
- MacAdam, W I 1887 'Notes on the ancient iron industry of Scotland', *Proc Soc Antiq Scot*, 21 (1886–7), 89–131.
- McLees, C 1996 'Itinerant craftsmen, permanent smithies and the archbishop's mint: the character and context of metalworking in medieval Trondheim', *J Hist Metallurgy Soc*, 30/2 (1996), 121–35.
- Mattusch, C 1988 *Greek Bronze Statuary: from the beginning through the fifth century BC*. Ithaca, New York.
- Moloney, C & Coleman, R 1997 'The development of a medieval street frontage: the evidence from excavations at 80–86 High Street, Perth', *Proc Soc Antiq Scot*, 127 (1997), 707–82.
- Photos-Jones, E 1997 *The Metallographic Analysis of the Stiddriggs Hoard*. Unpublished internal report by Scottish Analytical Services for Art and Archaeology, Glasgow.
- Photos-Jones E, Atkinson, J A, Banks, I & Hall, A J 1998 'The Bloomeries of the Scottish Highlands: Part I, the archaeological background', *J Hist Metallurgy Soc*, 32 (1), 15–31.
- Pryde, G S 1965 *The Burghs of Scotland: a critical list*. Edinburgh.
- Reg Regum Scot Barrow, G W S (ed) 1960 *Regesta Regum Scotorum*, vol ii, Edinburgh.
- Robinson, D 1995 'The botanical remains: Mill Street and King Edward Street', in Bowler, D *et al*, 990–3.
- Rostocker, W & Bronson, B 1990 *Pre-Industrial Iron*. Philadelphia.
- Simpson, A T & Stevenson, S 1982 *Historic Perth: the archaeological implications of development*. Scottish Burgh Survey, University of Glasgow.
- Spearman, M 1987a 'Canal Street II', in Holdsworth, P (ed), 59–83.
- Spearman, M 1987b 'The metalworking: debris and mould and crucible fragments', in Holdsworth, P (ed), 157–9.
- Spearman, M 1988 'Workshops, materials and debris — evidence of early industries', in Spearman *et al* (eds), 134–47.
- Spearman, M, Lynch, M & Stell, G (eds) 1988 *The Scottish Medieval Town*. Edinburgh.
- Stevenson, A 1988 'Trade with the South, 1070–1513', in Spearman *et al* (eds), 180–206.
- Stones, J A (ed) 1989 *Three Scottish Carmelite Friaries*. Edinburgh (= Soc Antiq Scot Monogr Ser, 6).
- Tylecote, R F 1986 *The Prehistory of Metallurgy in the British Isles*. London.
- Verschuur, M 1987 'Merchants and craftsmen in sixteenth-century Perth', in M Lynch (ed), *The Early Modern Town in Scotland*, 36–54. London.
- Whyte, I D 1995 *Scotland before the Industrial Revolution: an economic and social history c 1050–1750*. London.
- Wordsworth, J 1982 'Excavations at Castle Street, Inverness, 1979', *Proc Soc Antiq Scot*, 112 (1982), 322–91.
- Yeoman, P A 1995 *Medieval Scotland: an archaeological perspective*. London.

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