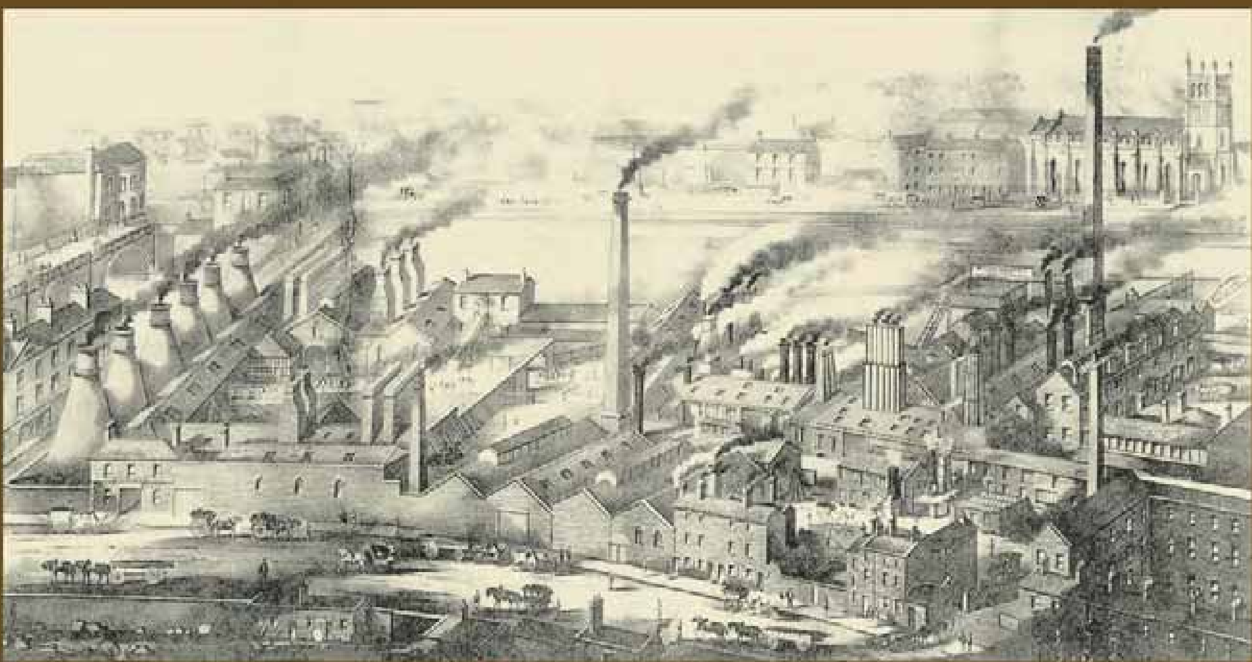
Riverside Exchange, Sheffield

Investigations on the site of the Town Mill, Cutlers' Wheel, Marshall's Steelworks and the Naylor Vickers Works

By Phil Andrews



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with contributions by
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Front cover
Top: Artist's view (from west) of former Naylor Vickers works, after its purchase by William Charles and Co in 1865 (source unknown)
Bottom left: Paring knife and table knife: photo-micrographs of etched microstructures
Bottom right: Excavation of Cutlers' Wheel (view from north) (© University of Sheffield. Reproduced by permission)

Back cover
Top: Remains of early cementation furnaces at Marshall's steelworks, now preserved *in situ* below the new development (© University of Sheffield. Reproduced by permission)
Centre: Elemental map (potassium) of crucible sample 5377–2
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Sources for maps, drawings and other illustrations are given, as far as is known, in the figure captions. In this respect we would particularly like to thank the University of Sheffield, Pat Dallman from the local studies section and Tim Knebel from archives at Sheffield Libraries Archives and Information, the Hawley Collection Trust and Sheffield Museums and Galleries Trust. Much information has been gathered from the published and unpublished sources of a number of researchers, notably Ken Barraclough, Joan Unwin, Ken Hawley, Victoria Beauchamp, Neville Flavell, David Crossley and Derek Bayliss, and we would like to take this opportunity to fully acknowledge the value of these sources.

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Abstract

Excavations at Riverside Exchange in the centre of Sheffield revealed significant evidence of the city's post-medieval industrial expansion and, in particular, unique remains relating to early steelmaking.

The extensive site, formerly known as Millsands, was the location of the medieval Town Mill, though nothing of the early mill survived. However, the Town Mill goit, an artificial watercourse which supplied water to the mill, remained an important element within the site.

Tanning pits of mid-17th-century date provide the earliest archaeological evidence for industrial use of the area which, when coupled with documentary sources and supplemented by finds assemblages, demonstrate the development of this previously marginal land prone to flooding.

The Cutlers' Wheel was built in the mid-18th century, providing a water-powered grinding workshop for cutlers in the area. This was followed soon after, in the mid-1760s, by the establishment of Marshall's steelworks, an innovative, integrated works which combined the conversion of wrought iron to blister steel in cementation furnaces and the newly developed process of melting and refining the blister steel in crucibles to produce crucible steel, a high quality, homogeneous steel required by cutlers, edge tool manufacturers and toolmakers. Excavations uncovered the remains of three early cementation furnaces, one of probable single-chest construction and dating to the late 18th century; this furnace is of national significance and along with the two slightly later brick-built furnaces has been preserved *in situ*. Analysis of two late 18th-century steel-making crucibles has provided the earliest evidence for their composition (mullite and graphite) from a time when this was a closely guarded secret, and suggests manganese dioxide was a deliberate addition to the process, potentially identifying the mysterious fluxes mentioned in early literature.

Elsewhere on the site were elements of the Naylor Vickers works, which took over Marshall's and later became one of Sheffield's major steelworks. Alongside this was a patchwork of other crafts, industries and businesses which continued in various guises until the second half of the 20th century, gradually replaced by the expanding steelworks, then a brewery and bottling plant and finally, following their demise, by the early 21st-century regeneration of this former brownfield city centre site.

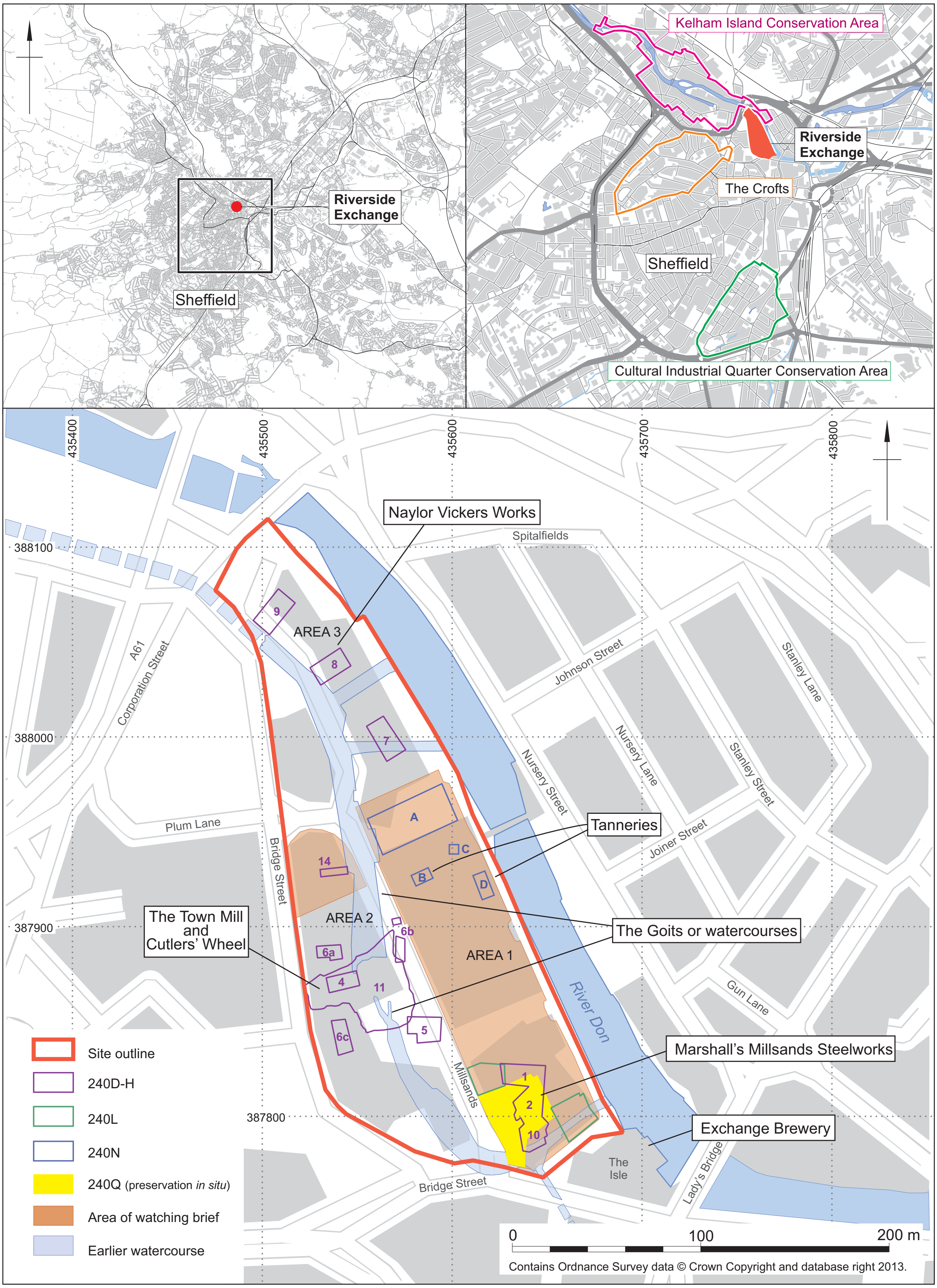


Figure 1 Site location plan, showing excavation areas, trench numbers and letters, and ARCUS numbers (see Appendix)

Chapter 1
Introduction

Project Background

Riverside Exchange, formerly known as Millsands (or Mill Sands), is located on the edge of the historic core of Sheffield on the west bank of the River Don (Fig. 1). Urban regeneration and new development there in the first decade of the 21st century provided a rare opportunity to excavate a large area in the centre of the city, with a recorded history for the site going back 800 years. The history is complex, beginning with the medieval town mill and continuing through to the beginnings and subsequent development of the steel industry from the mid-18th century onwards. By the end of the 19th century, in addition to the steelworks, there was a variety of trades, crafts and industries represented on the site and in the immediately surrounding area. However, the second half of the 20th century saw decline and dereliction of this inner city area, prior to its redevelopment and renaissance.

Up to the mid-18th century Riverside Exchange was semi-rural, on the periphery of the built-up area of Sheffield, in what was traditionally known as Hallamshire. However, from the 1760s onwards, when John Marshall's Millsands steelworks was established, the area became more intensely industrialised, and the Riverside Exchange site became a focus for iron and steel working in the city, most notably Naylor Vickers, and a major steelworks continued operating there until the 1980s. Marshall's works was the first large-scale operation in Sheffield, and therefore the world, to combine all of the processes of steelmaking together in one complex (Pl. 1); consequently the site is of national, and arguably, international significance.

Because of the site's significance, particularly in terms of steelmaking, it was subject to an extensive programme of archaeological investigations which were carried out by ARCUS (Archaeological

Plate 1 Remains of Marshall's cementation furnaces (prior to preservation in situ*), with retained brewery buildings top left (view from north) (© University of Sheffield. Reproduced by permission)*

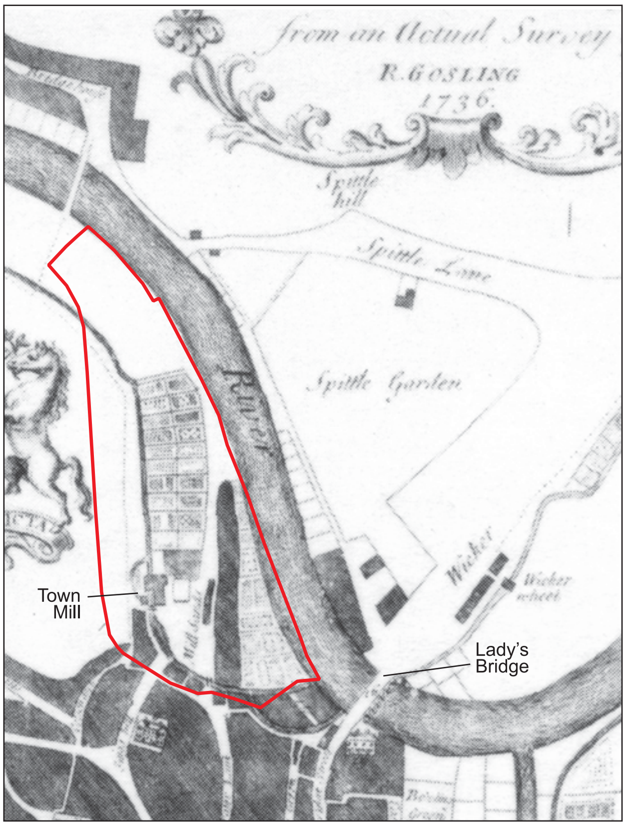


Figure 2 Extract from the Gosling map of Sheffield of 1736, with the Riverside Exchange site highlighted (Sheffield City Council, Libraries Archives and Information: Sheffield Local Studies Library S30L)

Research and Consultancy at the University of Sheffield) prior to and during redevelopment.

Topography and Geology

Riverside Exchange (National Grid Reference SK 3566 8782) occupies a roughly triangular area of land approximately 9 hectares in extent, bounded by the River Don to the east and Bridge Street to the south and west. From probably the 12th century onwards the site has been bisected by an artificial watercourse or goit (variously called the Town Mill, Millsands or Kelham goit) which flows from north to south. Originally open, this channel has been progressively culverted from the latter part of the 19th century such that what remains of it now runs almost entirely below ground within the limits of the Riverside Exchange development.

The ground within the site is fairly level, at 50 m above Ordnance Datum, and solid geology comprises Coal Measures (*Geological Survey of Great Britain*, sheet 100), indeed coal outcrops at the surface approximately 2 km north of Riverside Exchange. However, within the site the Coal Measures are overlain by thick deposits of alluvium which underlie all the archaeological deposits recorded. The area has in the past been subject to flooding, most notably during the Great Sheffield Flood of 1864 which briefly inundated the area and caused widespread damage both there and elsewhere in the town.

Prior to the main phase of archaeological excavations much of Riverside Exchange was occupied by relatively modern buildings associated with the Whitbread brewery. However, with the exception of a single complex of mid-19th-century brewery buildings which have been retained to the south of the site (see Pl. 1), the remainder were cleared leaving only a surface of hard-core and concrete.

Historical Background

It is likely that the town corn mill was built by William De Lovetot, Lord of the Manor, at Millsands in the 12th century (Ball *et al.* 2006, 24), probably the first 'industrial' use of waterpower in Sheffield and central to the development of this area (Fig. 2). The mill originally lay in sight of the castle which stood at the confluence of the River Sheaf with the River Don a short distance to the south-east, the castle surviving until demolition after the Civil War. William De Lovetot also built a timber bridge across the Don, immediately to the south-east of Millsands, which was subsequently to become known as Lady's Bridge (see Fig. 2). The erection of the castle and the building of the bridge marked the origins of Sheffield as an important settlement. The wooden bridge was replaced in stone in 1486 (Hey 1991, 41), by which time this location had become a major crossing point on the river, providing a link between the castle on the south side and the Wicker or Assembly Green to the north on the opposite bank (*ibid.*, 36–7). Lady's Bridge continued to mark the north-eastern limit of the town of Sheffield until around 1740 when expansion in this area began (*ibid.*, 63).

The new bridge of 1486 was the work of William Hill, a master mason who was contracted by the townsmen to build a stone bridge of five arches, 14' 6" (4.42 m) wide. Some of the ribbed arches of this bridge can still be seen from the Castlegate side. The name Lady's Bridge is taken from a chapel which once stood at the south-east end of the bridge, and in the will of George, 4th Earl of Shrewsbury, dated 1538, it is referred to as 'the Chapel of Our Blessed Lady of the Bridge' (Hey 1991, 41–2). In 1547, the townsmen saved the chapel from demolition during Henry VIII's dissolution of the monasteries by turning it first into a warehouse and then an almshouse. The bridge was widened in 1760 to accommodate an increasing volume of traffic, this act destroying the chapel. The bridge has been widened a further three

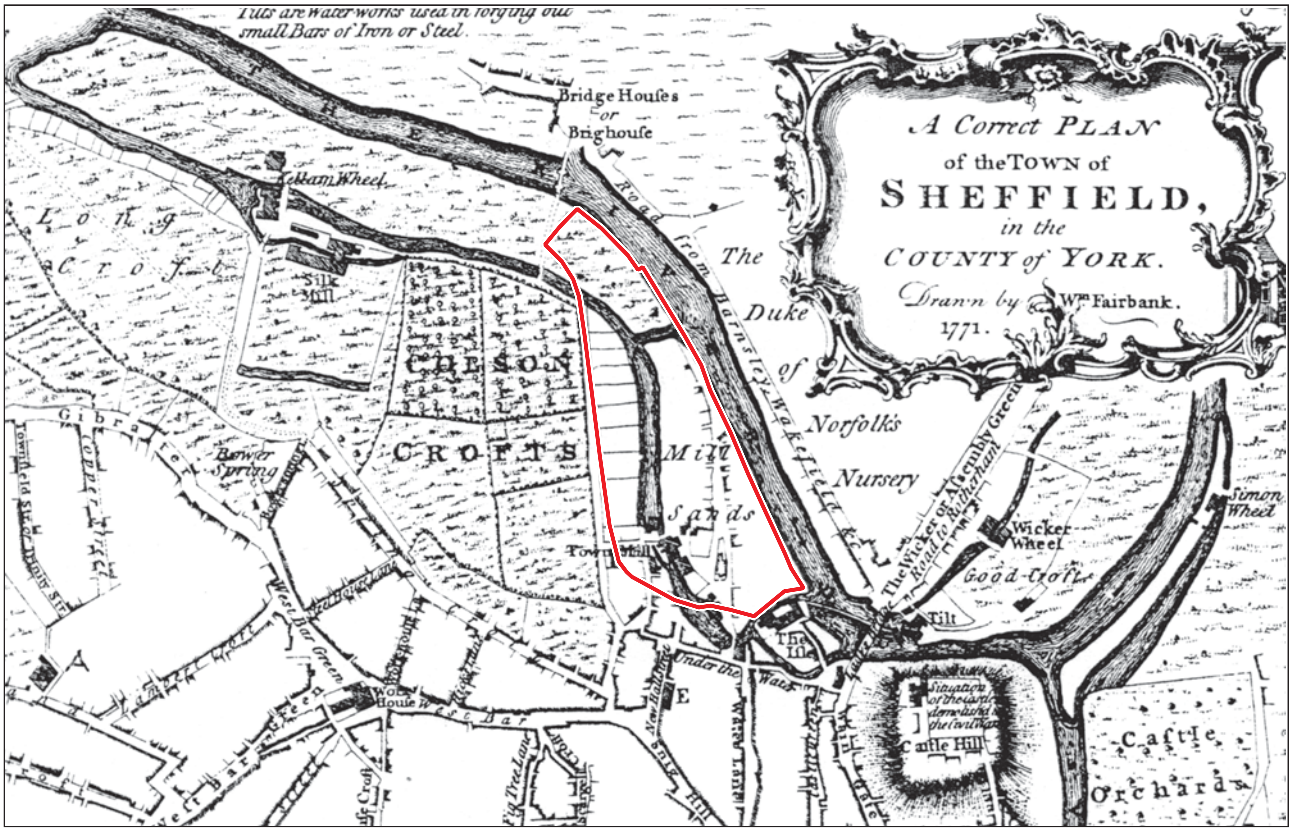


Figure 3 Extract from the Fairbank map of Sheffield of 1771 (Sheffield City Council, Libraries Archives and Information: Sheffield Archives FC She 1S), with the Riverside Exchange site shown in outline

times since that date to allow passage for trams and other heavy vehicles, and it survived the Great Sheffield Flood of 1864 intact, when several other bridges were swept away (*ibid.*, 41).

In addition to the new bridge, a hospital dedicated to St Leonard was also built in the 15th century, on the east side of the Don, providing an indicator of Sheffield's aspiration to urban status at this time (Hey 1991, 42). However, the Millsands area, on the northern periphery of the medieval settlement, remained largely as semi-rural gardens and orchards, with a few workshops (see Fig. 2). Records from the 16th and 17th centuries show that people were living on and around Millsands by that time, and in John Harrison's survey of the manor of Sheffield in 1637 about 20 people are listed as having gardens in and around Millsands (Ronksley 1908). This pattern of use continued until the second half of the 18th century when John Marshall's Millsands steelworks was established on land then held by the Duke of Norfolk.

Millsands was traditionally the name given to the area between the Town Mill or Kelham goit and the River Don, whilst the area to the west of the goit formed part of Colson (or Colston) Crofts (Fig. 3). However, Millsands also included an area variously known as 'between the waters', 'the Isle' and the 'Isle of Wight' immediately beyond the southern end of the Riverside Exchange site. This small area lay between two branches of the goit, which split into two just before rejoining the River Don. The road to the south of the 'Isle' was known as 'Under the Water', later Bridge Street (from 1789, when it was widened), because it was low lying, as was the adjacent 'Isle'.

The 'Isle' was inhabited from at least the middle of the 16th century. In 1566 Robert Roger had a 'house between the waters' and 'a garden stede in the Mylne sannds', and it is known that a William Rodger, presumably a descendant of Robert Roger, lived in this area between 1647–1657 (Leader 1897). Also in 1566 there are entries in the rate books for 'Humffrey Bayte [and three others] for his pyttes in the Mylne sands' attesting to activity other than corn milling in this area, to the north of the 'Isle' (*ibid.*). There are later records of works done at various times to secure the banks of the 'Isle', for example in 1691 money was 'Paid for powles, stones, cramps and workmanship rayleing and walling up by the water syde against the Isle of Wight' (*ibid.*), and a year later in 1692 there was a further outlay 'Paid for paving the water side against the Isle of Wight' (*ibid.*).

By the 17th century (and probably long before) there is likely to have been a raised footway along Millsands, running south to north midway between the river and goit, and in 1678 there is a reference that probably relates to this route. This records 'payd

Plate 2 The significance of the earliest cementation furnace explained to visitors (© University of Sheffield. Reproduced by permission)

Richard Hynd for mending the way that millstones and draughts may pass to the mill sands' (Leader 1897), while slightly later, in 1681, the Town Trustees paid Daniell Bridges 'towards making a foot cawsey from Milnsands head towards Brigghouse' (*ibid.*). In 1714 there is a reference to 'Bridgehouses steppings' leading from the 'cawsey' (*ibid.*). This probably refers to stepping stones that crossed the River Don from the northern end of the Millsands causeway prior to the building of a wooden bridge, which was supposedly constructed in 1726 (Leader 1901). These stepping stones, and subsequently the bridge, provided a link between Millsands and the small suburb of Bridge Houses across the Don to the north. Fairbank's map of 1771 (Fig. 3) clearly shows the suburb, bridge and the track or roadway leading to it across Millsands.

The footway along Millsands continued in use and became the principal route into the area from the south, providing access to many of the properties and associated trades, crafts and industries which became established there and developed from the middle of the 18th century onwards. This route later became known as Millsands and survived until the end of the 20th century and the redevelopment of Riverside Exchange.

Archaeological Investigations

The ARCUS investigations at Riverside Exchange comprised a staged programme of work spread over a period of seven years, commencing with an archaeological desk-based assessment in 1996 (ARCUS 1996a).

For development purposes, the site was divided into three areas (Areas 1–3). The archaeological work also followed this structure (see Appendix, which provides a concordance of Area, trench and ARCUS project number), and focused on six 'sites' of significance (see Fig. 1) identified in the desk-based assessment. These were:

- Marshall's Millsands steelworks (Area 1)
- Tanneries (Area 1)
- The Town Mill (Area 2)
- The Cutlers' Wheel (Area 2)
- Vickers' rolling mill, part of the Naylor Vickers works (Area 3)
- The Goits or watercourses (Areas 1, 2 and 3)

The desk-based assessment was followed by an evaluation of the southern end of the site in the same year (ARCUS 1996b). Three trenches were excavated for this evaluation, but there was no subsequent work until 1999, after a change to the proposed development scheme. In 1999–2000, additional evaluation was undertaken, concurrent with an open area excavation and several watching briefs (ARCUS 2005a). In early 2003, further excavation and watching briefs were carried out (ARCUS 2005b) and, at the end of that year, a final phase of limited excavation and a watching brief concluded the programme of fieldwork (ARCUS 2004). This final phase of work was mainly concerned with the preservation *in situ* and preparation for display of the earliest steel cementation furnace (Pl. 2). The relevant documents and reports issued during the course of the investigations are listed in two reports issued in 2005 (ARCUS 2005a; ARCUS 2005b).

The results of the archaeological investigations were summarised in the two reports issued in 2005 (ARCUS 2005a; ARCUS 2005b), which together accounted for virtually all of the areas evaluated, excavated or subject to a watching brief. Each of these documents included an introductory section, briefly described the stratigraphic sequences in the individual areas, and also assessed the finds and environmental assemblages. Recommendations were made as to what further analysis of the stratigraphic sequences, finds and environmental remains was thought necessary, in order to consolidate the archive and publish the results of the archaeological work.

Following the assessment reports of 2005, some further analysis was undertaken, principally on parts of the pottery, clay pipe and animal bone assemblages, but post-excavation work largely ceased in 2007, prior to the closure of ARCUS in 2009.

The Riverside Exchange project was inherited by Wessex Archaeology when it established a Sheffield office, and a publication report was required in order to fulfil the requirements of the planning condition for the development. A proposal for a monograph publication was prepared by Wessex Archaeology

(Wessex Archaeology 2012), and this incorporated the aims expressed in the previous proposals for publication outlined by ARCUS (ARCUS 2005a; 2005b). Limited further analysis and research was proposed culminating in the publication of a synthetic monograph report setting the site in its local, regional and national context.

Four themes were identified based on a review of the original research aims and the additional potential identified in the previous proposal for publication (ARCUS 2005b; Wessex Archaeology 2012).

- Theme 1: Technological aspects of steel production
- Theme 2: The use of waterpower on the site
- Theme 3: Chronology and the ordering and use of space
- Theme 4: Patterns of consumption

Detailed excavation of the six highlighted 'sites' (see above) was focused largely within the building 'footprints' of the proposed new development, where archaeological deposits would be destroyed, and concentrated on areas of the trenches that were generally unaffected by later 20th-century disturbances.

All initial excavation was undertaken by machine and recent (later 20th century) levelling and demolition deposits as well as other, modern intrusions were removed as far as was practical. Subsequent excavation was by hand, except in the watching brief areas where machine excavation continued and only ceased when features or deposits of archaeological significance were encountered. In the few cases where such remains were exposed, they were investigated and recorded prior to further machine excavation down to the required formation level.

Fieldwork strategies were sometimes modified as excavation progressed, most notably in the case of the important early steel cementation furnaces where the surviving remains were subject to more limited excavation prior to recording and subsequent preservation *in situ*.

In some areas, particularly where excavations were limited in extent, it was sometimes difficult to relate the structural sequences recorded to the map and documentary evidence. This difficulty was increased where the sequences had been disrupted to varying degrees by later disturbances and where the associated artefactual material was insufficient to closely date individual phases, some of which are likely to represent only minor or localised developments.

The majority of the surviving structures and deposits represented below-ground foundations, the floor levels having been removed by phases of demolition, levelling and rebuilding, a particular characteristic of inner city sites such as Riverside Exchange which have seen extensive post-medieval industrial development.

In general there was a distinct lack of 'working deposits', perhaps because floors and surfaces were regularly cleaned. Nevertheless, the combination of structural and finds evidence has confirmed the identification of certain processes and working areas within the site, and this has contributed to a better understanding of these functions and their place in the history of Riverside Exchange and the surrounding area.

Detailed context descriptions, drawings, site matrices, finds catalogues and other records are contained in the site archive, which has been deposited with Museums Sheffield.

Chapter 2
The Goits, Town Mill, Cutlers' Wheel and Tanneries

Goits

Goits, a name which seems peculiar to Sheffield, are artificial watercourses. Often known elsewhere as leats, races or mill streams, they were dug to bring water to drive waterwheels, the channel from the river to the wheel being known as the head goit, with the tail goit taking water from the wheel back downstream to the river. The goit passing north–south through the Riverside Exchange site and bringing water to the Town Mill from the River Don beyond what is now Kelham Island must have been dug in the 12th century (see Fig. 1), when the demesne corn mill was built by the De Lovetots (Ball *et al.* 2006, 24). Further south of the mill the tail goit split into two, passing either side of the Isle, before rejoining the River Don. Whether both branches of the tail goit were dug at the same time, in the 12th century, is unknown, but it is more likely that they were not contemporary, the northernmost branch perhaps being dug later (but prior to the mid-16th century) as a subsidiary channel.

Plate 3 Recording part of the Town Mill goit and the wheel pit of the Cutlers' Wheel (view from south) (© University of Sheffield. Reproduced by permission)

A substantial sandstone wall in excess of 16 m long, 2.4 m wide and 2.8 m high at the southern end of Area 1 was probably a retaining wall on the southern side of the Town Mill goit before it split into two branches (Pl. 3). This wall, of probable 18th-century date, ran east–west, turning to the north-west at the west end, and survived up to 17 courses high, built on a foundation of roughly hewn sandstone blocks. The path of the goit in this area contained a double culvert, the northern arm built in brick and probably of 19th-century date. This arm is likely to have been backfilled when the culvert following the southern branch of the goit was lined with cement and redirected beneath the brewery buildings on the former 'Isle', probably in the 20th century (see Fig. 1). A short length of a substantial, north–south aligned sandstone wall in an evaluation trench in this area may have been part of an 18th-century lining to this southern part of the goit.

Fairbank's map of 1771 shows another, short goit between the Town Mill goit and the River Don towards the north end of the Millsands area (see Fig. 3), the first appearance of this goit on maps, though it is not clear what its function was at this time, prior to the establishment of the Naylor Vickers works on the site.

The southern end of the Town Mill tail goit was arched over in 1789–91 (WC 1374 M) and the Isle ceased to be an island; a further part of the goit by the Town Mill was built over by *c.* 1850. The covering over of the head goit, above the Town Mill, began in 1808 and by 1889 it had been almost completely contained within a culvert and remained open only at the north end of the site.

Map evidence indicates that from the mid-19th century onwards, the banks of the river were built out eastwards into the Don and this gradual encroachment continued thereafter. A substantial stone wall which ran parallel and close to the River Don, recorded in an evaluation trench towards the south-east corner of the site, is likely to have been part of a riverside embankment, probably of pre-19th-century date.

Town Mill

Trench 5 (see Fig. 1) was sited to investigate the Town Mill, but no structural remains of certain pre-19th-century date survived, and no evidence was found in this area of the orchards and gardens recorded in the 16th and 17th centuries and shown on 18th-century maps (see Fig. 2). Instead, various levelling layers directly overlay alluvial silts, some of this material probably imported to the site in order to consolidate and raise ground levels to reduce the risk of flooding. A small area of stone slabs was exposed in an adjacent part of trench 11 to the north-west, in the probable area of the mill waterwheel, though this surface remains undated. The principal surviving structure was part of a wall built of large, re-used sandstone blocks, the machine-tooled surfaces indicating a probable 19th-century date and likely to be remains of a late phase of the mill. Amongst the finds from this area were a few sherds of medieval ware and some 16th/17th-century Cistercian wares, as well as the earliest of the wine bottles of 17th-century date, although in all cases these were mixed with later material.

William De Lovetot, Lord of the Manor of Hallamshire, had the Town Corn Mill built at Millsands in the 12th century (Ball *et al.* 2006, 24). The supply of grain and sales of malt and flour from the mill are mentioned in the Shrewsbury accounts from 1578, and all tenants of the Lord of the Manor were obliged to have their corn ground there (Ball *et al.* 2006, 24; ACM S115).

The Town Mill was leased by 1664 when the tenants were Thomas Cooke and Edward Hobson, but it is uncertain how consistently it was let out (Ball *et al.* 2006, 24; ACM S127). A bye-law of 1709 instructed Kellam Homer (from whom Kelham Island derives its name) and any of his tenants who had water-powered grinding wheels on the Kelham Island goit, which supplied the Town Mill, not to impede the flow and to ensure that sufficient water was always available to power the Town Mill, or there would be penalties (Leader 1897).

Thomas Ford took the lease on the Town Mill in 1740 and approximately 10 years later, in around 1750, built what became known as the Cutlers' Wheel (Ball *et al.* 2006, 24; ACM S377). It is clear from documentary sources, nevertheless, that the Town Mill continued to operate a little further downstream in its corn-grinding capacity (Fig. 4). Gosling's 1736 plan (see Fig. 2) shows a different layout to that shown on maps after the Cutlers' Wheel had been built, but whether this is simply a cartographic rather than an actual change is uncertain. There are references to various repairs in the 17th and 18th centuries (Ball *et al.* 2006, 24), but not a rebuilding of the Town Mill, though clearly there must have been some major changes between the 12th and 20th centuries.

In 1761 John Vickers took a 21-year lease of the mill and Cutlers' Wheel, and the Town Mill subsequently remained in the family for just over a century, Vickers and Robert Rodgers buying the mill, wheel and adjacent properties from the Norfolk estate in 1805 (Ball *et al.* 2006, 24–5).

The Town Mill is marked as a corn mill on the 1851 Ordnance Survey map, around the time that it was let to Samuel Price, from the 1850s to the late 1870s (Ball *et al.* 2006, 25). Documents dating to 1856 make reference to a steam engine installed for the purposes of working the corn mill and grinding wheel (Cutlers' Wheel), as the waterwheel had been removed and water from the Town Mill goit was now being used to power the Naylor Vickers rolling mill to the north (Aurora MS 510/9). However, the 1895 list of wheels states that waterpower was not abandoned until 1877 (1895 Don list; Ball *et al.* 2006, 25). The Town Mill in 1856 included the corn mill with granaries, barns, stables, homestead, yards and vacant land, sheds and other buildings, steam engine, engine house, boiler, machinery, gearing and millstones. It was also recorded that the owners of the corn mill could take water free of charge from the goit to supply the steam engine, and could also charge for supplying water to other premises (Aurora MS 510/9). Samuel Price and Son, millers, are listed in the 1864 Sheffield Flood Claims Archive, with the substantial sum of £490 awarded against a claim of £524 5s 10d (claim 2753). http://www2.shu.ac.uk/sfca [accessed 8/8/13]).

The corn mill is still named as such on the Ordnance Survey map of 1889, and in 1888 (Kelly's Directory for 1888) and 1901 (White's Directory for 1901) it was registered to Price and Sons, millers (Town Mills). The mill buildings survived until dismantled in 1939 (*Sheffield Telegraph and Independent*, 22 December 1939), after which they were built over as part of an extension to the Whitbread brewery.

Cutlers' Wheel

In around 1750, Thomas Ford, who had held the lease on the Town Mill from 1740, built what became known as the Cutlers' Wheel (Ball *et al.* 2006, 24; ACM S377), the name given to the workshop and the associated waterwheel. This lay immediately upstream of the Town Mill, north of Mill Lane and within the area of the goit itself, necessitating some significant structural works.

Although nothing of the medieval Town Mill was found, the structural remains associated with the Cutlers' Wheel survived better, in trench 11 (Fig. 5). Two large retaining walls (11016 and 11023) built of

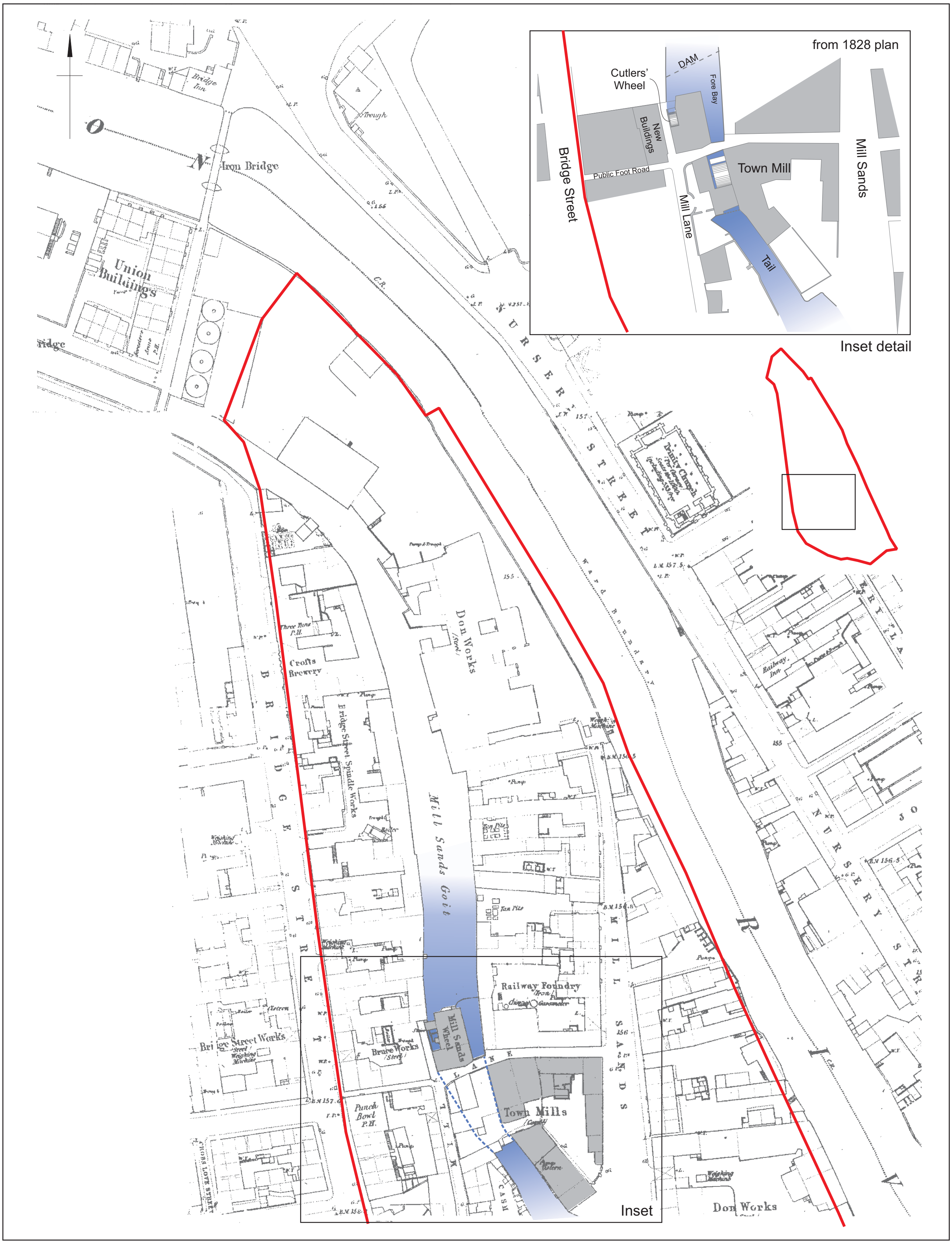


Figure 4 Extract from 1850 Ordnance Survey Map 26" to 1 mile (Sheffield City Council, Libraries Archives and Information: Sheffield Archives), with Mill Sands (Town Mill) goit, Town Mills and Mill Sands (Cutlers') Wheel highlighted. Inset: Detail of Town Mill and Cutlers' Wheel, redrawn from a plan of 1828 (Sheffield City Council, Libraries Archives and Information: Sheffield Archives FC She 714S)

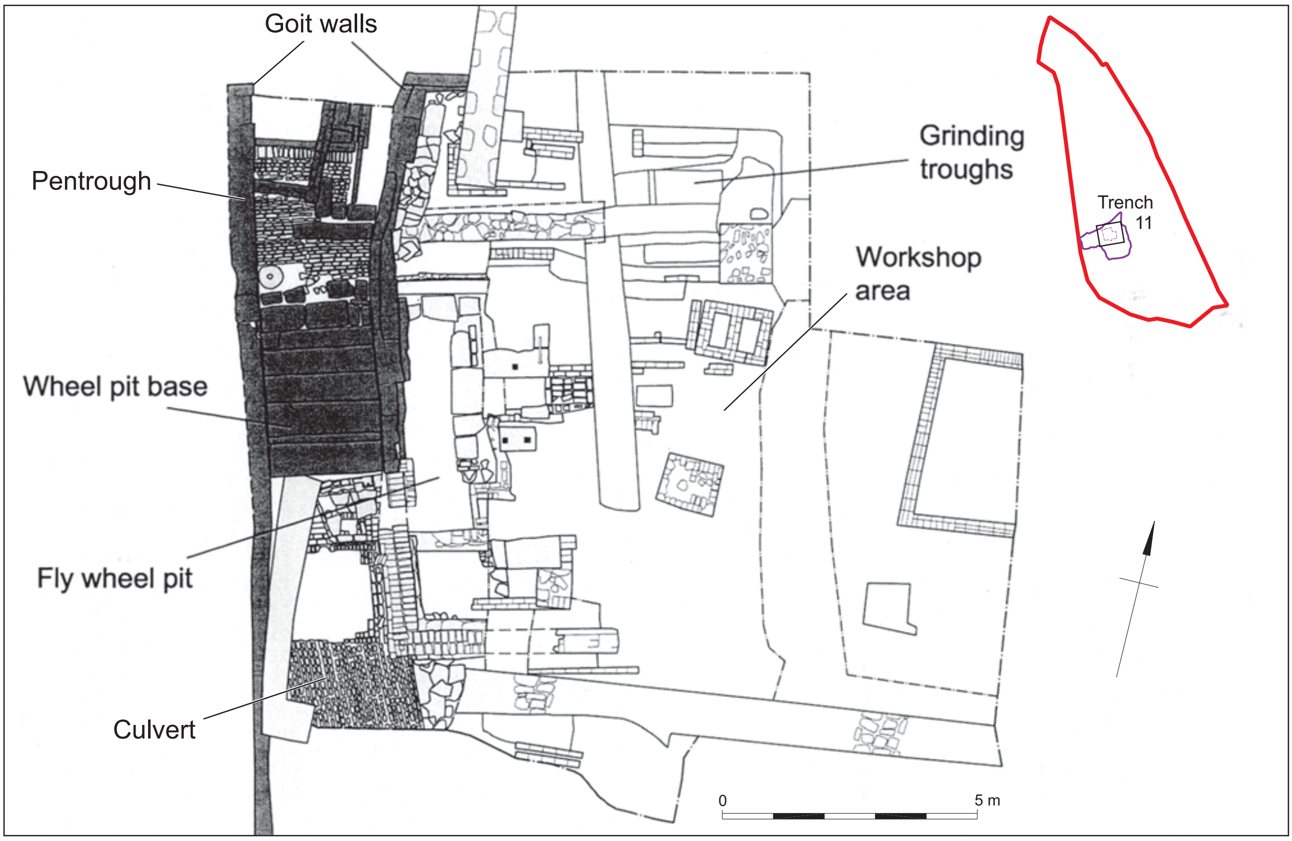


Figure 5 Excavation plan of Cutlers' Wheel (© University of Sheffield. Reproduced by permission)

Plate 4 Excavation of Cutlers' Wheel (view from north-west). Inset shows surviving stone troughs in scythe grinding hull at Wisewood, Sheffield (© University of Sheffield. Reproduced by permission)

rough-hewn sandstone slabs would have funnelled water in the goit towards the waterwheel, of which nothing remained. This area was known as the forebay, and on the east side of the Cutlers' Wheel was a deep channel which formed the by-pass system which allowed an unimpeded flow of water to the Town Mill. At the end of the forebay was the pentrough, also built of large blocks of stone, and here the penstock (of which nothing survived), controlled from the workshop, would have regulated the flow of water to the waterwheel. The waterwheel was contained within a wheel pit built of stone, with a base of timber, and this supported an undershot wheel with an estimated diameter of 18 feet (5.5 m) diameter. The sides towards the base of the wheel pit were curved and would have fitted closely with the wheel so that little water was lost along either side of the wheel, thereby minimising the amount of water required to drive the wheel efficiently. A culvert at the end of the wheel pit allowed the water to escape freely into the tail goit and provide power to the Town Mill immediately downstream. Adjacent to the wheel pit was a narrow rectangular pit, the fly wheel pit, where the gear mechanism was located for transferring the power by belt drives from the waterwheel to the grinding troughs in the workshop. Only vestiges of this workshop or 'hull' survived (Pl. 4), but the east wall was defined by a sandstone wall which had been later robbed and within the interior were several, shallow sub-rectangular features which were probably the emplacements for grinding troughs. Several stone troughs survived in the scythe grinding hull excavated at Wisewood in Sheffield, the arrangement broadly similar to that which is likely to have existed within the Cutlers' Wheel workshop (see Pl. 4).

When John Vickers took over the lease of the Town Mill in 1761 the grinding works was described as a 'Cutlers Wheel of one end and ten troughs' (Ball *et al.* 2006, 24; ACM S378), a trough being where a single grinding wheel was set up, and thus the workshop would have accommodated ten grinders. By 1794 this had increased to 34 troughs employing 38 men, and in 1805 the Norfolk estate sold the Town Mill and Cutlers' Wheel to John Vickers (Ball *et al.* 2006, 24; ACM S158; WRRD EY 512 651).

The grinding wheel was recorded as empty in 1845/6 and no longer appeared in the rate books by 1855, though it had been advertised to let in 1849 (Ball *et al.* 2006, 24). A reference in 1877 records '*… all that piece of land … part of which was formerly the site of Cutler's Grinding Wheel (now long since pulled down)*', and in the same year the site of the Cutlers' Wheel and part of the Town Mill dam was sold to Tennant and Moore (Aurora MS 510/8), the owners of the Exchange Brewery, which much later, as Whitbread's, came to occupy a large part of the Millsands area.

The interior of the Cutlers' Wheel workshop appears to have been kept relatively clean during use, though 38 pieces of worked bone – debris from handle-making – and an almost complete grindstone came from the fly wheel pit and approximately 2500 items of mainly pottery, glass, clay pipes and metalwork were recovered from the bottom of the waterwheel pit. These were deposited there from the mid-19th century, though they included some earlier material, for example two mid-18th-century knives (see Metalwork, below).

A 19th-century pit in the vicinity of the Cutlers' Wheel contained a small quantity of antler and wood remains which are likely to be debris from the preparation of handles, and several scale cutters and hafters are known to have been working in this general area in the mid-19th century. After the Cutlers' Wheel ceased operation a small steelworking shop was established in the late 19th century (Ordnance Survey 1889), powered by steam, and the remains of a condenser pit survived, associated with what was probably the base for a Cornish-type boiler and the footings for an associated chimney, whilst a nearby dump containing wheel swarf sealed layers containing copper wire pins of late 19th- or early 20th-century date.

Grindstones

A total of 42 grindstones have been catalogued from Riverside Exchange, of which 18 are complete examples and the remainder fragmentary (eg, Fig. 6). All appear to be in local fine-grained sandstone (Beauchamp 2002, 68; Unwin 2002, 28), the use of which pre-dated the introduction of artificial grindstones at the beginning of the 20th century. Twenty-one grindstones have reasonably secure contexts, though many of these are from cleaning layers and several had been re-used as foundation or paving material. A further 14 grindstones are recorded as unstratified and seven have uncertain provenances.

The complete grindstones range in diameter from 9" (210 mm) to 25¾" (656 mm), with 11 over 16" (411 mm). Thicknesses range from 2½" (60 mm) to 8" (205 mm) for grindstones that were 16" (402 mm) and 12" (305 mm) in diameter respectively. Where the form of the central holes could be determined, 23 were square and five circular. A square hole for an iron axle, secured with wooden wedges, may be characteristic of earlier grindstones, whilst later ones may have had a circular hole with the stones attached by iron side plates and secured with a nut.

Different sizes of grindstone were used by grinders in various branches of the trade, the table-blade grinders using ones about 48" (1.2 m) in diameter

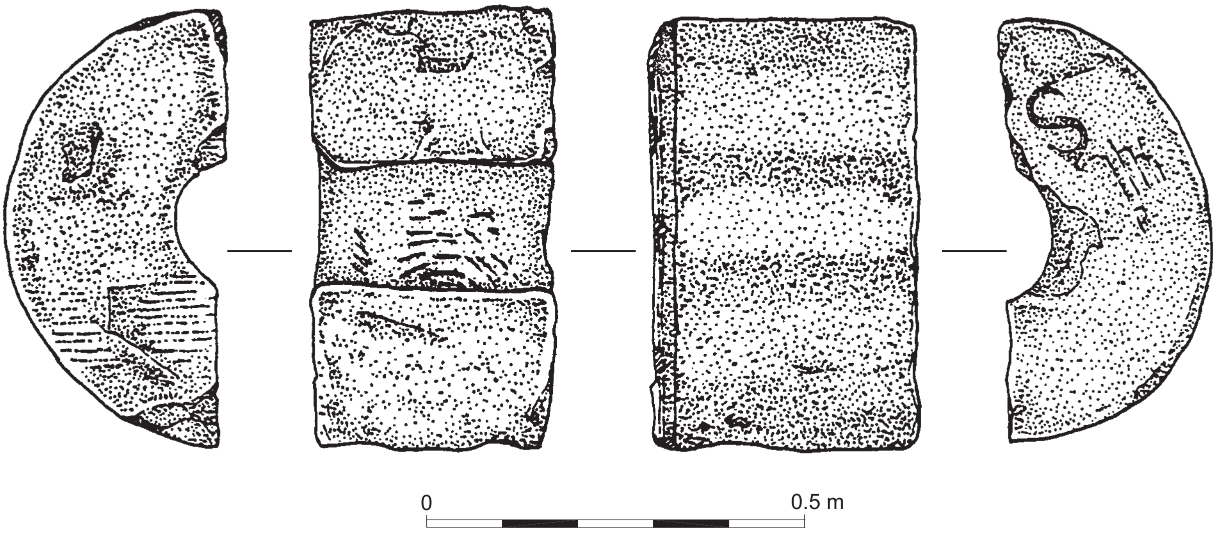


Figure 6 Grindstone fragment recovered from the Town Mill goit (© University of Sheffield. Reproduced by permission)

and 10" (250 mm) thick (Symonds 2002, 28), considerably larger than any of the examples at Riverside Exchange. However, stones were often used by table-blade grinders until they were reduced to half their original diameter, following which they were acquired by other grinders who used smaller stones.

Tanneries

Two groups of tanning pits were uncovered at Riverside Exchange, the earliest of probable mid-17th-century date in trench D on the east side of the site close to the River Don. The other group, probably constructed in the early 19th century, lay closer to the Town Mill or Millsands goit in the centre of the site.

The 17th-century tanning pits in trench D were only partly exposed and had been extensively disturbed by later development (Fig. 7). However, parts of at least three, square, plank-lined pits were recorded (15152, 15214 and 15373), pit 15152 containing a deposit of lime. To this group can be added barrel 15199, set into the ground and also containing lime. A remnant of cobbled surface (15374) adjacent to pit 15373 in the south-east corner of trench D was probably part of an open yard, whilst walls 15141, 15205 and 15385, with contemporary flagstone surface 15140, in the north-west corner represented one or more phases of associated structure, perhaps forming a covered area here. A relatively large assemblage of animal bone was recovered from the tanning pits and other deposits and analysis of this suggests that it represents tanning waste (see Viner-Daniels, below). Later, 19th-century deposits in trench D also contained several hundred fragments of worked bone deriving from the production of scale-tang knife handles (see Viner-Daniels, below).

A further eight, rectangular, plank-lined tanning pits, of probable early 19th-century date, were recorded in trench B (Fig. 8). This group was still in existence in 1851 as they are clearly shown on the Ordnance Survey map of that year (see below), the layout closely reflecting the excavated plan, though the excavations revealed at least two phases of pits.

Harrison's description of the Manor of Sheffield in 1637 (Ronksley 1908) contains references to several 'Tann Offices', but their locations are not given. However, it is possible that the group of tanning pits recorded in trench D was one of these. Almost a century and half later William Marsden, fellmonger (dealer in animal skins and hides), and Richard Yeomans, brown bazil tanner and red leather dresser, are recorded at Millsands in 1774 (Sketchley's Directory of 1774), whilst a map of 1781 (ACM SheS 1495 L) shows two adjacent skinners' yards (belonging to Marsden and Yeomans respectively) and a dye house next to the River Don, the latter possibly in another property then held by Marsden (Fig. 9). William Marsden was subsequently listed in 1787 (Gales and Martin's Directory of 1787) as a fellmonger and glue maker, and his principal property is shown to the north of the Town Mill and east of the goit with another, smaller property to the east, perhaps that containing the dye house and known as the 'glue field', extending between the route later known as Mill Sands and the River Don; at the same time, Richard Yeomans also held an adjacent property to the south (see Fig. 9). In 1825 fellmongers and leather dressers are listed working at Millsands or nearby Colston Crofts (Gell's Directory of 1825), but no tanning pits or related structures are shown on the 1851 Ordnance Survey map in what had been William Marsden's property. However, a small group is shown in Richard Yeoman's property immediately to the north, and beyond this the small group of tanning pits

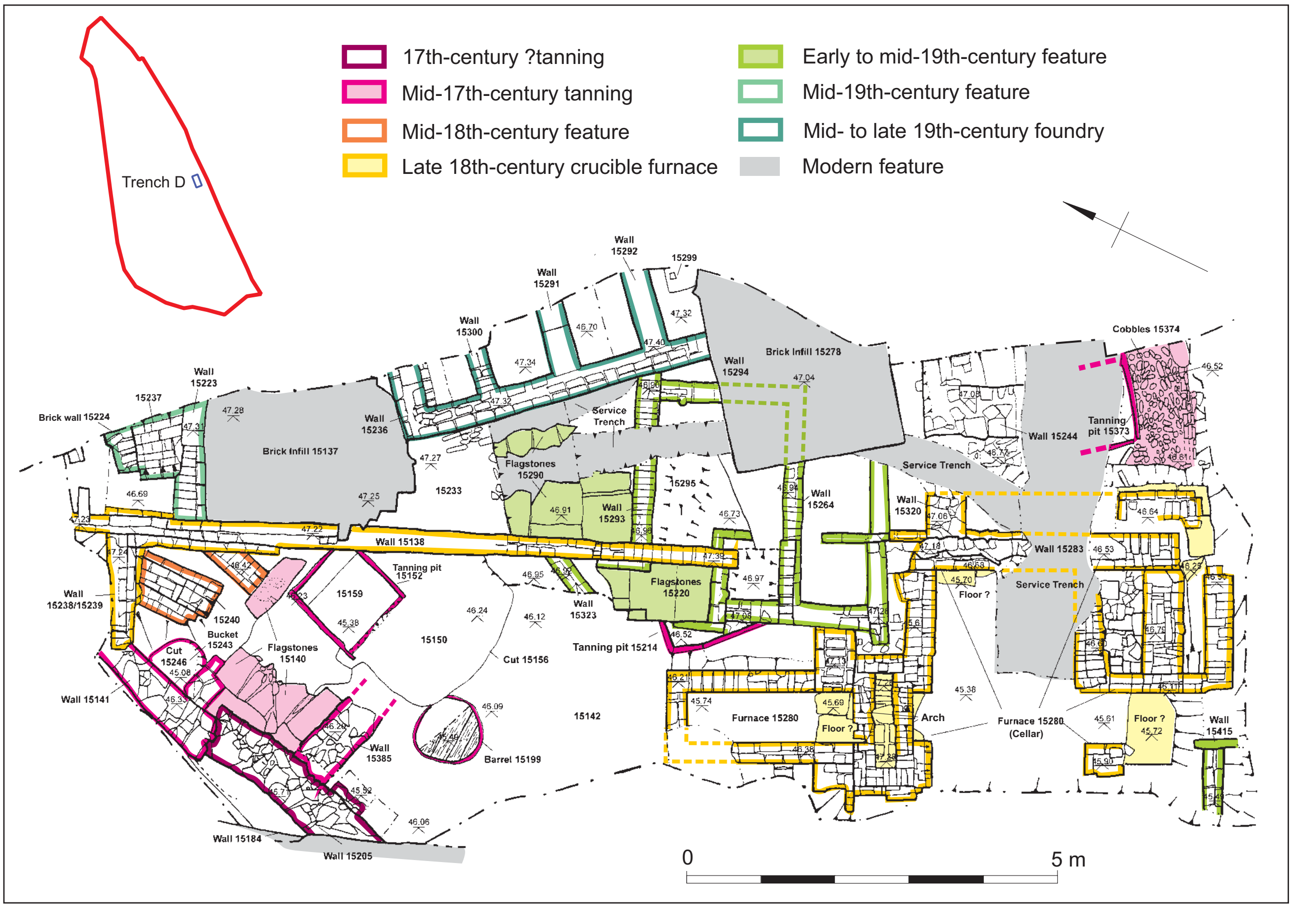


Figure 7 Excavation plan of crucible steel furnace cellar, earlier tanning features and later remains in Area D (© University of Sheffield. Reproduced by permission)

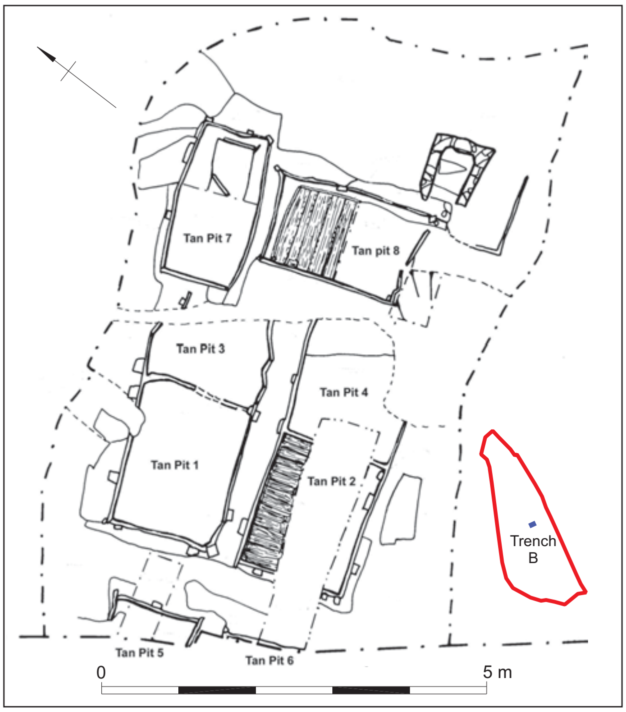


Figure 8 Excavation plan of 19th-century tanning pits in trench B (© University of Sheffield. Reproduced by permission)

excavated in trench B also appear (see Fig. 9). In 1862 Naylor Vickers took over part of the site, including the area where a fellmonger's warehouse and shops formerly stood (Aurora MS 500/3), and this may mark the end of tanning on the site as no tanning pits are shown on later maps. However, it was not the end of leather preparation, and a Morocco leather manufacturer (John Debell) is listed in the 1864 Sheffield Flood Claims Archive, with the relatively large sum of £98 3s 0d awarded (claim 4833; http://www2.shu.ac.uk/sfca [accessed 8/8/13]).

Animal bone

by Sarah Viner-Daniels

Material from the early stages of excavation at Riverside Exchange has been assessed (Bell 2005), while that from the later stages has been both assessed (Hammon 2005) and analysed (Viner nd). The summary here is largely drawn from the results of the analysis, with additional information included from the assessments where appropriate.

All animal bone was hand-collected and recorded using a modified version of the method outlined by

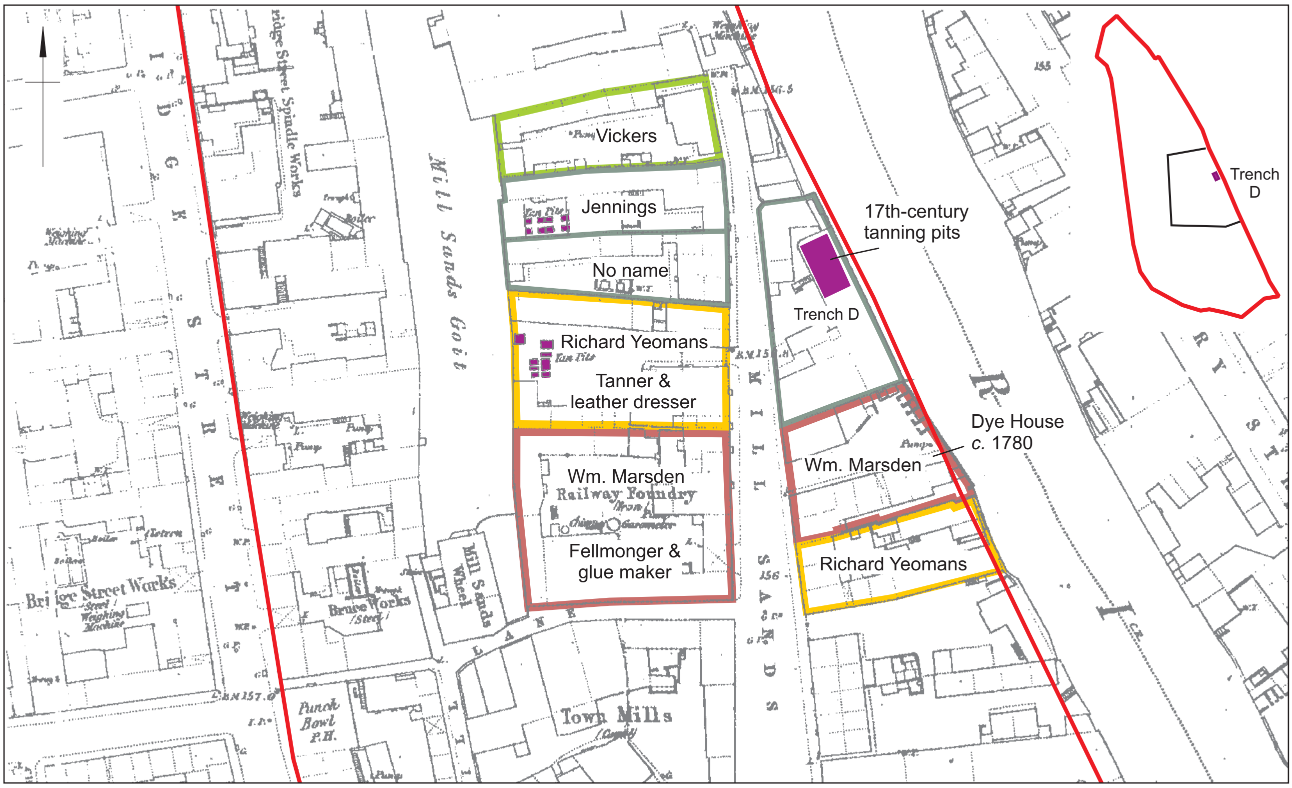


Figure 9 Extract from 1850 Ordnance Survey Map 26" to 1 mile (Sheffield City Council, Libraries Archives and Information: Sheffield Archives), with tan pits highlighted and selected late 18th-century properties/tenants indicated

Davis (1992) and Albarella and Davis (1994). This method distinguishes between countable and non-countable bones based on the presence or absence of specific diagnostic zones. Where possible measurements were taken as outlined in Albarella and Davis (1994), Davis (1992) and defined in von den Driesch (1976). Full details of the recording methods are contained in the archive.

Trench D produced the largest and most significant assemblage of animal bone from the entire Riverside Exchange site, and was the only assemblage which warranted full analysis (Viner nd; see below). Bones from all trenches and areas were very well preserved, with little evidence for weathering or gnawing, suggesting that the bone had not been exposed long before burial. A total of 804 bone fragments were recovered from trenches 1, 2, 4, 5, 10 and 11, approximately 75% (589 bones) from the latter, open area excavation around the site of the Town Mill and Cutlers' Wheel. In addition to the bones from trench D dealt with in this report, trench 11 also produced a number of antler and horn core fragments, and approximately 100 worked bone fragments (Bell 2005). Many of these worked fragments derive from cattle metapodials and represent debris from the production of bone scale handles, several unfinished examples of which were recovered from the same contexts as the worked bone debris.

Trench 14, approximately 25 m to the north of trench 11, produced a further, substantial assemblage of worked bone and antler, all likely to be of mid- to late 19th-century date. A total of 554 fragments were recovered, virtually all of them antler, the majority comprising small offcuts, but also some larger pieces of tines and crowns, along with a few part-finished handles. The latter includes knife handle scales and solid handles.

Results

The phases (1–9) referred to below are area-specific chronological phases for trench D. The results are summarised in Table 1. For the purposes of analysis both NISP (number of identifiable specimens) and MNI (minimum number of individuals) have been used for quantification. A total NISP of 578 was recorded, *c.* 80% of this total from 17th-century (phase 3) contexts. The very small groups from possible pre-17th-century (phases 1–2) and 20th-century (phases 8–9) contexts are not further discussed below. The assemblage is dominated by the bones of sheep/goat (*Ovis/Capra*), with smaller numbers of cattle (*Bos*), pig (*Sus*) and dog (*Canis*). Among those bone elements included as non-countable are specimens identified as equid (*Equus*), chicken (*Gallus*) and a medium-sized fish.

Table 1 Animal bone: NISP and MNI values for each phase by species (trench D)

	Phase 3		Phase 4		Phase 5		Phase 6		Phase 7		Phase 8		Phase 9	
	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Cattle	11	2	4	2	12	3	3	1	11	2	–	–	–	–
Sheep	71	18	11	5	6	3	1	1	–	–	–	–	8	2
Sheep/goat	319	41	13	2	22	3	11	2	2	1	9	2	16	2
Pig	2	1	–	–	–	–	–	–	–	–	–	–	–	–
Dog	1	1	–	–	–	–	–	–	–	–	–	–	–	–
Rat/vole	3	1	–	–	–	–	–	–	–	–	–	–	–	–
Frog/toad	42	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	449		28		40		15		13		9		24	

Phase 3 (17th century)
Bones included here come from 15 contexts and the total NISP for this phase is 449, of which 87% are either sheep or sheep/goat. Morphological characteristics along with a comparison of distal metapodial measurements suggest that the majority of the animals were sheep rather than goat.

The distribution of sheep/goat body parts in phase 3 contexts provides information of importance to the archaeological interpretation of the assemblage. (Fig. 10 shows each element as a percentage of the total MNI). The large number of metacarpals, metatarsals and phalanges contrasts with the comparatively low frequency of all other elements. In fact, the frequency of meat-bearing bones is so low that the assemblage is unlikely to represent a mixture of food refuse with waste from craft activity, and is suggestive of an industrial process. The majority of sheep/goat bones were fused suggesting that most of the animals were mature.

Approximately 38% of the sheep/goat metapodials from phase 3 deposits showed evidence for butchery. These were mainly in the form of thin, sharp cut marks which were most commonly observed on the proximal or distal portions of the bone. Those found towards the proximal end of the metapodials most frequently occurred on the sides (both medial and lateral) or on the posterior aspect, and only one example of butchery on an articulation surface was recorded. A small number of phalanges had also been cut, but the absence of butchery marks on the articular surfaces is a further indication that the metapodials and phalanges remained attached to each other during butchery (O'Connor 1984, 38). There was no evidence of sawing on sheep/goat bones that would suggest they were used in bone working. This restriction of butchery marks to the metapodials, along with the skewed body part representation discussed above, both support the proposition that hide processing was being undertaken at the site during the 17th century.

Phases 4 and 5 (18th century)
The total NISP for phase 4 is only 28, probably reflecting the change in use during the 18th century from hide processing to steelmaking. The

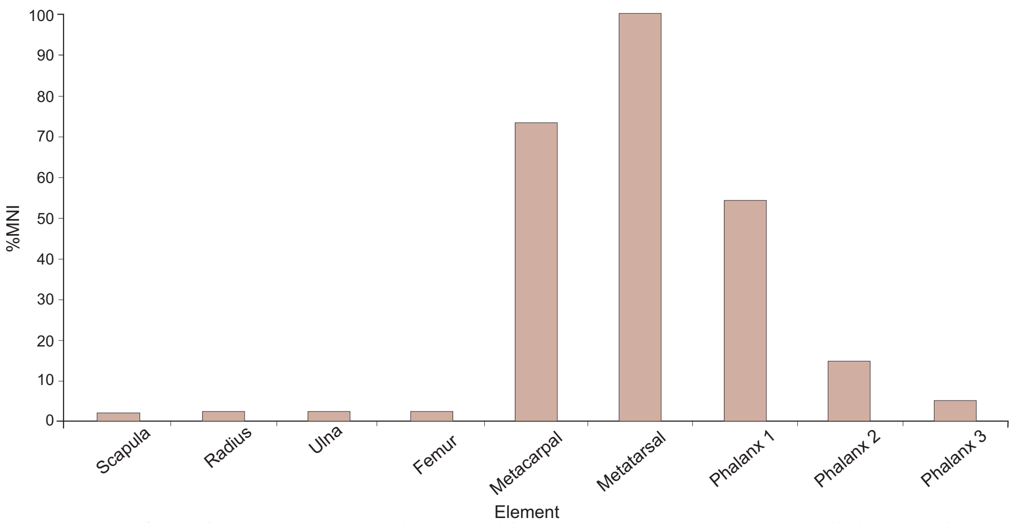


Figure 10 Sheep/goat element distribution (% total Minimum Number Individuals) for phase 3 (mid-17th century) in trench D

Plate 5 Sawn cattle metapodial and part finished bone blanks for scale-tang knife handles

predominance of sheep/goat metapodials and first phalanges continued into phase 4, though this might reflect material disturbed and redeposited from earlier contexts. In addition, there was a small number of cattle metapodials, three of which had been sawn across the shaft, probably for the manufacture of knife handles.

The pattern of faunal remains observed in phase 4 continued into phase 5, with a NISP of 40. Sheep/goat bones are present in the largest numbers, but again these may represent redeposited material originating in phase 3. The cattle remains are exclusively metapodials, eight of which had been sawn across the shaft in the same fashion as seen in phase 4 and, again, are perhaps indicative of the manufacture of bone knife handles.

Phases 6 and 7 (19th century)

The NISP of 15 from five phase 6 contexts includes a small number of sawn cattle metapodials, added to which there are 52 'non-countable' (for NISP purposes) sawn 'blanks' and waste from bone working. Phase 7 is the only phase where the remains of sheep/goat are outnumbered by those of cattle. Three contexts produced animal bone, most of which are cattle metapodials, and 82% of which were sawn across the shaft. There are also 649 'non-countable' sawn 'blanks' and waste, out of a total of 749 worked bone fragments from all phases of trench D, with the relatively large numbers of worked bone fragments reflecting the production of scale handles for knives (Pl. 5).

Discussion

The absence of meat-bearing bones and the highly specialised nature of the faunal remains from Riverside Exchange, particularly in the 17th century (phase 3), supports the conclusion from excavated features, including three plank-lined tanning pits and a barrel containing lime, that the area was involved in the production of leather. It appears likely that sheep/goat skins, with the feet still attached – probably for use as 'handles' to lift and move the skins (O'Connor 1984), were brought to the site, and the pattern of cut marks on the bones is characteristic of skinning.

Leather production was an important, usually urban activity during the medieval and post-medieval periods, and was separated into two distinct 'heavy' and 'light' industries (Albarella 2003, 73). The 'heavy' leather industry concentrated on cattle hides and employed tanning processes which used animal faeces, urine and oak bark. In contrast, the 'light' leather industry, often called tawyering, exploited a more diverse range of species including sheep, pigs and smaller animals such as cats, evidence for which has been recorded at, for example, The Green, Northampton (Harman 1996, 94) and Oxford Road Watermill, Aylesbury (Baxter 2004). The process of tawyering used substances including lime, alum and oil in a method that was faster than tanning, and more suited to the smaller, lighter hides. The bone assemblage from Riverside Exchange indicates that the animals exploited were mainly sheep, and the evidence suggests that the industry was primarily a 'light' tawyering one. However, a small number of cattle metapodials provide evidence that some 'heavy' leather production was also taking place, though the relative proportions of sheep/goat and cattle bones indicate that this was of secondary, probably minor importance.

Tanning and tawyering employed a large number of people throughout the country, including in Sheffield where the industry flourished during the 16th and 17th centuries (Clarkson 1960, 245). Leather production at Riverside Exchange appears to have declined after the 17th century, as steelmaking developed as the major industry, but cartographic evidence indicates that tanning or tawyering continued on a small scale on the site until the late 19th century.

A notable amount of worked bone, including sawn cattle metapodials, provides some evidence for bone working in the later phases at Riverside Exchange, particularly in the mid-19th century (phase 7) in trench D. This material was associated with the manufacture of handles, specifically knife handle scales, which were then fitted to knives that may have been ground and sharpened at the Cutlers' Wheel operating on the site at this time. At least two scale cutters were recorded on or in the vicinity of the site at this time: Henry Beardsworth in 1854 and 1865, and John Frith in 1865 (Kelly's Directories of 1854 and 1865), and the bone-working debris may derive from one of these workshops.

Finds

Only the larger and more significant categories of finds are discussed here (Pottery, Clay Tobacco Pipes, Glass and Metalwork), along with additional items of intrinsic interest (Coins and Tokens). Grindstones, and Animal Bone including worked bone are discussed above, and Metallurgical Remains below. Information relating to other categories of material is contained in the archive. In all cases this was recovered in small quantities and did not warrant subsequent analysis; it includes building material, wood and other organic remains, as well as a few samples taken for the recovery of environmental remains, which initial assessment showed to be unproductive.

Pottery

by C. G. Cumberpatch

Introduction

The excavations at Riverside Exchange produced a large quantity of pottery, approximately 7100 sherds, the vast majority of it of domestic types and dating to the period between the early/mid-18th and late 19th centuries. This brief overview is based on the available data from Riverside Exchange (the assemblage has not yet been fully analysed) supplemented with evidence from sites of a similar date in other parts of Sheffield.

The study of pottery from the 18th and 19th centuries is a relatively new branch of archaeology. It is only in the last fifty years that archaeologists have begun to pay serious attention to the archaeology of the period, although industrial historians and collectors of ceramics, glass and other artefacts have been aware of its importance for rather longer. During the late 1970s and 1980s archaeologists started to realise that Britain's industrial heritage was as worthy of study as the prehistoric, Roman and medieval periods and the sub-disciplines of industrial archaeology and historical archaeology began to receive detailed attention. The building boom on inner city 'brownfield' sites that began in the late 1990s offered an unprecedented opportunity to study the archaeology of industrialisation and the associated social history of Britain. Nowhere was this as clear as in Sheffield, a city with a good claim to have been one of the centres of the Industrial Revolution. Riverside Exchange was one of the first large sites in the centre of the modern city to be investigated archaeologically and the pottery assemblage proved to be of a substantial size in spite of the industrial history of much of the site.

The archaeology of the 18th- and 19th-century pottery industry has, for many years, been synonymous with the archaeology of Staffordshire and, to a lesser extent, London, and has tended to exist in the shadow of research carried out by collectors and connoisseurs of ceramics. While not being specifically archaeological in nature, this work has nevertheless provided a solid foundation on which archaeologists have been able to build and to develop their own particular avenues of research. Archaeological interest in ceramics is somewhat broader than that of collectors who tend to concentrate on the better quality tablewares and are less concerned with the utilitarian and traditional tablewares which make up a high proportion of 18th- and 19th-century pottery assemblages from archaeological sites. This broadening of interest is revealing increasingly more about the place of pottery manufacture and use in 18th- and 19th-century society and the part played by the pottery industry in the Industrial Revolution and in the revolution in consumption that accompanied it. There are several ways in which the pottery assemblage from Riverside Exchange can make a unique contribution to our understanding of 18th- and 19th-century Sheffield and the contemporary pottery industry. Apart from helping in the dating of features and deposits on site, particular areas of interest include understanding site formation processes and contributing to our knowledge of 18th- and 19th-century pottery production and consumption.

Site formation processes

Understanding the ways in which archaeological sites are created is of considerable importance if we are to interpret the archaeological evidence correctly. The idea that a pottery assemblage consists of objects that were being used on the site up to the time when the site was abandoned is, generally speaking, an oversimplification of reality, and many factors can affect the types of pottery found on a site. An understanding of the nature of the archaeological deposits which constitute a site comes partly from the study of the archaeological features and their inter-relationships but also from the evidence of artefacts, including pottery. Assemblages that consist of material of widely varying dates can indicate that the deposits have been disturbed on one or more occasion, usually either as the result of groundworks which have mixed archaeological deposits on the site or because material from elsewhere has been brought onto the site for some reason, perhaps connected with building or rebuilding or to raise the level of land threatened by flooding or subsidence.

The archaeology of Sheffield is distinctive and rather unusual in having seen a great deal of redeposition, particularly on low lying sites in the valleys or where building work required quantities of hardcore on which to build. The study of this process is at an early stage and it requires further research, but it appears that from the first half of the 19th century individuals were employed in ‘scavenging’ or collecting waste and refuse from the streets and from houses. In his contribution to the *Royal Commission on Health in Towns* (1842) James Smith wrote of Sheffield:

> *The streets are regularly swept and cleansed under the authorities and the refuse is carried off by the scavengers and deposited in a dung-yard in the lower part of town, where it is made up for sale. The scavenging costs about 900£ per annum and about 600£ is got for the dung &c.*

Elsewhere we read of the establishment of ‘depots’ for waste, although unfortunately the details of their nature and location are limited and none have been investigated archaeologically. We know that organic waste was sold to farmers as fertiliser and that barges carried blood, bone and other waste from the slaughterhouses adjacent to the markets as far as Lincolnshire where it was spread on the fields. It is less clear from the documents what happened to the solid waste, including pottery, after it reached the depots, but the archaeological evidence suggests that it was made available to builders who needed hardcore to prepare sites for building. Sites across Sheffield have produced distinctive assemblages which incorporate 18th-century pottery with mid- to late 19th-century pottery and seem to be the result of this practice. Industrial waste was used for similar purposes and also for building, as the well-known crozzle (broken clay waste from the cementation process) walls testify. It seems very likely that the dumping of waste played an important part in the formation of at least parts of the Riverside Exchange site, although the complicated history of the site and the recovery of a substantial pottery assemblage from the goit and wheel pit indicate that a number of formation processes were operating. Although this complicates the interpretation of the site, this degree of variability makes it an ideal candidate for comparing and contrasting the characteristics of assemblages with very different histories.

Plate 6 Pottery: Rim of a plate with a stamp recording the name of the customer, A. E. Mather, a crockery dealer in Detroit

18th- and 19th-century pottery production and consumption

South and West Yorkshire were home to an important and diverse pottery industry which flourished in the 18th and 19th centuries. Although the Staffordshire pottery industry is more famous, the Yorkshire potteries were by no means unimportant and their wares were not only sold in Britain but were also exported widely to the Empire and to other overseas markets, principally via the port of Hull.

One very clear example of the international trade in pottery is the sherd from Riverside Exchange which bears the name of a ceramics dealer in Detroit, A. E. Mather (Pl. 6). Records from Detroit identify A. Mather as the proprietor of a crockery store between the years 1837 and 1850. It is probable that Mather had commissioned a batch of pottery with his name printed on the underside and that the potters had produced an excess to cover spoilage during the manufacturing process. Once the order had been fulfilled the surplus was sold locally, used and eventually discarded. Misfired pots (seconds) which were still usable might also have been sold locally at discount prices. We do not know which of the local potteries Mather was working with and further documentary research is required in order to complete the picture.

Although we have useful documentary and eyewitness accounts of some aspects of life in Sheffield in the past, these often focus on spectacular or tragic events (such as the Dale Dyke Dam disaster in 1864), on the industrial history of the city (often concerned with the technical aspects of the iron and steel trades) or on issues which attracted the attention of journalists or social reformers. The latter tend to be concerned with the worst aspects of life in the industrial cities and to focus on slum housing, the plight of the poor and dispossessed, conditions in the workhouses and so on. They are less informative about the general conditions of life, particularly for those who were not destitute or living in the worst kinds of accommodation. Attention to the pottery assemblages can give us a clearer insight into the kinds of crockery and tableware that people used and, in some cases, the sorts of products that they were purchasing in pottery containers. As pottery is almost never a purely functional item but reflects wider social conditions, perceptions about the world and the aspirations of its users, the analysis and interpretation of data from assemblages like that recovered from Riverside Exchange can give us a unique insight into past societies. This is as true for the 18th and 19th centuries as it is for prehistory, hence the importance of recovering large and diverse assemblages from sites such as Riverside Exchange.

Prior to the 18th century virtually all pottery was produced in local potteries, using local resources, including local clay, to manufacture a relatively limited range of pottery vessels. The volume of production could be high and the technology was far from unsophisticated, but the potteries were essentially pre-industrial in character. This pattern of production continued through the 18th century and into the 19th century, but from the first half of the 18th century onwards it was increasingly challenged by pottery factories producing fine white stonewares and, later, high quality refined earthenwares using imported clay and other raw materials. The potters responsible for the manufacture of these wares were interested in improving the quality and attractiveness of the ceramic bodies and in establishing and expanding a lucrative commercial market for their products (although the two aims were not always compatible, as the history of potteries such as Rockingham shows). These developments formed part of a wider revolution in 18th-century civic society which included greater formality at the dinner table and the rise in the popularity of tea and coffee drinking both at home and in coffee houses. Entrepreneurial potters saw an opportunity for profit and began to market increasingly attractive and sophisticated wares, changing styles and patterns to maintain the interest of their customers in a competitive market place. All the evidence from archaeological sites in Sheffield tells us that from the early 18th century onwards such fashionable and relatively expensive wares were available in Sheffield and were being bought and used by at least some sections of the population. These wares are represented in the Riverside Exchange assemblage by the White Salt Glazed Stoneware (Pl. 7a and b), Creamware and Pearlware. Alongside these new and fashionable wares the more traditional vernacular tablewares remained popular throughout the 18th century. These included brightly coloured Slipwares (Pl. 7c and d), the distinctive brown Mottled wares and the ubiquitous Late Blackwares. All of these wares were made in and around Sheffield and we know of small 'country potteries' at Midhope, Bolsterstone and Silkstone to the north of Sheffield, on the site of Sheffield Manor and elsewhere in South and West Yorkshire. Unfortunately we do not know exactly how the traditional wares and the fashionable formal tablewares were considered in relation to each other, although it seems likely that the more expensive and fashionable products were not in everyday use and that the traditional wares continued to be used for many purposes in the majority of households.

The main exceptions to this picture involve two highly distinctive types of pottery – Tin Glazed Earthenware and Porcelain. Tin Glazed Earthenware, sometimes known as Delftware, was manufactured widely in Britain (Bristol, Norwich, Whitehaven, Glasgow, London) from the mid-16th to the mid-18th century and significant quantities were also imported from the Low Countries. The pottery has a very soft body and hard but brittle glaze which flakes easily from the body, which means that it survives poorly in archaeological contexts (Pl. 7e). The precise dating and attribution to a specific pottery of individual sherds depends upon the identification of the painted designs. This is rarely possible with archaeological examples as they tend to be too badly damaged for positive identification. The significance of Tin Glazed Earthenware is that prior to the development of White Salt Glazed Stoneware it was the only type of indigenous European pottery to have a white surface that could be readily decorated with coloured designs and it was both relatively expensive and relatively rare. Its presence on sites in Sheffield, including Riverside Exchange, indicates that the town was home to individuals who could afford to buy and use luxury products, presumably ordering them from dealers in London or one of the other major cities of pre-industrial Britain.

Tin Glazed Earthenware was one of the attempts made by European potters to emulate the Chinese porcelain that was imported by the East India Company as a component of its extensive trade in luxury goods, which also included tea, spices and silk. Porcelain was immeasurably superior to Tin Glazed Earthenware in its quality, strength and whiteness, and was imported in huge quantities into Europe. Competition to produce a European product with

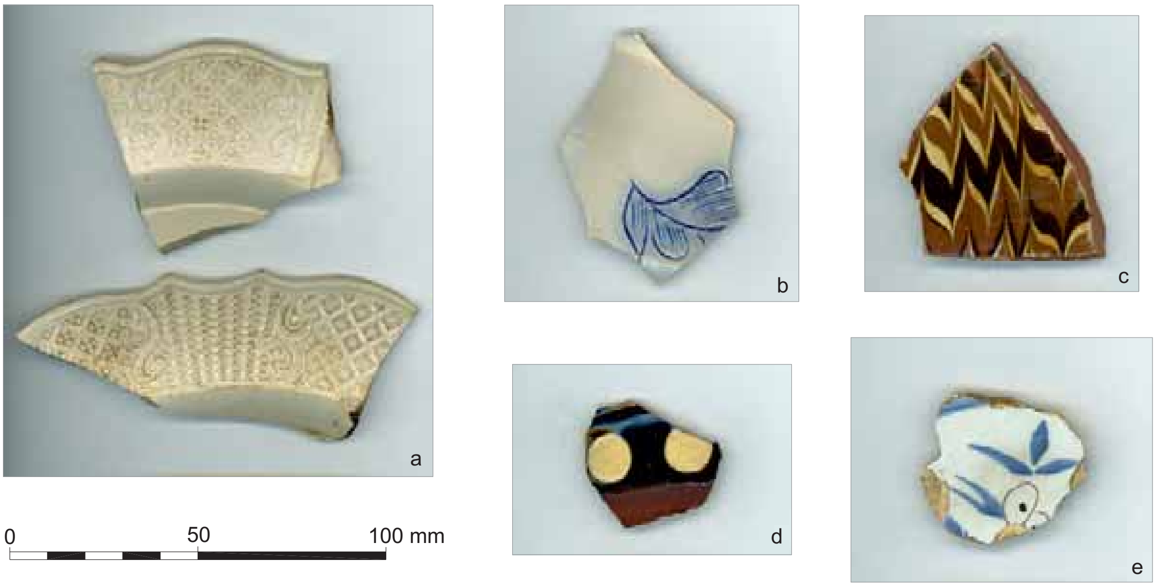


Plate 7 Pottery: a) White Salt Glazed Stoneware plate rims (trench A, contexts 15085 and 15087); b) White Salt Glazed Stoneware with a 'scratch blue' design (trench D, context 15398); c) Interior of a press-moulded slipware dish (trench D, context 15358); d) Exterior of a cup or mug with slip decoration (trench D; context 15315); e) Sherd from a Tin Glazed Earthenware plate or dish (trench A, context 15085)

similar properties was intense, but was not achieved on a practical scale until the development of the white stoneware body in the early 18th century. The subsequent discovery that a practical porcelain body could be made using china clay from Cornwall by William Cookworthy in 1768, together with the high volume production of high quality refined earthenwares, spelled the end of the large-scale trade in pottery with China, although the influence of Chinese designs persisted into the late 19th century and is still discernible today. Porcelain is a regular find on sites throughout Sheffield, including Riverside Exchange, although it rarely constitutes a significant proportion of the total. Its presence is, nonetheless, an indication both that it was available to people in Sheffield and that there was a demand for it.

The manufacture of the vernacular tablewares seems to have ended almost entirely by the end of the 18th century and many of the country potteries ceased production. Those which survived seem to have increased production of utilitarian wares, notably large pancheons, bowls and jars of the Brown Glazed Coarseware type. These wares are ubiquitous on sites in Sheffield and Riverside Exchange is typical in this regard. They seem to have had a variety of uses within the household and remained in production until the mid-1960s, albeit latterly in small quantities.

The vernacular tablewares appear to have been replaced at the end of the 18th century and the beginning of the 19th century by the cheaper types of transfer printed ware and by a variety of other refined earthenwares. These included the distinctive Cane Coloured ware, Blue Banded and other slip banded wares and Colour Glazed wares. Simple and cheap to produce (the decoration required little skill to apply) these wares occur on every 19th-century site excavated in Sheffield. From around 1830 they were joined by Sponged ware and from 1840 by Sponge Printed ware. As the names imply, these wares were decorated with pigment (usually blue but sometimes red or brown) applied with a small sponge, later cut to create a simple design that could be easily replicated across the surface of a pot.

The arrival of the coal-fired cast iron domestic kitchen range in the early 19th century created a demand for robust, heat resistant cooking wares suitable for use in an oven. This demand was met by the production of Brown Salt Glazed Stonewares which were manufactured in huge quantities in north Nottinghamshire and north-east Derbyshire. Nottingham, Alfreton and Chesterfield were all sources for such wares which form a substantial part of most pottery assemblages from Sheffield. Brown Salt Glazed Stonewares had been made during the 18th century, but the vessel types were mainly mugs and tankards. From the 19th century onwards cooking vessels (stew pots, hash pots, loaf pots, or nappers), storage jars, flagons and bottles of various sizes became common. All are found in large numbers on sites in Sheffield, including Riverside Exchange.

The identification of the origin of individual vessels, either through the evidence of the stamped and printed maker's marks on individual vessels or from the petrographic and geo-chemical analysis of the pottery fabrics, allows us to identify the origin of the pots and hence the changing patterns of supply to the population of the city. The Riverside Exchange assemblage includes many stamped and marked pieces, but it appears that Staffordshire was not a significant source of pottery until the mid- to late 19th century. Prior to this it seems that local potteries played a major part in fulfilling the demands of the population. This includes both small-scale local potteries and the larger pottery factories. The evidence from a site in Upper Allen Street showed that the local factories, including the Don Pottery, continued to supply Sheffield with pottery well into the late 19th century, alongside the Staffordshire potteries.

The Riverside Exchange assemblage

The pottery assemblage from Riverside Exchange is diverse in nature and includes examples of many of the types of pottery mentioned above. This summary is based on the data currently available.

The earliest pottery from the site is of medieval and early post-medieval date and this almost certainly relates to the use of the area before it was extensively built on. We know from documentary evidence that the medieval Town Mill was located on the site, in the area of trench 11. Furthermore, Riverside Exchange lay close to the northern edge of the medieval and post-medieval town and in sight of the Castle and Assembly Green (now The Wicker) so some activity during the medieval period is unsurprising, although the course of the river and the state of the banks and flood plain might have limited this to some extent. In general the establishment of the steelworks seem to have almost obliterated the evidence for pre-18th-century activity, and the small quantity of medieval pottery that was recovered appears to be the only tangible evidence of medieval activity to have survived the subsequent industrial development. Examples include the base of a Cistercian ware cup and a sherd of late medieval Gritty ware.

The data available from Riverside Exchange suggests that the assemblages from the various trenches and areas of excavation can be divided into groups based upon the representation of different types of pottery. These groups are:

- *Group 1*: Assemblages consisting primarily of pottery dating to the 18th and early 19th centuries (trenches 1, 2 and 5).
- *Group 2*: Assemblages consisting of mixed groups of 18th- to early 19th-century and mid- to late 19th-century pottery (trenches 6a and 8 – both very small assemblages, and trench 10).
- *Group 3*: Assemblages consisting primarily of mid- to late 19th-century pottery (trenches 6b, 9 and 14 – all very small assemblages, and trenches 4, 11, 11a and 11b).
- *Group 4*: An assemblage consisting of mid- to later 19th-century ware with a small early 20th-century component, from the goit and one of very few wheel pits excavated in Sheffield (trench 11).
- *Group 5*: Insufficient data (trench 7).

This variable pattern of deposition is not unique to Riverside Exchange and has been noted on sites elsewhere in Sheffield, notably at Suffolk Road and London Road (unpublished) where the patterns of deposition were even more marked than at Riverside Exchange. In part they seem to relate to the patterns of waste disposal and reuse discussed above. With the exception of unusual contexts such as the wheel pit (trench 11) the different groups seem to represent distinct horizons of deposition, but the significance of the horizons is difficult to interpret. It is possible that they indicate phases of activity on the site which involved the deliberate dumping of pottery, but if the pottery was being brought onto the site from elsewhere on anything but an *ad hoc* basis it may also be possible that they represent different phases of activity on the sites (probably the 'depots' or dung yards referred to in the documents) from which the material was taken. Thus the Group 1 and Group 2 assemblages would represent older deposits with, in the case of the Group 2 assemblages, later material mixed in during the extraction and movement of the material. In contrast the Group 3 assemblages seem to represent more chronologically homogenous groups perhaps exploited soon after their deposition. This is not, however, the full story and a combination of formation processes is involved with the wheel pit and the goits perhaps receiving material from different sources. The preliminary conclusion must be that the varying character of the pottery assemblages represents different types of formation process acting on different parts of the site.

Clay Tobacco Pipes

by S. D. White

The excavations produced a total of 1,498 clay tobacco pipe fragments consisting of 162 bowls, 1,294 stems and 42 mouthpieces, from seven different areas of the site. Two detailed reports were prepared by the author in 2002 (Areas 240D–H) and in 2007 (Areas 240L and N) and are available as part of the site archive. This report comprises a synthesis of the pipes from all seven areas.

Clay tobacco pipes are probably the most useful dating tool for archaeological deposits of post-medieval date. They are found almost everywhere, were short-lived and were subject to rapid change in both size and shape. They can usually be tied to a

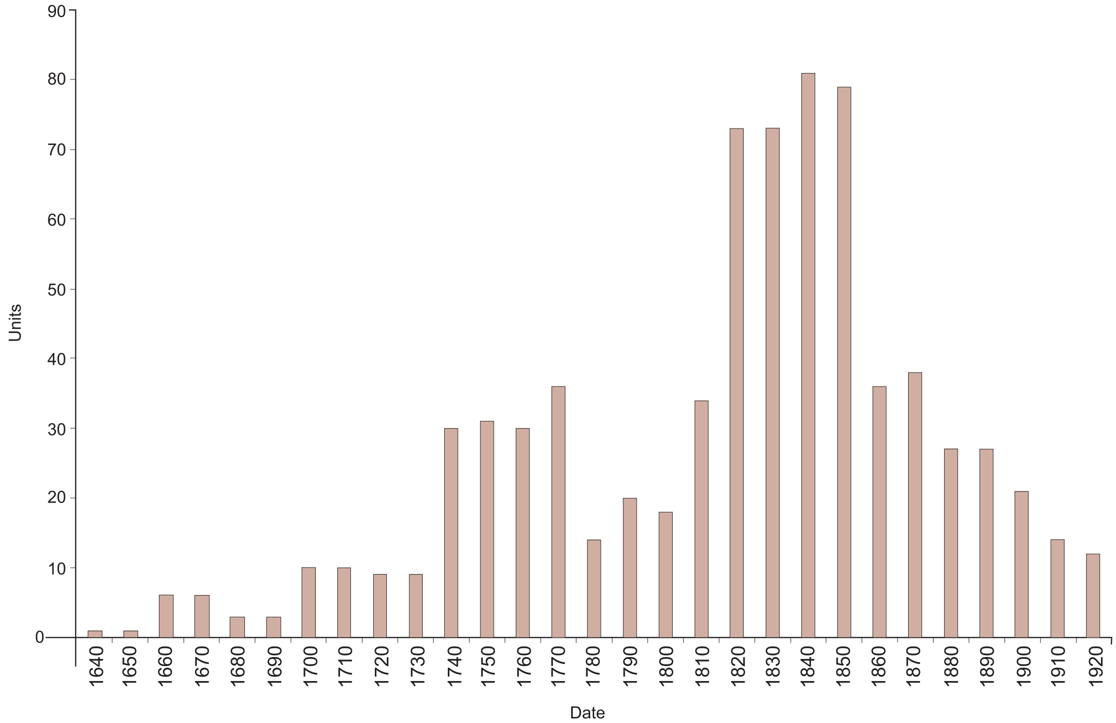


Figure 11 Chronological distribution of datable pipe bowls and marked fragments

specific production site or, at the very least, to a regional centre. Subtle differences in style and quality enable them to be used as indicators of social status as well as a means by which trade patterns can be studied. Not only does the assemblage from Riverside Exchange address all of the issues listed above, but they also provide Sheffield with a 'first' – evidence for industrial doodling.

Chronological distribution of the pipes

The initial reports looked at the chronological distribution of the pipes across the site. In order to do this the number of occurrences, per decade, of the datable pipe bowls and marked stem fragments, were plotted onto a bar chart (Fig. 11). Each pipe fragment was examined and one unit entered for each decade of its likely date range, for example, if a fragment was dated from 1740–1760 the decades 1740 and 1750 would each be marked once. This method has the effect of smoothing out the curve created by the graph since it spreads the information over each decade rather than creating marked steps and plateaux, as is the case when broad typological date ranges are used, for example 1610 to 1640, 1640 to 1660 etc. The result is a more realistic picture of the main periods of activity on the site. It is clear from the data plotted that although there were a small number of pipes deposited on the site from the mid-17th right through to the early 20th century, the main period of deposition was from *c.* 1740 onwards, with two 'peaks' of pipe activity on the site. The first peak was *c.* 1740–1770 and the second *c.* 1820–1850.

The two peaks of activity correspond broadly with what is known about the site from documentary sources. There is no problem with the second peak, in the first half of the 19th century, which ties in with the activity around the Cutlers' Wheel pit and the Town Mill. The first peak (*c.* 1740–1770), however, is a little early for the founding of Marshall's steelworks in the 1770s, when an increase in pipe deposition would be expected.

Since the initial reports on the pipes were compiled, however, further research by the author (White 2011) suggests the roll-stamped stems, which are the cause of the first 'peak' in the graph, should be dated a little later in the 18th century, to *c.* 1750–1790. The documentary evidence would certainly support this re-dating of the marked stems and would push the first 'peak' to a position that would coincide with the founding of Marshall's steelworks in the 1770s.

Sources of the Riverside Exchange pipes

Previous studies have established that most pipes did not travel very far from their place of manufacture, on average approximately 20 miles. Clay pipes display strong regional variation, particularly from the mid-17th century through to the early 19th century. This feature, combined with the occurrence of makers' marks, means that it is often possible to identify the exact origin of excavated pipes. Not only does this tell us where the pipes were being sourced but it is also a good indicator of where other goods and services might have been obtained.

There is very little evidence for the production of clay tobacco pipes in Sheffield itself during the 17th and 18th centuries and there are certainly no known marks. It is possible that Sheffield makers chose not to mark their products and that some of the earlier plain pipes recovered from the city were produced locally (Fig. 12.1–4). However, given that many of the contemporary pipemakers in the region were marking their pipes, one would have expected to have seen some marked Sheffield products had they existed.

What the excavations did yield were fragments from pipemakers operating in the neighbouring towns, such as the 17th-century bowl with its heel stamped MP (Fig. 12.5). This particular mark can be attributed to Matthew Powell of Wakefield, who is known to have been working from at least 1690 when he appeared in the Quarter Sessions Rolls accused of '*neglecting to teach his apprentices the art of pipemaking at Potovens*'. He appeared again in 1698 when he was bound by an indenture to '*teach Hester Beckett's … children the trade of making tobacco pipes at Potovens*'. It is assumed that he would have continued pipemaking until his death in 1701 (White 2004, 177). This is the only marked 17th-century pipe from the site, although a range of plain forms also appear (Fig. 12.1–4 and 6). It is quite possible that this single marked example is a casual loss rather than evidence of an organised trade in pipes.

Very few 18th-century bowls survive, but this may partly be due to the fact that the bowls of the period had much larger, thinner walled bowls than previously, and they do not survive well in the archaeological record (Fig. 12.7–8). What the site did produce, however, are the associated stems with elaborate roll-stamped marks (Figs 12 and 13.9–17). Enough of these survive to indicate trading patterns rather than individual casual losses.

The excavations produced 27 18th-century stems with roll-stamped marks. All of the stamped marks from the site have been impressed and recorded for the National Clay Tobacco Pipe Stamp Catalogue, which is being compiled by Dr David Higgins. When a new mark is identified it is allocated a unique die number (Higgins Die) and a twice-life size drawing is made for future reference. Table 2 provides details of the roll-stamped marks from the site.

From this table it is clear that by the 18th century a large proportion of the pipes that were being utilised were coming from Rotherham, with a small number from Leeds/Birstall. At least one of the Rotherham makers – Jonathan Crosland – had connections with Sheffield that went beyond the pipe trade. Jonathan's son was apprenticed to John Salt, cutler of Sheffield, in 1764 for eight years and then to George Pearson, cutler of Sheffield, for one year in 1772.

It was not until the 19th century that Sheffield began to have its own pipemakers. By this period pipes had started to become much more elaborately mould-decorated and the strongly regional forms that were typical of the 17th and 18th centuries made way for bowl forms that occur over much larger areas of the country. The coming of the railways from the 1830s onwards improved transport networks, allowing goods to be moved over greater distances than ever before, and impacted trade and marketing in a way that the canal system never did. This new-found freedom to move goods saw the emergence of bigger pipe manufacturing firms and allowed a much wider distribution of their products and designs, which were often then copied or adapted elsewhere.

In addition to a number of plain bowls, pipes with moulded decoration ranging from simple leaf seams through to bowls covered with floral motifs, flutes, vines, Masonic motifs and even symbols of organisations such as the Ancient Order of Foresters, all appear in the excavated assemblage (Figs 13–14, 15.18–46). Although some of these pipes have moulded makers' marks, the vast majority of fragments recovered are plain (*c.* 70%).

At least three Sheffield makers have been identified amongst these 19th-century pipes, such as products of the Erratt family, who were working in the Sheffield area from at least the 1850s to 1870s (Fig. 14.28). Frederick Cartwright was working in Sheffield *c.* 1854–1860 (Oswald 1975, 199) and is represented by a spur fragment with the moulded initials F C (Fig. 15.44). Finally, T. Pinder, probably Thomas, who appeared in the Sheffield Trade Directories for 1825–1829 (*ibid.*, 201), is represented by a pipe with heavy scrolls and floral motifs, a form of decoration that was very fashionable during the late 1820s and 1830s on other forms of ceramic object and, in particular, porcelain (Fig. 13.24).

The assemblage also includes material that had been imported to the city from manufacturers elsewhere, including examples made by the Tunstalls of Leeds (Fig. 15.40), John Pollock of Manchester (Fig. 15.38) and William Southorn of Broseley, Shropshire (Fig. 14.32).

Internal bowl marks

Internal bowl crosses or marks are formed by a design cut on the end of the stopper that was used to form the bowl cavity during the manufacturing process. Jarzembowski (1985, 394) suggested that one of the purposes of these internal bowl marks was to prevent the stopper from sticking when pressed into the bowl. The internal bowl crosses in the pipes from Riverside Exchange are quite distinctive as they have two cross bars '‡', which are shown as a detail in Figure 14.25. Although there has been no systematic survey of internal bowl crosses from Yorkshire, these do appear to be of a form that is peculiar to Sheffield. This very distinctive feature suggests that the bowls were either

Table 2 Clay tobacco pipes: roll-stamped marks

Illus.	Site	Tr. / Area	Ctxt	SF	Date	Mark	Higgins Die No.	Maker
9	240N	D	15374	–	1740–1770	CROSLAND	1920	Jonathan Crosland, Rotherham *fl.* 1747–1772
9	240N	D	15374	–	1740–1770	I CROSLAND	1920	Jonathan Crosland, Rotherham *fl.* 1747–1772
–	240D	2	1187	0256	1740–1780	Midland border	–	Unknown
–	240D	2	1156	0293	1740–1780	Midland border	–	Unknown
–	240F	11	11424	0422	1740–1780	Midland border	–	Unknown
–	240L	–	16018	–	1720–1780	Midland border	–	Unknown
–	240N	D	15419	–	1740–1780	Midland border	–	Unknown
–	240N	D	15420	–	1740–1780	Midland border	–	Unknown
10	240F	11	11402	0368	1750–1790	BENIAMIN MAZDEN	1834	Benjamin Marsden of Rotherham *c.* 1757
11	240L	–	16013	–	1760–1790	TT	1839	Possibly Thomas Turner of Leeds/Birstall *c.* 1756–1786
12	240L	–	16013	–	1720–1780	I WILD with Midland border	2181	John Wild of Rotherham *c.* 1722–1750
13	240D	2	1221	0114	1740–1780	THO WILD with Midland border	1833	Thomas Wild (3) of Rotherham *c.* 1777
13	240D	1	1176	0151(9)	1740–1780	THO WILD with Midland border	1833	Thomas Wild (3) of Rotherham *c.* 1777
13	240D	2	1221	0114	1740–1780	THO WILD with Midland border	1833	Thomas Wild (3) of Rotherham *c.* 1777
13	240D	2	1187	0390	1740–1780	THO WILD with Midland border	1833	Thomas Wild (3) of Rotherham *c.* 1777
13	240D	1	1154	0402	1740–1780	THO WILD with Midland border	1833	Thomas Wild (3) of Rotherham *c.* 1777
13	240L		16013	–	1740–1780	THO WILD with Midland border	1833	Thomas Wild (3) of Rotherham *c.* 1777
14	240F	11	11451	–	1740–1780	THO WILD	1832	Thomas Wild (3) of Rotherham *c.* 1777
15	240L		16013	–	1740–1780	THO WILD	2190	Thomas Wild (3) of Rotherham *c.* 1777
16	240F	11	11424	0417	1750–1790	THO WILD (Part of a roll stamp mark with heart border)	2089	Thomas Wild (3) of Rotherham *c.* 1777
16	240N	D	15392	–	1750–1790	THO WILD	2089	Thomas Wild (3) of Rotherham *c.* 1777
17	240D	1	1032	0023	1760–1780	WILL WILD	1925	William Wild, Rotherham *fl.* 1764–1774
17	240D	1	1154	0201	1760–1780	WILL WILD	1925	William Wild, Rotherham *fl.* 1764–1774
17	240D	1	1154	0201	1760–1780	WILL WILD	1925	William Wild, Rotherham *fl.* 1764–1774
17	240L	–	16036	–	1760–1780	WILL WILD	1925	William Wild, Rotherham *fl.* 1764–1774
–	240D	1	1011	0031	18th century	Part of a roll stamp mark; traces of large scrolls visible	–	Unknown
–	240L	–	16013	–	1720–1780	Fragment of abraded mark – illegible	–	Unknown

produced by a number of manufacturers using stoppers supplied by the same mould maker or that these bowls were produced in a single workshop where this particular motif was added to the stoppers.

Industrial doodling and other modified stems

The modification of stems can take a number of forms, but usually occurs for one of two main reasons. Firstly, the grinding or scraping of the stem for reuse after the original mouthpiece has broken off. This type of modification is characterised by even grinding round the end of the stem and, occasionally, by the appearance of tooth wear as well. Two examples of stems with this kind of treatment have been recovered from the excavations (Fig. 15.50–51).

The second type of modification is when the stem has been used as a medium with which to draw or write graffiti, resulting in the formation of distinct facets at one, or both, ends of the stem.

However, some of the modified stems that have been recovered from Riverside Exchange fall into a third category as they appear to have been cut or ground down by mechanical means (Fig. 15.47–49), resulting in perfectly smooth and sharply defined cut facets. All of the stems in this category were found in the bottom of the wheel pit of the Cutlers' Wheel.

Discussion

The Riverside Exchange excavations have produced a rare example of a late 18th- and early 19th-century clay pipe assemblage from Yorkshire, and the first of this date from Sheffield, and provide an important snapshot of pipe production and consumption within the city.

Figure 12 Clay tobacco pipes (Nos 1–13; roll-stamped stem marks at 2:1)

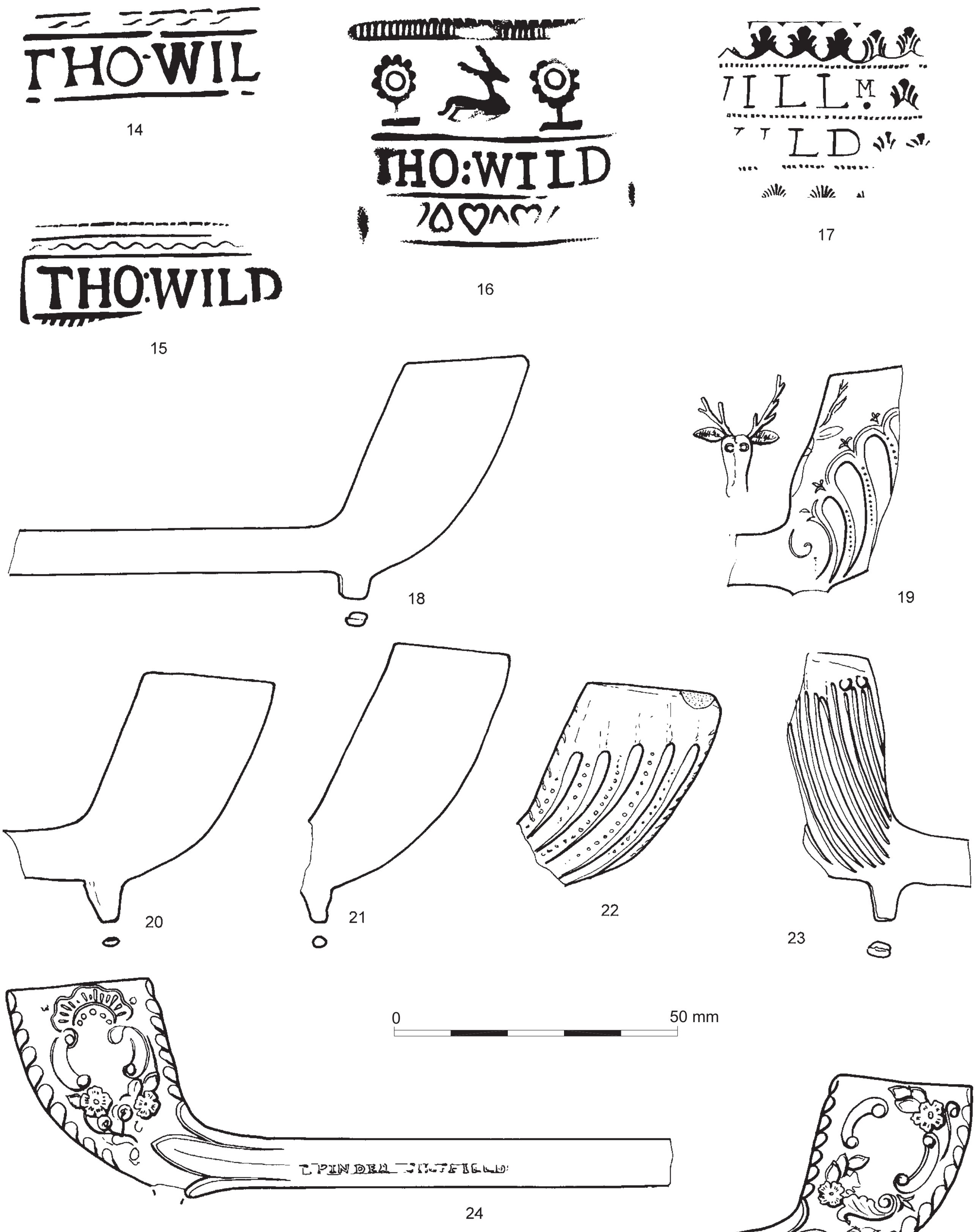


Figure 13 Clay tobacco pipes (Nos 14–24; roll-stamped stem marks at 2:1)

One of the most important elements of this assemblage is that its social context is known, in that it is from an industrial site. Although the range of pipes is typical of the area, the presence of burnished pipes, and of pipes with 'classy' designs, indicates that the workers were not only aware of quality goods and styles that were highly fashionable, but were actively participating in the use of such products. The site also produced evidence for what would appear to be the first documented case of 'industrial doodling', in the form of the ground stems, suggesting that some grinders in the most arduous working conditions of the Cutlers' Wheel still had occasional idle moments to fill.

Another part of the picture that is slowly emerging is that Sheffield does not seem to have had its own pipemakers during the 17th and 18th centuries, but relied instead on supplies from neighbouring centres such as Wakefield, Rotherham and Leeds. It would appear that it is not until the 19th century that a pipemaking industry of any size developed in Sheffield itself.

List of illustrated clay tobacco pipes

All illustrations are at 1:1 with the exception of the roll-stamped stem marks, which have been drawn at 2:1. Site information is given at the end of each entry, in the form of: (area [trench] context, small find number if applicable).

Figure 12

1. Heel bowl (*c.* 1640–1660); not burnished; rim bottered and milled; no internal bowl cross; stem bore 6/64" (240H [14] 14125).
2. Heel bowl (*c.* 1660–1680); not burnished; rim bottered and three-quarters milled; no internal bowl cross; stem bore 6/64"; milled band across the heel of the pipe. This is not a typical Yorkshire form and this piece may well have been brought in from either Lincolnshire or Derbyshire (240N [D] 15141).
3. Heel bowl (*c.* 1660–1680); not burnished; rim bottered and three-quarters milled; stem bore 6/64"; milled band across the heel of the pipe (240N [D] 15206).
4. Heel bowl (*c.* 1660–1680); not burnished; rim bottered but not milled; stem bore 6/64". There appears to be a groove round the rim rather than milling (240F [11] 11512, SF: 0397).
5. 'Yorkshire Bulbous' heel bowl (*c.* 1660–1680); good burnish; rim bottered but not milled; no internal bowl cross; stem bore 6/64"; marked with the initials MP on the heel. Almost certainly a product of Matthew Powell of Potovens who is known to have been working from at least *c.* 1690 until his death in 1701 (240N [D] 15141).
6. Heel bowl fragment (*c.* 1660–1690); not burnished; no rim surviving; stem bore 6/64"; cut mark across the heel (240D [5] 5003, SF: 0013).
7. Heel bowl fragment (*c.* 1690–1740); no internal bowl cross; good burnish; no rim surviving; stem bore 5/64". Appears to be a B or a P moulded on to the left side of the heel. Stem decorated with bands of milling (240F [11] 11179, SF: 030).
8. Heel bowl fragment dating from *c.* 1690–1740; no internal bowl cross; good burnish; no rim surviving; stem bore 5/64" (240H [14] 14005).
9. Composite drawing of a roll-stamped mark (*c.* 1740–1770) reading I CROSLAND (Higgins Die 1920). Almost certainly Jonathan Crosland of Rotherham, known to have been working from at least 1747–1772. Two stem fragments with this mark recovered from the site (240N [D] 15374).
10. Stem fragment (*c.* 1750–1790) stamped with the lettering BENIAMIN MAZDEN (Higgins Die 1834); stem bore 4/64". A Benjamin Marsden of Rotherham, pipemaker, is recorded from a marriage in the parish records in 1757 (240F [11] 11402, SF: 0368).
11. Composite drawing of a roll-stamped mark (*c.* 1760–1790) with the initials TT (Higgins Die 1839). Possibly Thomas Turner of Leeds/Birstall who is known to have been working *c.* 1756–1786. Single example recovered from the site (240L 16013).
12. Composite drawing of a roll-stamped mark (*c.* 1720–1780) with I WILD incorporated into a Midlands Style border (Higgins Die 2181). Almost certainly John Wild of Rotherham who is known to have been working *c.* 1722–1750. One example recovered from the site (240L 16013).
13. Composite drawing of a roll-stamped THO WILD mark (*c.* 1750–1790) with a Midlands Style border (Higgins Die 1833). Almost certainly Thomas Wild (3) of Rotherham who appears in the Sheffield Quarter Sessions in 1777. Six examples of this mark were recovered from the site (240D [1] 1154, SF: 0402; 240D [1] 1176, SF: 0151(9); two from 240D [2] 1221, SF: 0114; 240D [2] 1187, SF: 0390 and 240L 16013).

Figure 13

14. Composite drawing of a roll-stamped mark (*c.* 1740–1780) reading THO WILD (Higgins Die 1832). Almost certainly Thomas Wild (3) of Rotherham who appears in the Sheffield Quarter Sessions in 1777. One example from this site (240F [11] 11451).
15. Composite drawing of a roll-stamped mark (*c.* 1740–1780) reading THO WILD (Higgins Die 2190). Almost certainly Thomas Wild (3) of Rotherham who appears in the Sheffield Quarter Sessions in 1777. One example from this site (240L 16013).
16. Composite drawing of a roll-stamped mark (*c.* 1750–1790) reading THO WILD with a border comprising hearts, flowers and a running deer (Higgins Die 2089). Almost certainly Thomas Wild (3) of Rotherham who appears in the Quarter Session in

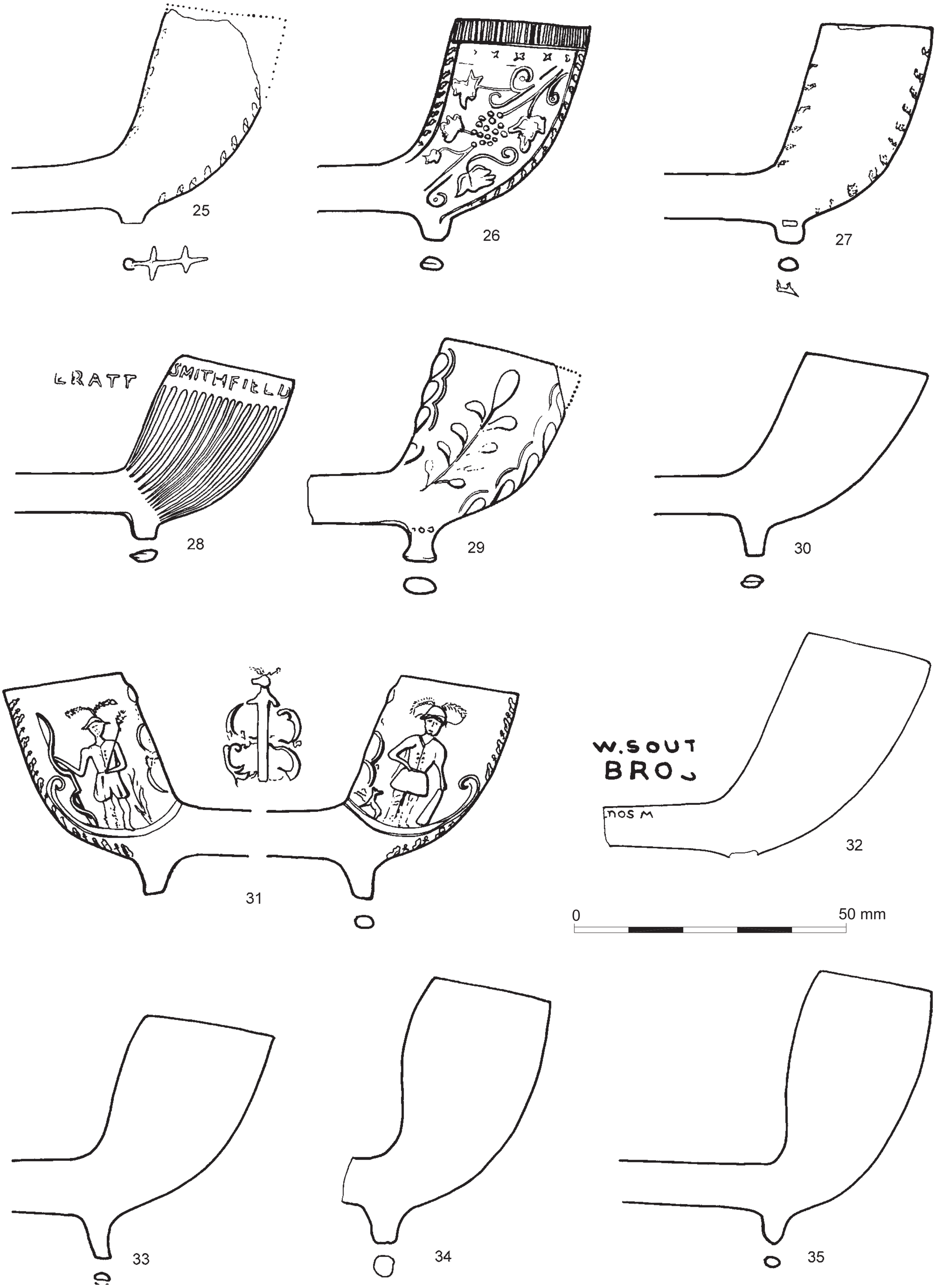


Figure 14 Clay tobacco pipes (Nos 25–35)

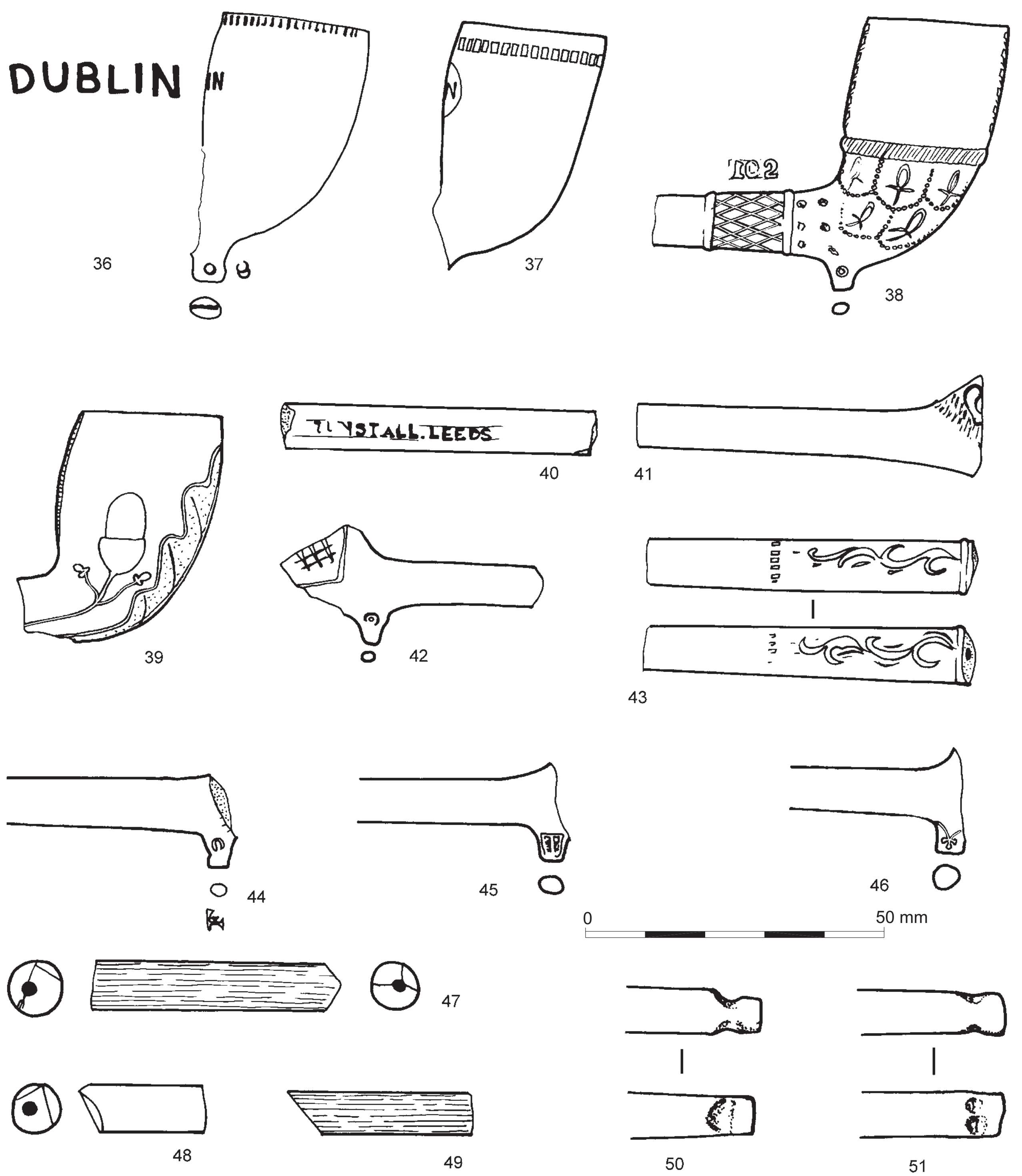


Figure 15 Clay tobacco pipes (Nos 36–51)

Sheffield in 1777. Two examples from the site (240N [D] 15392 and 240F [11] 11424, SF: 0417).

17. Composite drawing of a roll-stamped mark (*c.* 1760–1780) reading WILL WILD (Higgins Die 1925). Almost certainly a product of William Wild of Rotherham who is known to have been working *c.* 1764–1774. Four examples recovered from the site (240D [1] 1032, SF: 0023; two from 240D [1] 1154, SF: 0201 and 240L 16036).
18. Spur bowl (*c.* 1750–1800); no internal bowl cross; not burnished; rim cut and not milled; stem bore 5/64" (240F [11] 11467, SF: 0495).
19. Originally a spur bowl, although the spur is now missing (*c.* 1760–1800); mould-decorated with staggered flutes/scallops together with a stag's head on the seam of the bowl facing the smoker; no internal bowl cross; not burnished; rim cut and not milled; stem bore 4/64". Similar pipes are known to have been

made by Samuel Lumley of Doncaster who is known to have been working until his death in 1769 (240F [11] 11451, SF: 0477).

20. Plain spur bowl (*c.* 1820–1860); not burnished; rim cut and not milled; stem bore 4/64". The bowl form is similar to a London Type 28 (240F [11] 11346, SF: 0622).
21. Plain spur bowl (*c.* 1840–1880); no internal bowl cross; not burnished; rim cut and not milled; stem bore 5/64". This is possibly a Broseley product (240F [11] 11348, SF: 0625).
22. Bowl fragment (*c.* 1800–1840) mould-decorated with narrow flutes and dots; no internal bowl cross; not burnished; rim appears to have been wiped; no milling (240F [11] U/S, SF: 0474/14).
23. Spur bowl (*c.* 1790–1820); not burnished; rim cut but not milled; stem bore 5/64"; decorated with fine flutes (240N [A] 15085).
24. Spur bowl (*c.* 1810–1840) mould-decorated with floral motifs and with the relief moulded lettering T. PINDER SHEFFIELD along the side of the stem; no internal bowl cross; not burnished; rim cut and not milled; stem bore 5/64". Thomas Pinder is known to have been working in Sheffield *c.* 1825–1829 (240F [11] 11467, SF: 0495).

Figure 14

25. Spur bowl (*c.* 1810–1850) with leaf-decorated seams; very distinctive internal bowl cross; not burnished; rim damaged; stem bore 4/64" (240H [14] 14029).
26. Spur bowl (*c.* 1830–1850) mould-decorated with a bunch of grapes motif; not burnished; rim cut with moulded milling; stem bore 5/64". Similar examples of this design in the collections of Sheffield Museum are marked 'J Dee Sheffield' who is known to have been working *c.* 1833–41 (240F [11] 11064, SF: 0073).
27. Spur bowl (*c.* 1810–1850) with leaf-decorated seams; no internal bowl cross; not burnished; rim cut and not milled; stem bore 4/64". There is rather poorly moulded lettering on the sides of the spur which appears to read FI (240F [11] 11330, SF: 0619).
28. Heel bowl (*c.* 1840–1880) mould-decorated with fine flutes with the moulded lettering ERRATT / SMITHFIELD around the rim; no internal bowl cross; not burnished; rim cut and not milled; stem bore 4/64". Although documentary evidence shows that the Erratt family were working in Sheffield during the 1850s to 1870s, the bowl form would suggest that they could have been working as early as the 1840s (240F [11] 11291, SF: 0569).
29. Bowl with a pedestal heel (*c.* 1810–1850) mould-decorated with a leaf motif; no internal bowl cross; not burnished; rim cut and not milled; stem bore 5/64" (240F [11] 11047, SF: 0043).
30. Plain spur bowl (*c.* 1840–1880); not burnished; rim cut and not milled; stem bore 4/64" (240F [11] 11348, SF: 0625).
31. Spur bowl (*c.* 1840–1880) decorated with the Foresters' Arms; no internal bowl cross; not burnished; rim cut and not milled; stem bore 4/64" (240D [5] 5003, SF: 0106).
32. Originally a spur bowl, although the spur is now missing (*c.* 1850–1960); not burnished; rim cut and wiped but not milled; no internal bowl cross; stem bore 4/64"; marked with the lettering W SOTH[HORN & CO] / BRO[SELEY …] along the stem. William Southorn and Co was a prominent firm of pipemakers working in Broseley, Shropshire from 1823 through to the firm's closure in 1960. This style of incuse stamped mark was not used until after *c.* 1850 (240N [B] 15107).
33. Plain spur bowl (*c.* 1840–1880); no internal bowl cross; not burnished; rim cut and not milled; stem bore 5/64" (240F [11] 11179, SF: 0307).
34. Plain spur bowl (*c.* 1860–1900); no internal bowl cross; not burnished; rim cut and not milled; stem bore 5/64" (240F [11] (11348), SF: 0625).
35. Plain spur bowl (*c.* 1860–1900); no internal bowl cross; not burnished; rim cut and not milled; stem bore 4/64". Found in the goit and donated by Mr Crowther, former site electrician.

Figure 15

36. Spur bowl (*c.* 1870+); not burnished; rim cut with moulded milling; no internal bowl cross; stem bore 4/64"; marked with the incuse stamped lettering DUBLIN on the bowl facing the smoker. Sides of the spur marked with a relief-moulded ring motif; on the smoker's left this appears to have been double stamped in the mould (240N [B] 15107).
37. Irish style bowl, spur now missing (*c.* 1840–1910); rim cut with moulded milling; stem bore 4/64". Marked with the incuse stamped lettering DUBLIN in an oval border on the bowl facing the smoker (240F [11] 11247, SF: 0361).
38. Spur bowl (1879+); mould-decorated; no internal bowl cross; not burnished; rim cut and not milled; stem bore 4/64". Pattern number 102 moulded into the side of the stem. This particular pattern number and design was produced by John Pollock and Son of Manchester, a company that was founded in 1879 (240F [4] 4037, SF: 0145).
39. Bowl (*c.* 1850–1910) mould-decorated with an acorn on either side of the bowl with a large oak leaf along the front seam; no internal bowl cross; not burnished; rim cut and not milled; stem bore 4/64" (240F [11] 11218, SF: 0342).
40. Stem fragment (*c.* 1840–1860) with the incuse moulded lettering … TUNSTALL LEEDS; stem bore 5/64". Probably either George Tunstall (recorded *c.* 1840–1847) or Henry Tunstall (recorded *c.* 1836–1861), both of whom were working in Leeds (240F [11] 11057, SF: 0065(7)).

41. Bowl fragment (*c.* 1830–1880); no internal bowl cross; not burnished; no rim surviving; stem bore 4/64". Part of a head bowl, the ear is clearly visible (240F [11] 11290, SF: 0565).
42. Spur bowl fragment (*c.* 1830–1870); no internal bowl cross; not burnished; no rim surviving; stem bore 5/64". A dot and circle mark can be seen on the sides of the spur together with traces of moulded decoration, which appears to be the bottom of a Prince of Wales feathers and may be part of the arms of Wakefield (240F [11] (11085), SF: 0173).
43. Stem fragment (*c.* 1820–1860); stem bore 5/64". Traces of a mould-decorated design comprising tendrils runing along the sides of the stem (240F [11] 11555, SF: 0641).
44. Spur bowl fragment (*c.* 1840–1860); not burnished; no rim surviving; stem bore 3/64". The initials FC are moulded on the sides of the spur. This may be Frederick Cartwright of Sheffield, recorded working from at least 1854–1860 (240F [11] 11179, SF: 0307).
45. Spur bowl fragment (*c.* 1840–1910); not burnished; no rim surviving; stem bore 4/64". Small shield design moulded on to the sides of the spur (240F [11] 11555, SF: 0641).
46. Spur bowl fragment (*c.* 1840–1910); not burnished; no rim surviving; stem bore 5/64". Small shamrock design moulded on to the side of the spur (240D [4] 4035, SF: 0065).
47. Burnished stem fragment probably dating from the late 18th century; stem bore 4/64". Stem has a number of sharply ground facets at both ends (240F [11] 11424, SF: 0417).
48. Stem fragment dating from the late 18th, or early 19th century; stem bore 5/64". Stem has three sharply ground facets at one end (240F [11] 11424, SF: 0417).
49. Burnished stem fragment dating from the late 18th, or early 19th century; finely burnished; stem bore 4/64". Stem has been ground very neatly at a *c.* 40 degree angle (240F [11] 11407, SF: 0391).
50. Stem fragment dating from the late 18th or early 19th century; stem bore 5/64". Stem has been modified for re-use and shows signs of teeth wear at one end (240F [11] 11209, SF: 0330).
51. Stem fragment dating from the 19th century; stem bore 5/64". Stem has been modified for re-use and shows signs of teeth wear at one end (240D [4] 4036, SF: 0154).

Glass

by Lorraine Mepham

A total of 1122 pieces of glass was recorded, deriving from various parts of the site, and including several complete vessels. It is, however, apparent that this total does not include all of the glass originally recovered from Riverside Exchange, from comparison with records compiled during the earlier assessment phases (Willmott 2005a; 2005b). No quantifications are available for the unseen glass; the quantifications given in this report, and the functional categories discussed, refer to the analysed assemblage only, with a few specific exceptions.

The analysed assemblage includes vessel and window glass, with a small number of objects and undiagnostic fragments. The date of the glass is exclusively post-medieval, covering the period from the late 17th to late 20th century.

Containers

Containers account for 361 pieces of glass, including 13 complete bottles and jars. These would have contained a wide range of beverages (both alcoholic and non-alcoholic), foodstuffs, pharmaceuticals and other household goods, and also in some cases materials for industrial use. The earliest vessels date from the late 17th/early 18th century, although the majority belong to the 19th and 20th centuries.

Beverages

The earliest beverage containers recovered comprise free-blown green wine bottles from the period from the mid-17th to the early 19th century. None of the earliest 'shaft and globe' (*c.* 1660–80) forms were identified, but there are fragments from 'onion' (*c.* 1680–1730), 'mallet' (*c.* 1725–60) and 'squat cylindrical' (*c.* 1740–1830) forms. All are fragmentary, and many show noticeable abrasion, suggesting that in many cases these fragments occurred residually. Most examples came from trench 11 in Area 2 (Town Mill and Cutlers' Wheel) and Area 1 (Tanneries).

Two fragments appear to derive from mould-blown prismatic (probably octagonal) wine bottles. These belong to a period of experimentation with mould-blowing in the 18th century, beginning *c.* 1730, but were never particularly common (Dumbrell 1992, 87–90).

There are a number of cylindrical beer bottles of late 19th- and 20th-century date in brown and green glass. One carries the mark of John Lancaster, Sheffield. John Lancaster (Botanical Brewer) is listed in White's Directory for 1911 at Hawksley Avenue, Hillsborough. Another, in colourless glass, is from Moors' and Robsons' brewery in Hull. The individual breweries of Henry and Charles Moor (Crown Brewery) and Edward Robson were acquired by Hull United Breweries Ltd in 1888, and the company then changed its name to Moors' and Robson's (http://www.breweryhistory.com/Breweries/YorksHull Moors&Robson.htm [accessed 13/3/13]). However, many of the beer bottles from the site can probably be linked to the presence here from the mid-19th century of Tennants' Exchange Brewery, later taken over by Whitbread, which subsequently included a large bottling plant.

Other soft drinks were contained in a succession of Hamilton (torpedo) bottles, round-ended bottles, Codd bottles and later crown closure or screw-top bottles, probably spanning a date range from the early/mid-19th to late 20th century. Only one carries an identifiable mark – a Codd bottle with a broken top, from JC Brothwell, Britannia Works, Sheffield, and dated 1901. Another has the mark of the bottle manufacturer – Rylands of Barnsley, who first made Codd bottles under licence in 1874, and by 1876 went into partnership with Codd himself (Stockton 1981, 135).

Foodstuffs

Containers for foodstuffs include one for the well-known local delicacy, Henderson's Yorkshire Relish, a spicy, fruity sauce. The sauce was first made in Sheffield in the late 19th century, and is still made in the city. Two other smaller bottles (height *c.* 110 mm), long-necked and with 'cracked-off' (unfinished) rims, are likely also to have contained sauce. A partial bottle carries the mark of the Victoria Vinegar Brewery Co. Ltd, of Sheffield. The company is listed in White's Directory for 1901 and 1911 at 74 Savile Street, Sheffield, but had disappeared by the time of the 1919 edition. A bottle stopper with a central perforation (to restrict the flow), from the same context, probably belonged to this bottle.

Preserves would have been contained in wide-mouthed jars, of which one complete example was recovered, and one stopper, the latter with the mark of Bertenshaw and Turner of Manchester, a jam and pickle manufacturer operating from the late 19th century (listed in Slater's Directory for 1895 and 1909).

Pharmaceutical

Of most interest within the category of pharmaceutical vessels is a small cylindrical bottle, found complete and with the cork closure still *in situ*, bearing the embossed mark of 'Dr Kilmer's Swamp-Root Kidney Cure'. The mark also identifies this as a 'sample bottle', and gives an address of 'London EC'. Dr Andral Kilmer, the inventor of the Swamp-Root, one of the best-known quack medicines of the 19th century, set up his business in New York state in the 1870s, developing a line of proprietory medicines, pills and ointments. By the 1880s he and his brother owned a plant with equipment capable of filling 2000 bottles an hour, and the company's products were actively advertised nationally. By 1895 the company produced a line of 18 different medicines (including the 'Indian Cough Cure' and the 'Ocean-Weed Heart Remedy'), of which the most popular was the Swamp-Root. Kilmer blended 15 herbal ingredients for this particular medicine, including peppermint, rhubarb root, mandrake root, cape aloes, sassafras, cinnamon and juniper, many of which have been used in the treatment of digestive and gastro-intestinal disorders. The medicine also contained around 10% alcohol, perhaps part of the reason for its popularity, particularly since it continued to be sold through the years of Prohibition in the United States. It can still be purchased today. The sample bottle from Riverside Exchange can be dated prior to *c.* 1906 by the use of the word 'cure' – sometime after the passage of the *Food and Drug Act* of 1906, 'cure' was replaced by the word' remedy' (http://www.antiquebottles.com/kilmer.html [accessed 13/3/13]; http://www.bottlebooks.com/drkilmer.htm [accessed 13/3/13]).

No other pharmaceutical bottles carry identifiable proprietorial marks, although one small cylindrical blue bottle carries the distinctive ribbing and exhortation 'Not To Be Taken' of the poison bottle. Two complete cylindrical phials would also have been used for pharmaceutical products, and several fragments of similar vessels were also recovered.

Industrial containers

Two small inverted spherical bottles with short cylindrical necks probably contained oil. The two vessels are in different sizes, the smaller (diameter 54 mm) marked '03' and the larger (diameter 75 mm) marked '02'. A similar bottle from the Wicker Iron Works carries the more explanatory embossed mark of 'Lieuvains 02 / The needle lubricator registered trade mark' (Brooks 2009). The needle lubricator (patented by Lieuvain in 1866) was used for keeping mechanical shaft bearings lubricated with oil; the bottle would have had a wooden plug, through which passed a wire needle or pin. When inverted over the bearing, the pin would gradually conduct the oil down over the shaft (Unwin 1895, 286–7).

Eight fragments from a very large, thick-walled vessel in colourless glass might be part of a carboy or similar industrial container.

Drinking vessels

While beverage containers are well in evidence here, drinking vessels are not particularly common. Five tumblers were identified, four of plain cylindrical form and one in a 'cut glass' style. Three fragments of wine glass in a strong turquoise colour, including one rim fragment and part of a bowl and stem, may belong to the same vessel.

The most interesting vessel in this category, however, is part of an optic-blown pedestal beaker of early 17th-century date. Pedestal beakers are the most common glass drinking vessel found on English sites of the 16th and early 17th centuries, although it was not until the introduction of the potash variety in the mid-16th century, superseding the earlier mixed-alkali or soda glass variety, that the form became truly ubiquitous (Willmott 2002, 45). Potash pedestal beakers were exclusively English products, and were made, for example, at Hutton and Rosedale, Yorkshire, and Haughton Green, near Manchester (Charleston 1972, 146–8; Hurst Vose 1994, 28–9). They are most likely to have been used to consume beer, and are often found on the more ordinary urban (as here) and even poorer rural sites, rather than in high-class establishments (Willmott 2002, 46).

Other vessels

Evidence for other glass vessels is confined to fragments from up to four cut glass vessels, one certainly a bowl and another possibly a vase. All are of 19th- or 20th-century date. While these could be pressed, it may be noted that a glass cutter was operating on the site in 1865, and these may be amongst his products. Six pieces of opaque white glass from two separate contexts could belong either to decorative bowls, or possibly to lampshades.

Window

A large quantity of window glass was recovered (656 fragments). Possibly the earliest pieces amongst this group came from two deposits in trench D, in the area of the tanneries established in the mid-17th century and could, therefore, belong to buildings associated with this industry. Some of the fragments are thin (*c.* 1 mm), in a dull, greenish or pale olive colour, and are partially reconstructable, belonging to rectangular quarries, although the size is unknown. They appear to date to the late 17th or 18th century (Willmott 2005a). While it is possible that further glass of this date is present in other contexts, none of the remainder can be definitively dated earlier than the mid–late 18th century at the earliest, and most has been broadly dated as 19th or 20th century.

A small group of fragments of crown glass derived mainly from trench 11. Most of the fragments are from the central 'bull's eye' portion. Crown glass is made by gathering molten glass on a blowpipe and blowing a balloon shape; the blowpipe is then replaced by a pontil rod, and the glass spun to create a disc. The outer part of the disc is used to cut into separate panes, and the central thick 'bull's eye' discarded – in other words, the fragments from trench 11 appear to represent the waste from the manufacture of window quarries. Although there is no evidence for glass manufacture at Riverside Exchange, it seems that blown crowns were being brought to the site for the final stage of preparation. Even more intriguing is the fact that these crowns seem to date from the 19th century, at a time when crown glass production was largely obsolete. By this time, the only buildings that were still glazed in the more traditional way were churches or large civic buildings, and it is possible that the bulls' eyes from trench 11 relate to a specific commission of this kind (Willmott 2005a). Trade directories reveal that in 1833 there were two glass cutters on or near the site, while in 1865 Joseph Wolstenholme is recorded as a glass cutter (White's Directory for 1833; Kelly's Directory for 1865).

Other 19th- and 20th-century window glass includes plate glass (more than 5 mm thick), including frosted and reinforced glass, types which are more likely to be associated with industrial settings, the remainder being sheet glass of less than 5 mm thickness. Again, much of this material came from Area 2, with a smaller group from Area 1 (the Tanneries).

Objects

Several objects recovered have a certain or probable industrial association. The most obvious is an extincture tube, marked with a patent number and 'AD 1915', and several other tube fragments (generally with a diameter around 12 mm).

An optical glass grinder, T.P.G. Osbourne, is known to have been operating on the site in 1865 (Kelly's Directory for 1865), and one small lens was recovered.

Discussion

The glass assemblage from various parts of the Riverside Exchange site is not particularly extensive, and much of it consists of commonly occurring types of domestic refuse – containers for foodstuffs, beverages, and other household goods, and window glass. Some of this may have been imported to the site along with other refuse, including pottery (see Cumberpatch, above), as part of the efforts to raise and level the ground prior to building work. There are, however, hints of the industrial nature of the site – two needle lubricators and another probable container for industrial materials, and probable products of the 19th-century glass grinder and glass cutters, and bottles associated with the 19th/20th-century brewery on the site.

The earliest glass from the site consists of wine bottles and window glass from the 17th and 18th centuries, prior to full industrial development of the area, although some of this glass could possibly relate to the tannery operating there in this period. At this point the Town Mill would have been in existence and, from around the mid-18th century, the Cutlers' Wheel, close to the mill, and a few other workshops and houses, although much of the site still comprised gardens.

Trade directories from the 1770s onwards chart the increasing industrialisation of the site, but it is virtually impossible to distinguish this in the glass assemblage. Some of the beer bottles recovered could belong to the brewery established on the site in 1852 (Tennants, later Whitbread), although none are marked. In contrast, the crown glass recovered from the area of the Town Mill, and which appears to represent on-site cutting of individual quarries from the parent crown, belongs to an undocumented industrial episode – the apparent 19th-century date for this glass is unusual, and it may relate to a specific commission.

Metalwork

by Joan Unwin, with Ken Hawley†

An important aspect of the work at Riverside Exchange is that it was one of the first excavations to be undertaken on a known metalworking site in Sheffield, and the metal objects recovered are therefore likely to include the items both being used and those being manufactured on the site. Just over 2250 metal objects were recorded (Unwin *et al.* 2005), the majority appearing to date to the later 19th and early 20th centuries, with most coming from trench 11, a relatively large area incorporating the site of the Town Mill and goit, and the workshop and wheel pit of the Cutlers' Wheel (see Fig. 1).

One of the problems in reconstructing metalworking activity on any site is that metal is a valuable commodity as scrap so that much reusable material is likely to have been scavenged. Secondly, ferrous metals corrode badly making identification difficult. However, the metal items recorded here represent parts of machines, building fittings, some tools, items being manufactured, as well as a small number of personal items. It is difficult to know how many articles were being made on the site over its long history, but it is possible to identify some manufacturing processes.

Table knives

Knife blades represent the largest group of metal finds, impossible to number since many are in parts and many are corroded together. Hardly any complete knives, with handles, were found. Part-finished table knives represent different production methods, either being stamped or roll-forged, some having bolsters and tangs. Most of the surviving items show damage or are faulty, and one layer (in trench 4) produced 10 examples of table blades where the tang is off-centre.

Flatware – forks and spoons

Few items of flatware were found, all being from the wheel pit in trench 11. They include ferrous two-, three- and four-tine forks, with possibly a two-prong toasting fork. The forks had scale- and whittle-tangs, and would have had bone, wood or horn handles attached. A spoon blank, plus 'fiddle pattern' handles from either non-ferrous spoons or forks, show that all-metal flatware was being produced at some time on the site.

Pocket knives

Only three identified items (a spring, a hook and a brass inner lining) relate to spring pocket knives, with nothing to indicate the manufacture of this type of knife on site, though at least one manufacturer is recorded there in White's 1833 directory.

Scissors

Only two items certainly relate to scissors – a blade and a blade with part of the tang. The presence of these may suggest some scissor manufacture on the site, possibly either grinding or assembly, and one is recorded in Gell's 1825 directory.

Files

The files represent a relatively large group of identifiable finds and include 10" and 12" flat files, half-round files and three-square (triangular) files. These were the most commonly used types in manufacturing processes and the files themselves suggest that most were used rather than made on the site, though there is some evidence for small-scale production. There were insufficient numbers of files in various stages of manufacture or in any one place to indicate a particular file workshop, although one item may have been a file 'prover' which was used to test the hardness of files. There were two file cutters' workshops and adjoining cottages near the entrance gates to the Naylor Vickers works in 1846, one subsequently described (in 1856, by which time it had been cleared) as '*file warehouses and file manufactory … occupied by John Martin*' (Aurora MS 500/2). Others are recorded from at least as early as 1833 (in White's directory) and Vickers certainly had a file works within their complex of buildings by 1872 (see Fig. 20).

Miscellaneous tools

Tools identified include chisels (mainly from trench 11), three spanners, two screwdrivers, punches, wedges and a spokeshave iron. Late 18th- and 19th-century directories indicate that edge tool makers worked in the area, and some of the items may have come from the workshops of Marsden Brothers and Co. on Bridge Street. Maintenance men may also have used several of these tools. One item was an unusual brass pad for a G-cramp, made on the site at the Campbell Works of Charles Neill, tool manufacturers from the late 19th century. Other toolmakers had workshops on the site or in the vicinity at various times, for example, the Gallimores, later known particularly as screw makers, from at least 1774. Although directory entries show

Plate 8 Knives. a) 18th-century paring knife (above) and table knife (below); X-rays of b) paring knife and c) table knife, showing cutler's marks on blades – b) '+' c) '+' above 'L'

some woodworkers occupied the site, there is nothing in the finds to suggest specific craftsmen such as joiners, carpenters or furniture makers.

Bolts, nuts, washers and bearings

There were a large number of these objects, especially in trench 11, with possibly more concealed under heavy surface corrosion. Several relate to large machinery, for example boilers, but heavy-duty bolts could have held down a variety of machinery and equipment, such as grinding wheels and presses.

Pins and wire

Perhaps the most unusual finds are the possible dressmakers' pins, seemingly in different stages of manufacture, plus rolls and cut sections of fine wire. All were found in the wheel pit in trench 11. There is no documentary evidence in trade directories to show that pin makers occupied the site, but the finds indicate that this was so. The pins are in varying lengths, usually approximately 30 mm long, with and without heads; there are, in addition, a number of small beads, which were presumably for heads. There are also some shorter pins, approximately 20 mm long, thicker and without heads, which might have been used by shoemakers, recorded on the site from at least 1825 (Gell's Directory).

Building fittings

Items used in the construction and furnishing of buildings include metal hinges from doors and windows, gas pipes, electrical-related material and lead pipe-seals.

Miscellaneous items

Apart from a large number of nails, other items included a fantail axe head (not found in any Sheffield Illustrated List), personal items such as metal buttons, a ring and an overall buckle of Rodgers and Sons, chains and links, a skate blade (probably made by Marsden Brothers and Co.) and various rods and bars, representing either manufactured bar for sale or material brought in for further processing, possibly by resident cutlers.

Analysis of Two Mid-18th-Century Knives

by Roderick Mackenzie

The excavations at Riverside Exchange produced approximately 2250 metal finds (see Unwin, above), the bulk (approximately 80%) of the assemblage recovered from trench 11, with most from the fill of the wheel pit of the Cutlers' Wheel, including many corroded fragments of cutlery. As an aid to identification X-rays were taken of these finds, and although the majority of items were found to date from the late 19th to early 20th centuries, two knives (a paring knife and a table knife) were revealed to have cutlers' marks dating to the mid-18th century. As the two knives were the earliest found on the site they were chosen for metallographic analysis.

Photographs were taken of the two knives before samples were removed (Pl. 8a), and the X-rays referred to when removing samples to avoid damage to the cutlers' marks. The samples were mounted in conductive Bakelite to show transverse sections of the blades, and then they were ground and polished, the final polishing carried out using 1 micron diamond paste. The samples were examined in the as polished state, before being etched with 2% Nital prior to further examination.

Paring knife

(Cat no. 0651/11555/s35; 107 mm in length)

The X-ray (Pl. 8b) shows the cross-shaped cutler's mark that has been dated to the mid-18th century. In the unetched condition the transverse view of the blade revealed clean areas of metal interspersed with bands of non-metallic inclusions. The inclusions are predominantly single-phase silicate slag, although there are a small number of two-phase inclusions present. Etching revealed a fine martensitic microstructure suggesting that the steel had been heat-treated; this was confirmed by an average hardness value of µHV 514. The etched microstructure showed that the blade was made of at least five layers of steel, with different inclusion abundances apparent in each layer (Pl. 9a).

Table knife

(Cat no. 0651/11555/s36; 150 mm in length)

The X-ray of this knife (Pl. 8c) shows the 'cross above L' cutler's mark that belonged to Joseph Antt and dates from 1750. Examination in the unetched condition showed the sample to contain a high abundance of non-metallic inclusions, predominantly single-phase silicate and two-phase silicate slags. Etching revealed that one area of the blade contained more cementite than other parts of the blade, suggesting that the metal has a higher carbon content in that area. Weld lines are also present in the blade and these and variations in the microstructure can be seen (Pl. 9b). The fine martensitic structure of the blade suggests that the knife had been heat-treated, and the average hardness value of µHV 537 confirms this.

Discussion

The photomicrograph of the paring knife shows at least five different layers of steel present in the blade. The layering originates from the piling together of separate bars (typically six) of blister steel that would have then been forged together into a single bar to produce a laminated steel, known as 'shear steel' (Barraclough 1984a, 46). It is interesting to note that pieces of better quality and cleaner blister steel appear to have been selected for the outside and centre of the shear steel, as these regions would have formed the exterior and cutting edges of the blade. The use of single shear steel suggests that this knife would have been of reasonable quality.

In contrast, the microstructure of the table knife shows a much higher abundance of inclusions. The blade appears to have been made up of separate pieces of steel, of varying carbon composition, suggesting that the blade may have been manufactured from recycled scrap blades. In the 18th century, steel was such a valuable material that it is perhaps unsurprising to find it recycled in this manner.

It has not been possible to determine the carbon content of the knives by chemical analysis or interpretation of the microstructures. Chemical analysis is a destructive technique and would have involved an unacceptable loss of material from the knives. It is also extremely difficult to estimate carbon content of martensitic steels with any reasonable accuracy Wayman and Craddock (2000, 10–11).

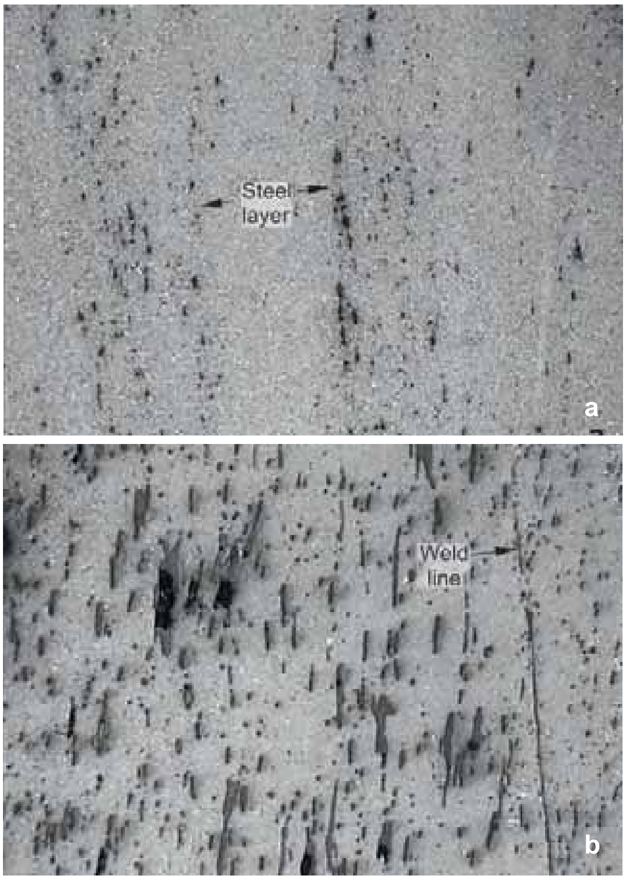


Plate 9 Knives. a) Etched microstructure of paring knife – transverse section through blade, showing at least five layers of steel forged into one piece. Dark spots are non-metallic (slag) inclusions (200x magnification); b) Etched microstructure of table knife – transverse section through blade, showing weld line and numerous non-metallic (slag) inclusions (200x magnification)

Conclusions

The two knives were selected for analysis as they date to the period in the mid-18th century when John Marshall established his steelworks at the site, and there was a possibility, therefore, that they were early examples of Sheffield crucible steel. Metallographic analysis, however, has shown them to be made of blister (shear) steel, indicated by the presence of slag inclusions, though the results are still of interest. Furthermore, it is unusual to be able to sample knives of this period as most complete examples are in museum collections.

In the case of the table knife, visually it appears to be a very well finished blade, in fact the better of the two. However, metallographic analysis has revealed that the blade is of a much lower quality than expected and appears to have been 'cobbled together' from scrap blades.

Plate 10 Gold guinea of George III

Of further interest is the fact that the cutlers' marks on the two blades may be 'related'. The '+' cutler's mark is the earlier of the two and, although the name of the cutler remains unknown, it is possible that he trained Joseph Antt, the cutler that manufactured the other blade, and this is perhaps why the latter, marked '+L', shares the cross sign. It was more common for a son to take an aspect of his father's mark than an apprentice from his master's, however, a cross is a common device, and two marks of just crosses were registered in the 1740s when Joseph Antt was active (Joan Unwin pers. comm.).

It is tempting to conclude that the good quality paring knife blade was the work of the 'master cutler', whilst the lower quality table knife blade was his apprentice's (possibly his son) work, implying that the apprentice had not yet acquired the skills to produce reasonable quality cutlery. However, the apprentice would not have been issued his own mark until he had served his full apprenticeship, and it is more likely, therefore, that the lower quality knife was from a cheaper range and was being deliberately made to a price. It is possible that the two cutlers shared a workshop, or that an apprentice took over his master's workshop when he retired or died, and this may explain why the two knives manufactured by two different but perhaps 'related' cutlers were found together in the same (very large) context, either lost or discarded, or perhaps redeposited in the wheel pit after the workshop had ceased operation.

Coins and Tokens

by Imogen Wellington

Very few coins and tokens were found at Riverside Exchange (Wellington 2005), but there are three items of some interest. The earliest is a worn, mid-16th-century token or jeton from Nuremberg, the pre-eminent producer of these pieces in the 16th and 17th centuries.

A second token, issued in the early 1830s, comes after the end of the third main period of token production in England, from 1648–72, 1787–97 and 1811–17 respectively. In the 19th century token use was on a more restricted scale than previously, largely coinciding with shortages of base coin, and also served for advertisement purposes. The use of tokens rather than coin as payment for goods or services ended with the *Truck Act* of 1817, forbidding the use of alternative methods of payment in factories. The Earl Grey token from Riverside Exchange is a political token, not designed for economic use, and was struck at the time of the *Great Reform Act* (1832), championed by Grey while he was Prime Minister (1830–4). The token has been pierced, and either painted or enamelled, showing it was probably worn around a neck.

The third coin of interest is a 'spade' gold guinea of George III (1760–1820) (Pl. 10), so-named due to the shield and crown on the reverse forming the appearance of a garden spade.

Chapter 3
The Growth of the Sheffield Steel Industry

Marshall's Steelworks

Historical and Documentary Background

Today, Marshall's is not a name that is well remembered amongst famous Sheffield steelmakers, though Thomas Firth (1789–1850) – one who is well known – began his career there as a melter (Tweedale 1986, 31). The history of Marshall's works at Millsands, within the Riverside Exchange site, is poorly documented, and there are only a small number of leases, maps and a will which are relevant. However, in its heyday, Marshall's was respected throughout Europe as a large producer, with a reputation for high quality steel. Marshall's also holds an important place in the history of steelmaking as being the earliest example of an integrated works, having cementation furnaces to convert wrought iron to blister steel, and also crucible steel furnaces to then refine the blister steel and produce crucible steel. The history and technology of the production of blister steel ('converting') and crucible steel ('refining') is described in greater detail below.

In 1759–60 John Marshall was steelmaker for the Cutlers' Company, and worked a cementation furnace in Scotland Street under the control of Joseph Ibberson, a former Master Cutler (Barraclough 1984a, 79). The Cutlers' Company were worried at that time by an apparent shortage of steel for the cutlery trades, and began a steelmaking experiment in the summer of 1759 in order to ensure that '… *the steel shall be disposed of amongst members … equally and impartially at the rate or price directed which … shall be something below the common market price and yet to bring a gain to the Company something more than equal to the expenses …*' (Barraclough 1972, 25). In 1763 this steelmaking experiment came under the direct control of the Master Cutler. Records show that on the 17 August 1763 John Morton, the mason of the Cutlers' Company, did work at 'Millsands Furnace', and it appears that steelmaking had begun in the Millsands area from around this time (Barraclough 1984a, 85). This is the first reference to steelmaking at Millsands and the only one apparently connecting it to the Cutlers' Company. The Company also had a 'new steel furnace', assumed to be a crucible furnace, which began operations on 6 July 1764, and Leader (1901, 174) suggests it was in the Furnace Hill area, but it could have been at Millsands (Barraclough 1984a, 85). This operation closed in 1769.

The first mention of John Marshall as a steelmaker in his own right comes in the 1765/6 Sheffield (Sheffield Lower) Rate Book no. 6 which notes Marshall's steel house under 'Water Lane' on what was probably the Duke of Norfolk's land. It is probably significant in terms of the development of the area that 'Millsands' did not yet have its own page.

In 1769 John Marshall is recorded as sub-tenant of Sarah Broadbent for a messuage, furnaces etc at Millsands (Lease Book, ACM S379 f.232), and it appears that John Marshall worked both a cementation and a crucible furnace (probably one of each) at Millsands by the late 1760s. The crucible furnace could have been that used by the Cutlers' Company until 1768–9, at which time the premises may have been taken over by Marshall (Barraclough 1984a, 85). However, Marshall's steelworks is not further mentioned in the rate books until 1772/3 when a 'Steelhouse [apparently still singular] & Tents etc' are recorded (and the rate paid has risen from 1s to 4s 6d per annum). Further confirmation of his presence and occupation is provided in directories of 1774 (Sketchley's Directory for 1774) and 1787 (Gales and Martin's Directory for 1787), where John Marshall is listed as a producer of cast steel. Between 1770 and 1774 he was supplying cast steel ingots to Benjamin Huntsman, each ingot weighing between 19 and 22 lbs (8.6–10 kg), and from the mid-1770s to 1786 he was supplying slightly larger ingots to Messrs Love and Spear of West Bar (Day and Tylecote 1991, 287).

The earliest relevant map, dating to *c.* 1770 (ACM SheS 1494S), shows fewer buildings than are present by 1780, by which time John Marshall owned 'eight houses, part of the Steel Furnice, Workshops and vacant ground' (Bag C297) (Fig. 16). There is some ambiguity here concerning the property(s) occupied by John Marshall at Millsands, for the Norfolk Rentals for Lady Day 1782 (ACM S158 LD 1782 f33) concerns that formerly sub-leased from Sarah Broadbent, with a steel furnace, whilst a second site is indicated by the Fairbank plan of 1781 (ACM SheS 1495 L). This latter property is clearly on Town Land, and this is confirmed by a West Riding Registry of Deeds Memorial (WRRD DA 106 114) of 1784 in which Marshall appears to be in partnership with

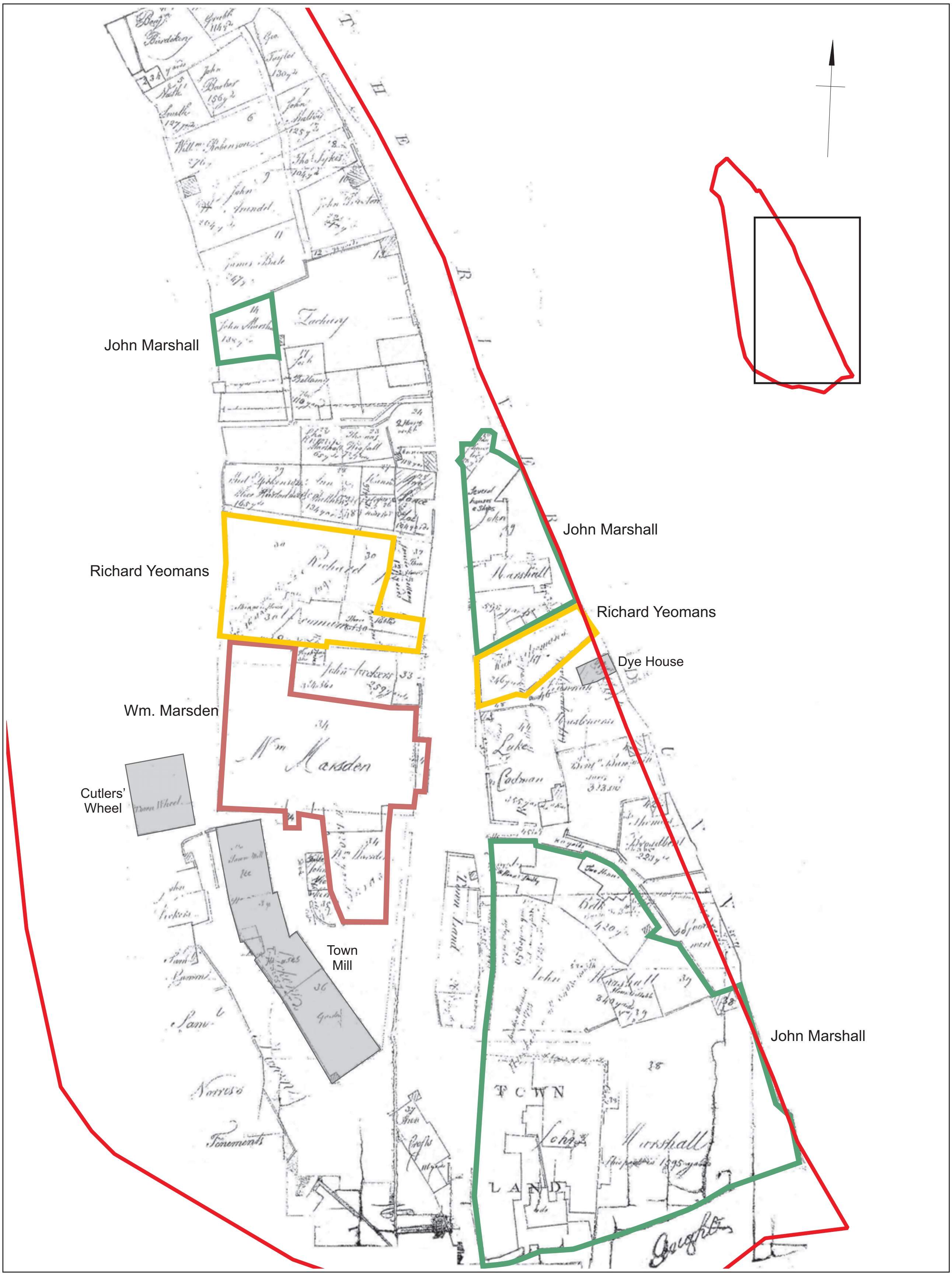


Figure 16 Extract from 1781 Fairbank Survey map (Sheffield City Council, Libraries Archives and Information: Sheffield Archives FC SheS 716L), with the Town Mill, Cutlers' Wheel, John Marshall's and other selected properties/tenants highlighted

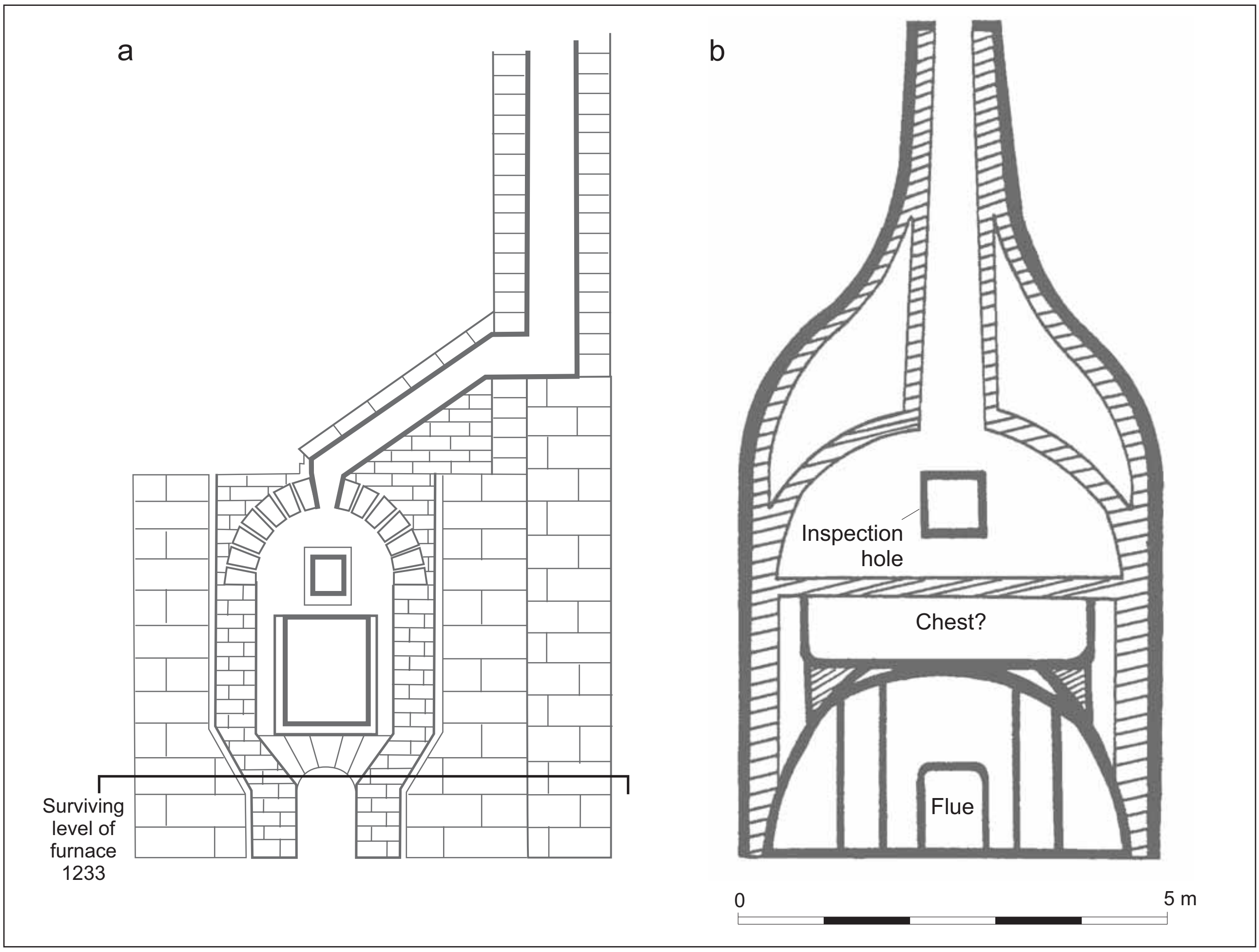


Figure 17 a) Sheffield single-chest cementation furnace 1766 (redrawn after Jars 1774 / Hassenfratz 1812); b) Marshall's single-chest cementation furnace 1796 (redrawn after Raistrick 1968)

Henry Crawshaw. All (or at least 968 square yards) of this property was subsequently conveyed by the Town Trustees to the Norfolk Estate in 1790 with steel furnace (still singular), messuages etc (WC 2375a). Perhaps at that time Marshall's steelworks were on two different but adjacent leaseholds until unified by this conveyance in 1790 (Neville Flavell pers. comm.).

During this period John Marshall and Jonathan Marshall, his nephew and successor there to 1830, were the only establishment consistently described at the time as 'convertors and refiners' (ie, having both cementation and crucible furnaces), and the Cutlers' Company records for 1774 confirm this (Barraclough 1972, 28; Barraclough 1984a, 90).

Evidence from 1796, recorded by Charles Hatchett on a tour of mines and manufactories, suggests the use of a single-chest cementation furnace with a capacity of approximately six tons on the Millsands site. He records that:

> *In the morning we went … to see a steel work (or where the iron is converted to into the blister'd bar steel) belonging to a Mr Marshall … To form what is called German Steel the blistered bar steel is forged under hammers and reduced even occasionally (as for watchmakers etc) to the size of an eighth of an inch square* (from Pybus 1994, 72).

He also drew a sketch (Fig. 17b) and described the operation of the cementation furnace as follows:

> *The bars [of iron] are of various sizes and are about 12 feet long. They are placed horizontally in the chest so as not to touch the other on a stratum of powdered charcoal and between each layer of bars a stratum of charcoal is placed and when the chest is thus filled the whole is covered with sand to prevent the combustion of the charcoal. The aperture by which the people entered to arrange the iron is then well closed up and then the fire is kindled (the Fuel is pit coal) and the Red Heat is kept up eg. From Sunday evening till Saturday following. There is a small aperture in the side by which a bar may be occasionally taken out and also the degree of heat seen. This forms blistered Bar Steel (N.B. here about 6 tons are made in each furnace) …* (from Raistrick 1968, 69–77).

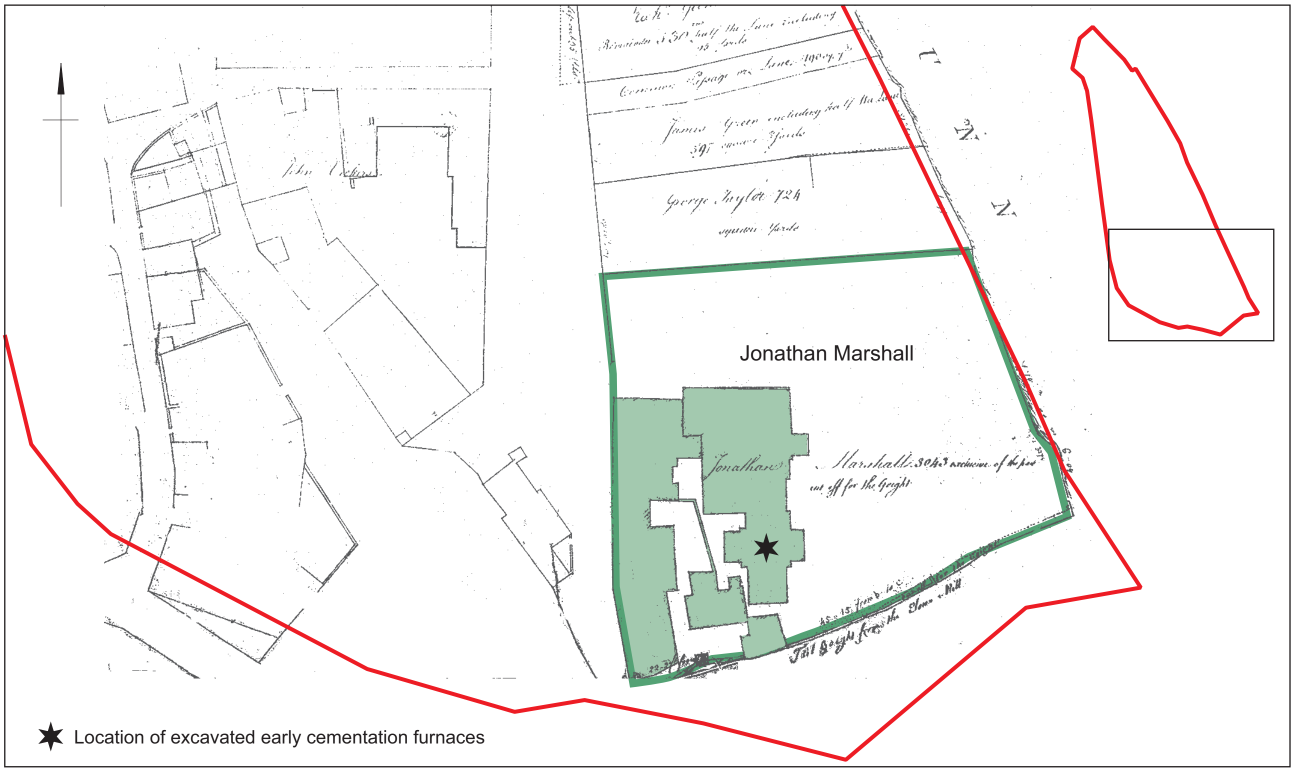


Figure 18 Extract from the 1787 map of Mill Sands (Sheffield City Council, Libraries Archives and Information: Sheffield Archives FC SheS 717L), with Jonathan Marshall's works highlighted

Maps of the late 18th century show Marshall's steelworks occupying a large property at the southern end of Millsands (Figs 16 and 18), adjacent to the branch of the Town Mill goit around the north side of the Isle. The works are shown as what appears to be an agglomeration of at least four buildings or structures around a yard with an entrance to the south. The use of individual buildings, or indeed the entire complex, is not indicated on either the 1781 or 1787 maps.

A somewhat idealised illustration of *c.* 1830 (provenance unknown, but reproduced in Scott 1962, frontispiece) (Pl. 11), at least in terms of the setting and layout of the buildings depicted, shows three steelworks, of which two have been identified as at Millsands (Marshall's and Naylor Vickers), with the third (another Naylor Vickers works) at Wadsley Bridge. Marshall's steelworks, on the left of the illustration, shows a building complex associated with cementation and crucible furnaces, together with a forge building, around a central courtyard with an imposing archway entrance, with the administrative block flanking it. The arrangement depicted only very broadly matches that shown on the earlier maps, even allowing that some rebuilding may have taken place during the intervening period, and some artistic licence can be assumed. The conical chimneys in the illustration represent four cementation furnaces, with a further four rectangular crucible stacks, each perhaps associated with 20 or 24 'holes', the individual holes probably accommodating two crucibles with a likely capacity of 28–36 lb of metal per crucible.

When John Marshall died in 1793 the works passed to his nephew Jonathan, and he continued the Marshall's steelmaking operations at Millsands for a further three and a half decades. In the late 18th century, four or five coke ovens were built by Jonathan Marshall and one by the Dore House Colliery Company (Hunter 172b) to provide fuel for the furnaces, and by 1810 he had at least two cementation furnaces in addition to the crucible melting holes (Barraclough 1984a, 103).

A survey in 1802 to assess the potential need for a proposed Tinsley to Sheffield canal, to make the Don navigable as far as the centre of Sheffield, put Marshall's as the largest customer of iron at 800 tons a year (though this may be an over-estimate). This would represent over 25% of all Sheffield steel production at the time, and significantly more than the nearest rival Walker and Wilde with an annual output of some 500 tons (MD 1740–21).

In 1829, following the death of Jonathan Marshall, the works were sold to Naylor, Vickers and Hutchinson. The new owners continued to use the 'Marshall' trademark for tool steel bars, but the works became part of the new owner's Don Works.

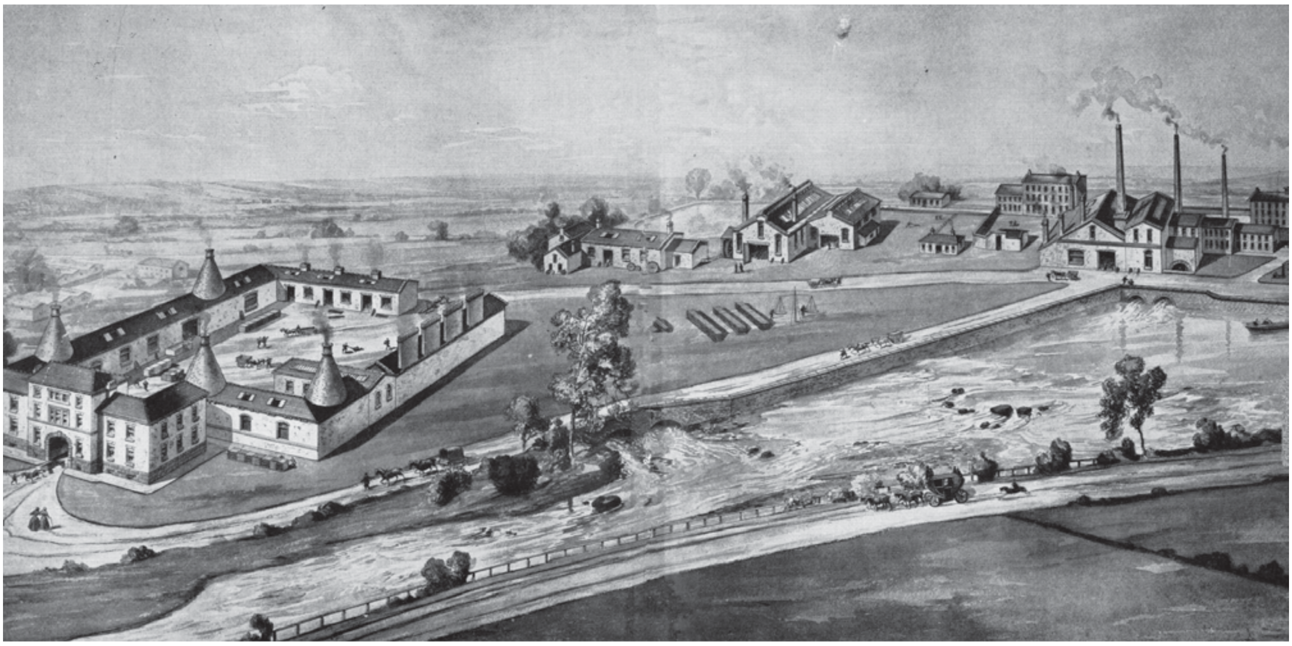


*Plate 11 Idealised depiction (*c. *1830) of three steelworks shown next to the River Don, with Marshall's works to left and Naylor Vickers to right (reproduced from Scott 1962, frontis / Sheffield City Council, Libraries Archives and Information)*

Archaeological Remains of the Furnaces

The Marshall's works lay towards the southern end of the Riverside Exchange site, and a group of excavation trenches (1, 2 and 10) were focused here with the aim of uncovering part of the works which the 1996 evaluation suggested survived in this area.

The excavations uncovered three cementation furnaces (in trench 2, where archaeological deposits were relatively undamaged), including one early and unique example dating to the second half of the 18th century (Pl. 12) and the others of probable late 18th- or early 19th-century date (Pl. 13). The lower part of the earliest furnace (1233) was unexpectedly well preserved, surviving to a height of 1.4 m, and because of this was subject to only limited excavation and has been preserved *in situ* (following excavation this cementation furnace was prepared for display and part of it is now visible beneath a glass panel in the forecourt of one of the new buildings at Riverside Exchange). The layout and form of cementation furnace 1233 is clear, comprising a stone-built, rectangular furnace 8.25 m long and 7 m wide, with steps leading down at one end to the rectangular stoke-hole (1 m long by 0.95 m wide), ash pit and central flue (0.4 m wide) (Fig. 19). A small excavation in the base of the ash pit/central flue revealed pre-furnace deposits containing sherds of mid–late 18th-century pottery and a few fragments of vessel glass and clay pipe. Sealing these deposits and forming the base of the ash pit/flue was a compact reddish silt containing some plaster fragments, overlain by a grey ash up to 0.08 m thick containing fragments of coal. The ash appeared to be *in situ*, thereby indicating that the stone surface at the base of the steps and flue entrance did not extend into the ash pit/flue itself, where the floor may have been of plaster. From the steps came three pieces of metal bar which have been shown to be blister steel (see Metallurgical Remains, below), very likely to be products of the furnace and perhaps pieces that had been cut from bars to assess the degree of carburisation. A deposit broadly contemporary with the furnace contained a group of 18th-century pottery including White Salt Glazed Stoneware, Slipware and Black Glazed Buff Ware.

It is known that Sheffield steelmakers experimented with a range of furnace types during this period, including ones with a single chest, rather than the double-chest version that became common later. Small capacity cementation furnaces, some without the characteristic conical superstructure, are also described in various publications of the 18th and early 19th centuries. The similarities in layout of furnace 1233 and a single-chest cementation furnace with a capacity of 3 tons from Sheffield that was recorded in 1766 and illustrated in G. Jars' *Voyages Métallurgiques*, published in 1774 (see Fig. 17a), led to the interpretation of furnace 1233 as a single-chest cementation furnace. Although the furnace recorded by Jars is only known to have been 'a Sheffield furnace' the later 18th-century account by Hatchett (see above), specifically records a single-chest cementation furnace at Millsands (see Fig. 17b).

Plate 12 Remains of earliest cementation furnace 1233 (prior to preservation in situ*), with steps and flue in centre (view from north-east) (© University of Sheffield. Reproduced by permission)*

Plate 13 Remains of cementation furnaces 1224 (right) and 1227 (left) (prior to preservation in situ*), earlier cementation furnace 1233 in foreground (view from north-east) (© University of Sheffield. Reproduced by permission)*

Figure 19 Excavation plan of three cementation furnaces (© University of Sheffield. Reproduced by permission)

The other two cementation furnaces (1224 and 1227) had, like furnace 1233, survived relatively well and have also been preserved *in situ*. These were later, of late 18th- or more probably early/mid-19th-century date, and had been constructed adjacent to each other and immediately south-west of stone-built furnace 1233 (Pl. 13). The juxtaposition of these and the earlier furnace suggests that at least two of them could have been in operation at the same time at the beginning of the 19th century. Furnaces 1224 and 1227 were also rectangular, but brick built, each being at least 9.5 m long and approximately 6 m wide, and each had a stoke-hole, ash pit and a main flue, either side of which were the platforms on which the supports for a pair of sandstone chests would have stood (Fig. 19). The chests are likely to have been approximately 4 m in length (and 0.9 m and 1.3 m in width and depth), sufficient to accommodate 12 ft (3.65 m) long iron bars, with each chest probably having a capacity of between 10 and 15 tons. Trench 10, a southern extension to trench 2, showed that the south-west ends of both later cementation furnaces, including the flues, had been destroyed by a substantial, probably modern intrusion. Forming part of cementation furnaces 1224 and 1227 were several brick and stone structures, only one of which (1072) was excavated, the remainder being preserved *in situ*. Structure 1072 comprised the stoke-hole and ash pit associated with furnace 1224, the stoke-hole 3.1 m long, 2 m wide and 1.15 m deep with a stone flagged floor. The ash pit/flue was up to 0.8 m wide.

All three furnaces were rectangular, and therefore broadly similar to the earlier furnace at Derwentcote, possibly dating to as early as 1720, which had a square base and a conical chimney (Cranstone 2008). Certainly, there was no surviving evidence for any surrounding circular structure, which may have formed the base of the chimney, and in this respect they seem to clearly differ from later cementation furnaces in Sheffield (see Pl. 24). This rectangular form may also be reflected in the few plans that survive of the steelworks at the end of the 18th century, which show no evidence for circular or sub-circular chimney bases (see Fig. 18), but which presumably became circular higher up, as at Derwentcote. The earliest (1737), admittedly small-scale illustration of a cementation furnace in Sheffield shows two conjoined circular chimneys (Barraclough 1984a, pl. 4a), and a similar form is shown for the mid-18th-century steel house in Birmingham.

In trench 10, to the south of brick-built cementation furnaces 1224 and 1227, was a complex of extremely fragmentary structures including walls, stone flagging and brick plinths, the latter possibly machinery bases. The phasing of these remains is problematic, but most are likely to have been associated with steelmaking, with one very heavily disturbed structure in the north-east corner of the trench possibly the remains of a cellar associated with a crucible furnace belonging to an early phase of Marshall's steelworks. Close to this was a deposit containing at least 30 fragments of crucibles, likely to be relatively early examples of late 18th-century date, which have been subject to subsequent petrographic and chemical analysis (see Spataro and Craddock below).

The south-west corner of another possible crucible furnace was partly exposed in an evaluation trench a few metres to the west of trench 10, with an associated levelling layer containing considerable quantities of crucible fragments of probable 19th-century date. A deposit of silica sand was also recorded, such sand being used to seal the hole left in the bases of crucibles by the moulding process, as well as being a necessary constituent of casting and lining processes. This crucible furnace would have been situated towards the south end of the eastern range of buildings shown as a row of crucible furnaces in the illustration of *c.* 1830 (see Pl. 11). Given that the Millsands works expanded its crucible capacity considerably during the second quarter of the 19th century, having 90 holes by 1853 (Barraclough 1984b, 187), it would seem likely that this structure formed part of an extension to or rebuilding of an earlier range of crucible furnaces.

Naylor Vickers

Although the Vickers family had been the town corn millers for nearly 65 years, since the mid-18th century, their interests had started to diversify into metal manufacture by the time John Vickers died in 1825. He leased the Cutlers' Wheel along with the Town Mill in 1761, and in 1805 the Cutlers' Wheel and the Town Mill were sold to Vickers by the (Duke of) Norfolk Estate (Ball *et al.* 2006, 24; ACM S377; S158), at the same time as other land was sold at Millsands by the Estate. John Vickers' son, Edward Vickers, was the miller, and his brother William Vickers built a water-powered rolling mill in the northern part of the Riverside Exchange site in 1825/6 (Ball *et al.* 2006, 24; Fairbank FB 171: 8, 34), the power coming from a new branch of the Town Mill goit to the north of the mill. This development marked the start of intense industrialisation of the area, and over the next few years the company developed, linking with other local firms through partnerships and marriage, and eventually William Vickers and George Naylor took over Jonathan Marshall's business and rented his works at the south end of Millsands (Tweedale 1986, 31). A new firm, known as Naylor, Hutchinson, Vickers and Congreve was formed in 1829 (Edward Vickers had married the daughter of the senior partner, George Naylor), and by 1850 had become Naylor Vickers and Co.; the other offshoot was Sanderson Brothers and Co., which was the main descendant of the old Naylor and Sanderson company (Scott 1962, 5).

The rolling mill was built on land bounded to the east by the River Don, to the west by the Town Mill goit, to the north by the Wash or Watercourse, and to the south by premises sold to William Hoole (Aurora MS 497/1). The somewhat idealised illustration of *c.* 1830, which also shows the Marshall's steelworks (see Pl. 11), depicts what are thought to be two Naylor Vickers works, one at Wadsley Bridge just outside of Sheffield, the other probably the Don Steel Works at Millsands. It is possible that this illustration was produced for advertising purposes by Naylor Vickers (Sheffield Archives SheS Leader 116–120a, on microfilm). If, as is presumed, the larger Naylor Vickers is the 1826 rolling mill at Millsands, then there is no evidence (in the form of cementation or crucible furnace chimneys) to indicate that steelmaking took place here at this time, and perhaps initially the works depended on the former Marshall's works for supplying steel for the rolling mill.

In 1837 the Naylor Vickers works was valued at £17,335, the valuation perhaps undertaken for the purposes of borrowing money, as the company had now purchased the freehold of the Millsands works (Scott 1962, 6). Along with the rolling mill were '*several workshops with hearths and smithies therein,*

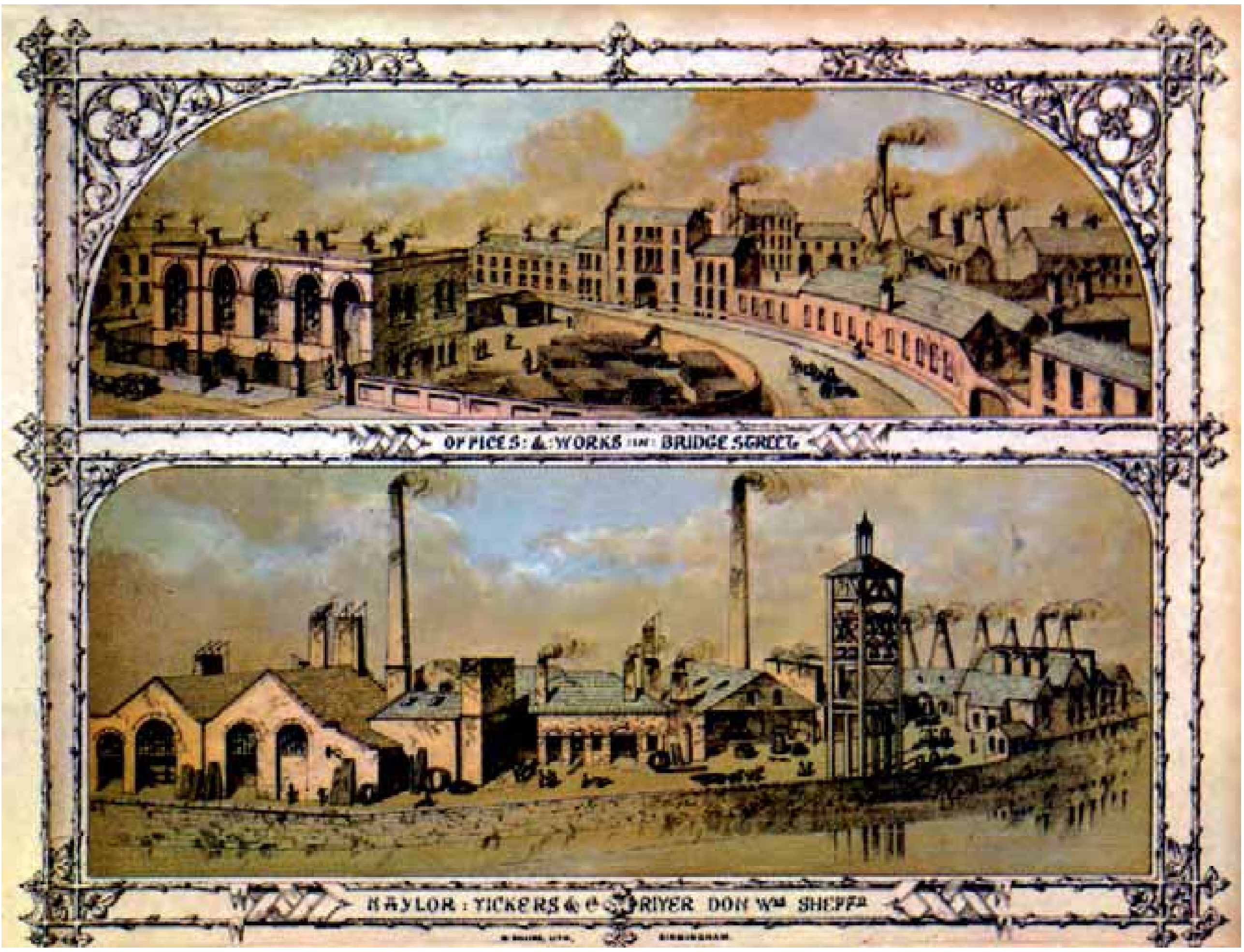


Plate 14 A print of the Naylor Vickers works in 1858 (Sheffield City Council, Libraries Archives and Information: Sheffield Local Studies Library GI 52 Acc no. 10993)

building used in the manufacture of gas, with gasometer, two dwelling houses (one used as a counting house) … and steam engine, waterwheel, boilers etc' (Aurora MS 497/1).

By the 1850s cementation and crucible furnaces had been added and the firm started to pioneer large steel castings in Britain. In 1851 there were eight cementation furnaces at Millsands (perhaps four in the Naylor Vickers works and four in the former Marshall's works) producing 2300 tons of steel (Barraclough 1984a, 105), and by 1853 there were 90 crucible melting holes (Barraclough 1984b, 157). In 1855 a licence was taken out to use the methods developed by Jacob Meyer in Bochum which involved crucible steel being used for large castings (*ibid*., 162).

A later description, in 1856, mentions rolling mills, forges, tilts, furnaces, iron warehouses and a weighing house (Aurora MS 500/2), while in 1857 six converting [cementation] furnaces, 48 melting [crucible] furnaces with bell foundry, a further 56 melting furnaces, model house and Naysmiths (steam) hammers shed, and an unfinished bell tower (for bell testing) are recorded (Aurora MS 141/B1/1). An 1858 illustration of the Naylor Vickers River Don (Millsands) works shows cementation furnaces, crucible furnaces, forge chimneys and a bell-testing tower (Pl. 14).

Naylor Vickers' had begun casting bells here in 1855 under the direction of T.E. Vickers (Pl. 15). For the International Exhibition, in 1862, they cast a four and a half ton bell which was at that time the largest single steel casting that had ever been produced in England (Sherlock 1970, 25). The casting required the molten steel of no fewer than 176 crucibles, each weighing 68 lb, to be poured by hand into the mould in just 11 minutes by a small army of skilled melters working to a strict programme. The bell now hangs in the entrance of the Kelham Island Museum. Vickers' supremacy in large castings including bells, railway wheels and later armaments (Barraclough 1984b, 162), and their global reach, is demonstrated by range of their customers. Bells, for example, were sold as far afield as Europe, USA, South Africa, Canada, Australia, New Zealand, Turkey, India and Syria (Sherlock 1970, 30). The properties of Vickers' cast-steel bells made them a popular choice and they were

Plate 15 Steel bell casting in the Naylor Vickers works (Sheffield City Council, Libraries Archives and Information: Picture Sheffield S10788)

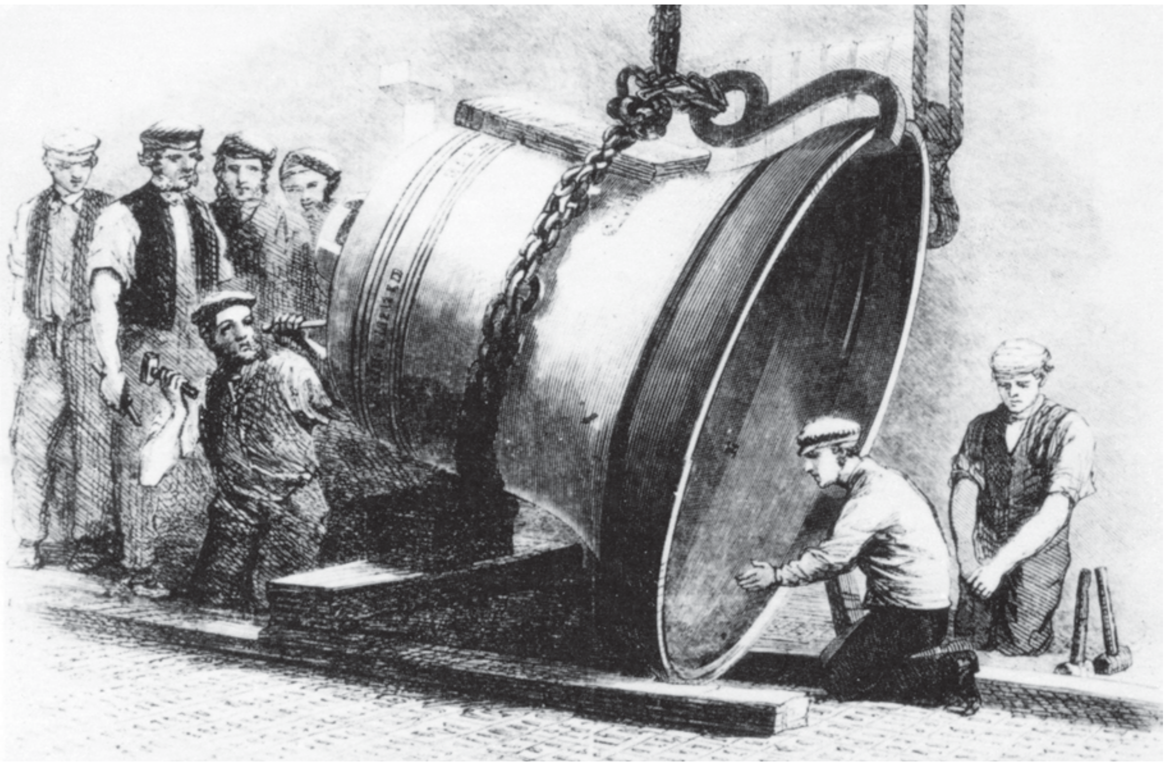


Plate 16 Finishing a large steel bell at the Naylor Vickers works (Sheffield City Council, Libraries Archives and Information: Picture Sheffield S10781)

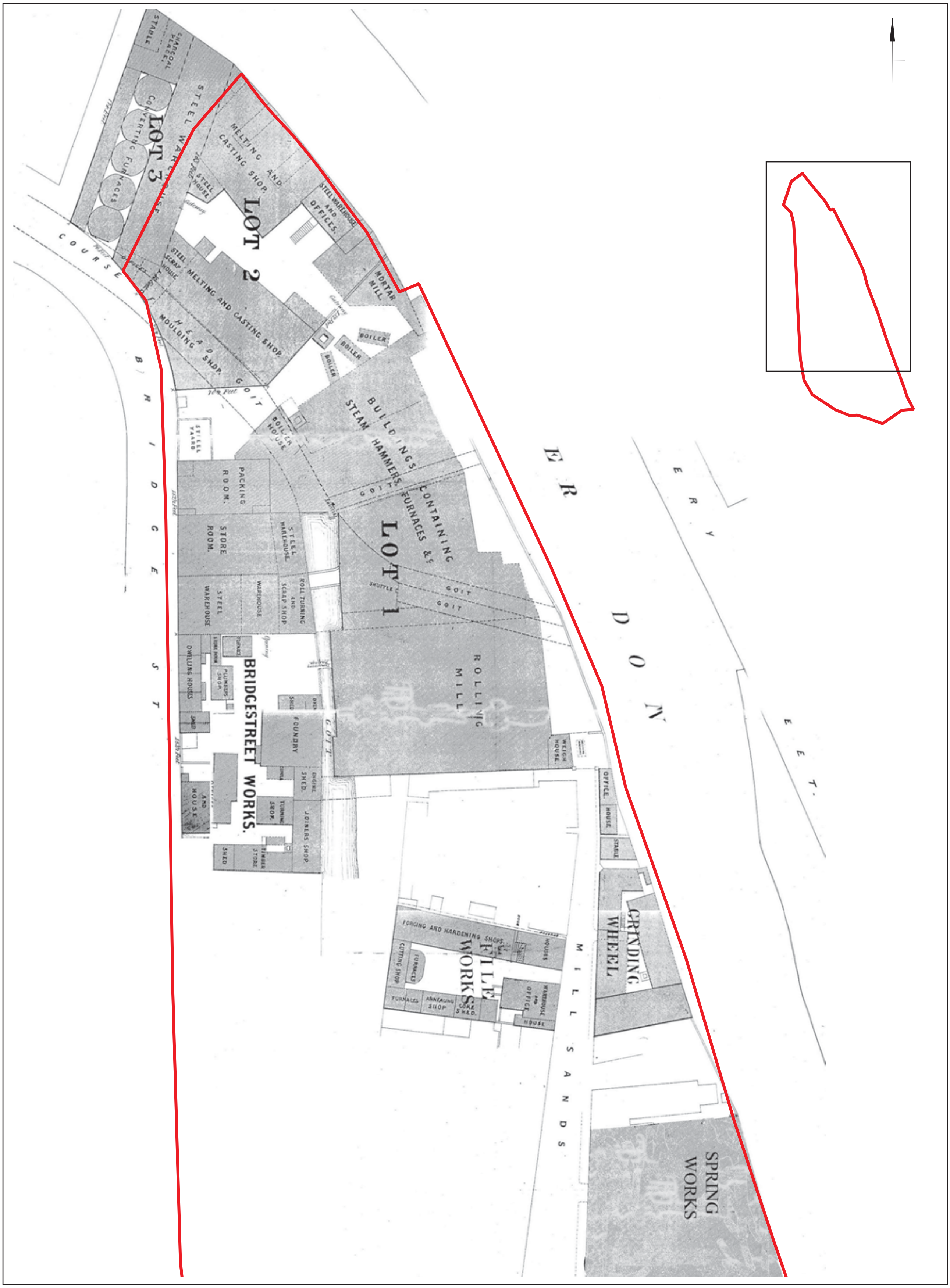


Figure 20 1872 sale plan of William Taylor Charles works (formerly Naylor Vickers works) (Sheffield City Council, Libraries Archives and Information: Sheffield Local Studies Library, Naylor Vickers' auction plans)

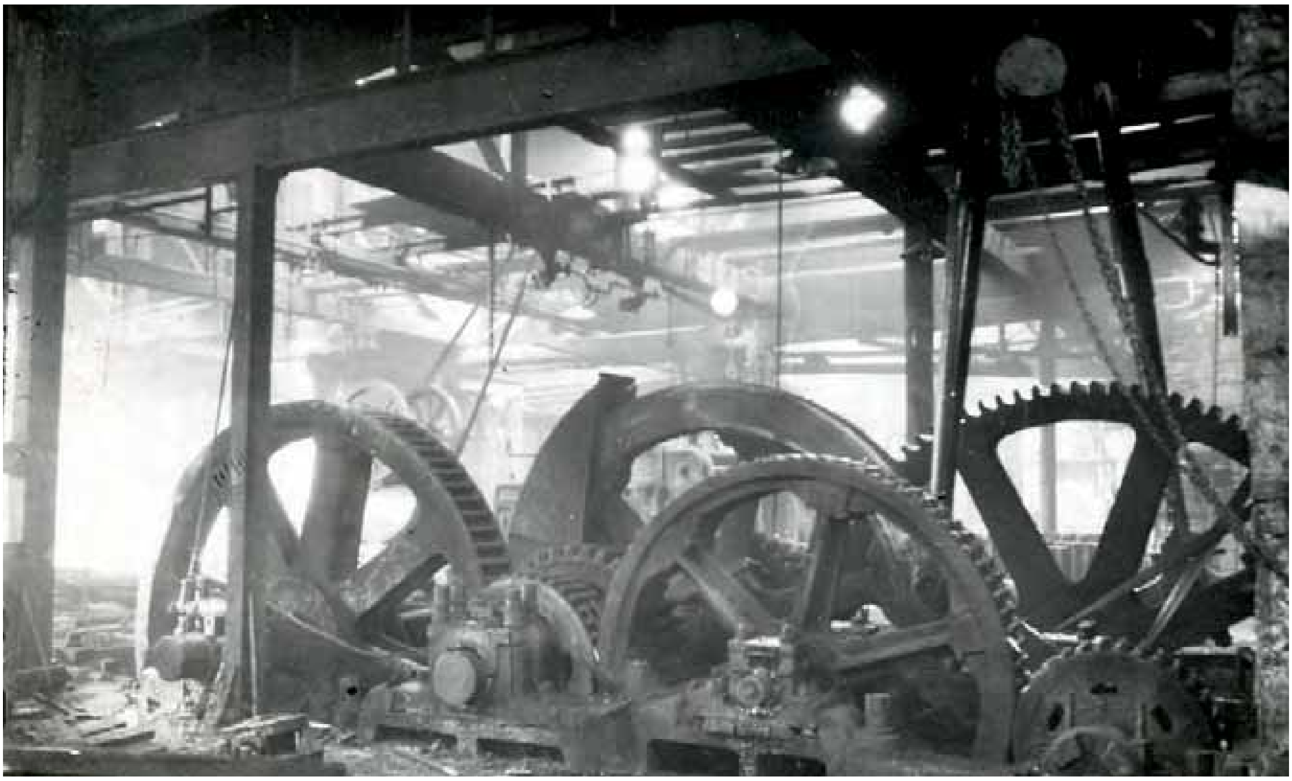


Plate 17 Former Naylor Vickers rolling mill (source unknown)

often chosen in preference to more traditional bronze bells (Pl. 16). They were said to be louder, clearer, cheaper, lighter and more resistant to frost fracture. Vickers' received many testimonials from satisfied customers and reproduced these in their trade catalogues (*ibid.*, 27–30).

By 1860 the Naylor Vickers Millsands works were becoming crowded with additional buildings and also outdated, with crucibles full of molten steel being wheeled from one works to another through public streets (Scott 1962, 11). Additional properties were taken over, for example the former Croft's brewery on the north-west edge of the site, but the extra space still proved insufficient. As a result, a much larger works, the River Don Works, was built at Brightside, and steelmaking was moved from Millsands to the new and more spacious site on the periphery of Sheffield in 1863 (Tweedale 1986, 65). However, the old works continued to operate for a short period after this as various entries in the 1864 Sheffield Flood Claims Archive makes clear (http://www2.shu.ac.uk/sfca [accessed 8/8/13]). A total of 61 claims relate to Naylor Vickers and their employees and suppliers, but that specific to the works (claim 2267) was reduced from £2927 9*s* 1*d* to an amended and agreed sum of £268 8*s* 1*d* in May 1865. By the early 1870s, innovative gas-fired Siemens open hearth furnaces were in use at the new River Don Works (Tweedale 1993, 152), each furnace hole with a capacity of up to 30 crucibles. By this time, with the death and retirement of all other partners, the company had become Vickers and Company (in 1867).

After Vickers' moved to Brightside, the Millsands works were sold to William Taylor Charles in 1865 (Aurora MS 500/6), whose family operated the Kelham rolling mill, but this new venture did not succeed and he was bankrupt by 1871 (Derek Bayliss pers. comm.). The whole of the northern part of the plant was offered for sale in 1872 (Fig. 20), either in one or three separate lots, and included five cementation furnaces (at the north end of the site), the 'Melting and Casting Shops' with 96 holes, and 11 steam engines (1872 sale plan). The sale plan shows two branches from the Town Mill goit running beneath the works to the Don, but there is no mention of waterwheels, and it is not known when the rolling mills stopped using waterpower, though it may not have been until after 1850.

Following the demise of William Taylor Charles, the Sheffield Forge and Rolling Mills Company was set up in 1872 to resume operations on the Millsands site, but it is not clear if it continued with steelmaking. The Ordnance Survey maps of 1889 and 1903 still show five cementation furnaces, though the former describes it as 'Forge and Rolling Mills', suggesting that steel production may have ceased by this time. This company continued until the late 1940s, when it was nationalised. A merger in 1961 saw the works taken over by the Balfour Darwin Group and then by Sheffield Rolling Mills Limited in 1968, this company part owned by the British Steel Corporation (Derek Bayliss pers. comm.).

The British Steel Corporation took complete control when the works were transferred to their Sheffield Division in 1974, and when the works closed in 1980 (*Sheffield Morning Telegraph*, 11 June 1980), the Millsands works were the last hand rolling mills in use by the Corporation (Derek Bayliss pers. comm.).

The archaeological investigations within the area of the Naylor Vickers works revealed relatively little of significance, probably in part due to the location and generally small size of the excavations. Furthermore, the row of cementation furnaces at the northern end of the works lay outside the Riverside Exchange development, though they were investigated as part of the Inner Relief Road project (Bell in prep). However, though surviving only to foundation level and heavily disturbed by later brewery structures, several elements of the works were recorded. Trench 7 exposed parts of two rectangular brick platforms separated by an ash-filled channel, possibly the remains of the foundations of a rolling mill which is known to have been located in this area (Pl. 17). Trench 8 contained the very fragmentary foundations of what has been interpreted as part of a crucible workshop, whilst trenches 7 and 9 both revealed elements of 20th-century firebrick-lined flues. Further to the south, trench A exposed further fragmentary foundations, but trench D contained the somewhat better preserved remains of a crucible cellar of probable late-18th-century date (see Fig. 7), almost certainly an element of the separate, northern part of Marshall's works adjacent to the River Don (see Fig. 16).

Metallurgical Remains

by Roderick Mackenzie

Analysis of Metal Bars

The excavations produced large amounts of refractory material (see below) and various sized pieces of metal bar potentially associated with steel production. As very few examples of steel bars from the cementation process survive, it was decided to focus analysis on them. Five pieces were selected for analysis, three of them found in association with the earliest cementation furnace (1233; see Fig. 19) on the site, from the steps leading down into the ash pit, and the remaining two pieces from a cleaning layer nearby.

Initial analysis of the three pieces of metal bar (samples 23, 24 and 25) associated with the furnace confirmed that they are 'blister steel', which is carburised wrought iron produced in the cementation process. It is possible that the three pieces were the

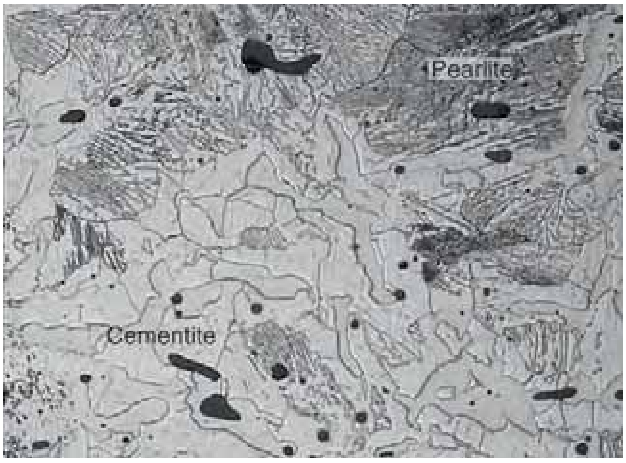


Plate 18 Blister steel bars. Sample 24 – etched microstructure of high carbon blister steel bar, showing an area where the cementite-rich microstructure meets an area of pearlitic microstructure. The dark grey / black spots are non-metallic (slag) inclusions (100x magnification)

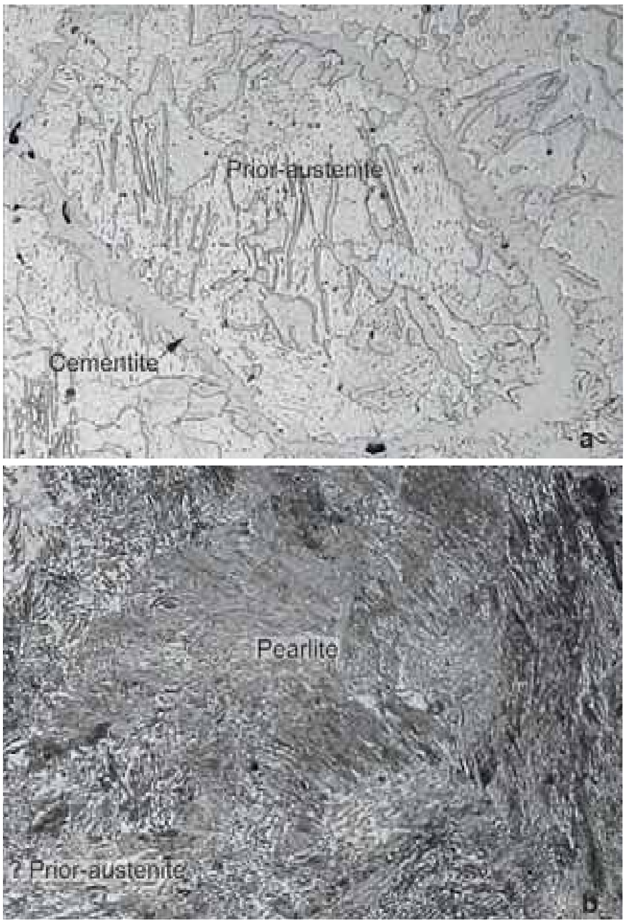


Plate 19 Blister steel bars. a) Sample 23 – etched microstructure of outer layer of blister steel bar, showing cementite around the edge of a prior-austentite grain boundary (100x magnification); b) Sample 23 – etched microstructure of inner 'sap' of blister steel bar, showing dense pearlite with possible edge of prior-austentite grain boundary (100x magnification)

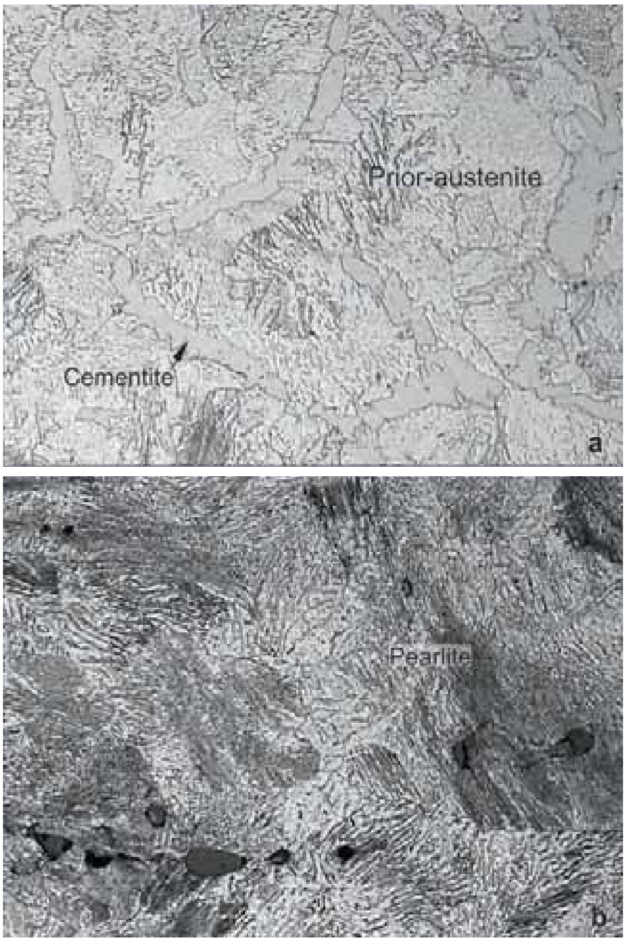


Plate 20 Blister steel bars. a) Sample 25 – etched microstructure of outer layer of blister steel bar, showing prior-austentite grain boundary cementite (100x magnification); b) Sample 25 – etched microstructure of inner 'sap' of blister steel bar, showing variations in pearlite and dark grey non-metallic (slag) inclusions (100x magnification)

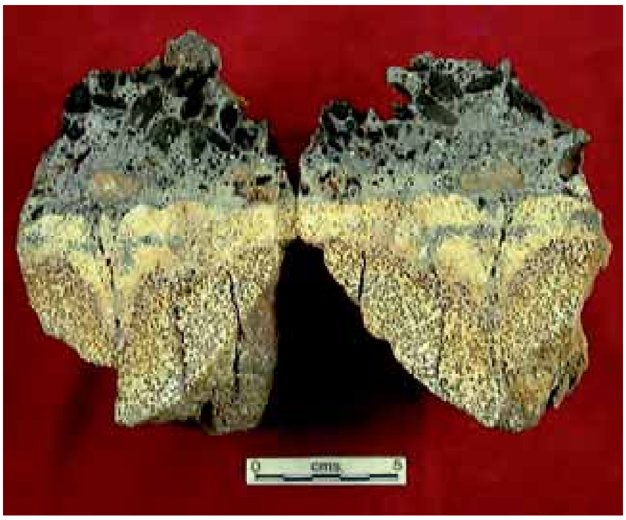


Plate 21 Section of refractory lining from early cementation furnace chest

ends of trial bars broken off by the furnaceman to assess the degree of carburisation of the bar.

Analysis of the microstructure of the three blister steel samples indicates that they have different compositions and carbon levels. Steels were produced with different carbon levels for particular applications, for example shear steel used in cutlery.

Sample 24 (Pl. 18) comprises a high carbon blister steel containing a large proportion of cementite, a hard, brittle compound of iron and carbon. Samples 23 and 25 contain lower proportions (than sample 24) of cementite in the outer layer, where it occurs in association with prior-austenite, an early stage in the formation of a solid solution of carbon in face-centred-cubic gamma iron (Pls 19a and 20a). The inner 'saps' (the central region of the bar not yet affected by carburisation; Barraclough 1984a, 44–5) of samples 23 and 25 comprise largely of pearlite, a lamellar structure present in carbon steel and some cast iron that consists of alternate plates of pure iron and cementite (Pls 19b and 20b).

The different carbon content or 'temper' in the three bars suggests that they could have been put to different uses, usually after forging or rolling. For example, high carbon 'melting heat' steel was used as part of the charge in crucible furnaces, whereas slightly lower carbon 'steel through heat' steel was suitable for razors, and 'shear heat' and 'cutlery heat' steel, with progressively less carbon, for good quality cutlery and edge tools and poorer quality cutlery respectively.

Analysis of the other two pieces of bar suggests that they are wrought iron, but as their context is not secure it is not possible to determine whether they were stock for the cementation furnaces or structural material. However, the results of all of the analyses undertaken here can be set alongside the results of earlier as well as more recent analyses of blister steel from Sheffield (Barraclough and Kerr 1973; Mackenzie and Whiteman 2006), the latter derived from the 19th-century cementation furnaces excavated at Jessop's works, Brightside, with the analysis also including samples of Swedish wrought iron.

Slag and Refractory Stone

The bulk of the slag and refractory stone assemblage recovered from the site is of very limited archaeological or archaeometallurgical significance in terms of providing further information on the nature and scale of the processes undertaken. However, after final recording of trench 2, one unusual fragment of slagged refractory material was noted which appeared to have fallen or washed out of the demolition fill of the stoke-hole/ash pit of the earliest cementation furnace (1233; see Fig. 19), and it was recovered by the author for further investigation.

The fragment consists of a mid-grey, siliceous, slag-like residue attached to a piece of refractory stone. The residue has numerous charcoal inclusions and it appears to have reacted with the stone during prolonged exposure at a high temperature (ie, >1000°C). The fragment was sectioned on a diamond bladed rock saw, and the resulting cross-section is shown in Plate 21.

Analysis and interpretation

The stone in the fragment has been identified as ganister, which is a specific type that is known to have been quarried locally and used for building the stone coffin-type chests within cementation furnaces in the Sheffield area. The cementation process used charcoal within the stone chests as a carburising medium, to convert the bars of iron into steel. All of the identifiable fragments of charcoal within the slag layer have been identified by a dendrochronologist as predominantly oak or other hardwood species.

Initial metallurgical and chemical analysis of a specimen of the slag-like residue from the fragment suggests that its constituent source materials include wood ash from the charcoal, alumina-silicates, either from fire-clay or refractory stone, and iron oxide from the presence of iron or flakes of iron scale. Preliminary interpretation of the results of analysis suggests that the slag is possibly a form of sintered clay formed by the heating together of the constituent elements.

Since the excavations at Riverside Exchange, the partial remains of several other cementation furnaces have been excavated in Sheffield. Very similar slag-like residues have been found associated with almost all of these furnaces, and in at least three furnaces the residue has been found *in situ* within cementation chests, including those within the furnaces that were excavated at the north end of the Riverside Exchange site as part of the Sheffield ring-road project (Bell in prep).

At the time of writing, it is not clear whether the residue within the chests formed as an incidental by-product of the cementation process, or whether it was a material that had been deliberately applied to the inside of the chests by the furnacemen.

From contemporary accounts, and the author's experience of cementation steelmaking experiments, one of the most important objectives is to ensure that the cementation chests or vessels remain completely air-tight during the entire firing cycle. The archaeological evidence from several furnaces suggests that the stone chests were very susceptible to cracking; it therefore seems likely that the steelmakers would have looked for a way to prevent or repair cracks in the chests, particularly during the firing cycle. However, none of the contemporary descriptions of the operation of Sheffield furnaces mention the addition of a sealing layer being applied to the inside of the chests before loading (Barraclough 1984a, 42). Nevertheless, one potential scenario is that fire-clay was applied to the inner surfaces of the chests before they were loaded. Then, if the clay had not solidified before the chests were loaded, the weight of the iron and charcoal might have squeezed the clay into any cracks within the chest that had appeared after the previous firing; this would also explain why fragments of charcoal have been found embedded within the residue.

Discussion

At the time of the excavation at Riverside Exchange, it was commonly thought that the cementation process was non-slagging and offered little in the way of process specific archaeological residues. However, although cementation steelmaking was not a slagging process in the traditional sense, it does appear to have a quite distinctive and unique process residue associated with it, represented by slagged refractory material. Initial analysis suggests that the slag-like layer found on the inner surface of the cementation chests was probably the result of a reaction between alkalis in the charcoal ash and the clay or stone lining of the chests. Analysis of the more recently excavated refractory materials from the mid-17th-century cementation furnaces at Coalbrookdale suggests that they came from the roof of the chamber (Dungworth 2007).

Further research to fully characterise and, if possible, explain exactly how the residue was formed is being carried out by the author. All of the evidence so far suggests that the material is specific to the cementation process and, as such, it is a useful diagnostic process residue for corroborating the presence of cementation steelmaking.

Metallurgical Crucibles

The crucible assemblage from Riverside Exchange consists of approximately 1000 fragments of used metallurgical crucibles. The majority of fragments which comprise lids, rims, walls, bases and pedestals relate to 19th-century steelmaking, although a small number appear to have been used for the production of brass, bronze or copper objects.

The crucibles associated with non-ferrous metalworking are smaller and thinner than the steelmaking crucibles, with rim fragments around 5 mm thick. Preliminary refitting suggests that the crucibles were around 160 mm tall and 120 mm wide. Fragments from the bases have a more vitrified outer surface than those from the walls of the crucibles.

Post-excavation assessment identified a small but important group of fragments of early steelmaking crucibles, found in a context (16018) assigned to the late 18th century and interpreted as a dump of fragments against what would have been the outside wall of Marshall's steelworks during this period.

The fragments of steelmaking crucible recovered from context 16018 are the earliest of their type that have been found in the Britain. Thirteen are from crucible bases and 27 are from crucible walls. The fragments range in thickness; most wall fragments are around 18 mm thick, whilst base fragments are around 35 mm thick. Twenty pieces of fuel ash slag and fragments of crucible pedestals were also recovered from context 16018. The pedestals are made from biscuit-coloured coarse refractory clay.

Because of their significance, samples from fragments of two of the late 18th century steelmaking crucibles were analysed to identify their mineralogical and chemical composition.

The Petrographic and Chemical Analysis of Two Huntsman Steelmaking Crucibles

by M. Spataro and P. Craddock

Introduction

From the inception of the Huntsman process of steelmaking at Sheffield it was recognised that the composition of the crucibles themselves was a crucial component of the process. Hence the great interest in their composition and production and the secrecy surrounding this. The speculative, and often conflicting, reports made at the time on their likely composition were emphatically denied by Huntsman and his successors and have led to continuing uncertainty over the true composition of the crucibles (for example, Robsahm 1763, as reported in Barraclough 1984, 9 and Andersson 1769, reported in Pipping and Barraclough 1988). The success of the 'English' process of steelmaking was widely believed to be due to the addition of certain fluxes and their nature also raised much speculation (for example, Jars 1774, 257–8, reproduced in Barraclough 1984, 13).

Only from the mid-19th century are there good, reliable descriptions of the composition and methods of manufacture of the crucibles (Barraclough 1984, 33–42; Brearley 1933, 23–35). Frustratingly, in a city where millions must have been made and discarded and where many garden walls are built of used crucibles, until recently there was no crucible material available for scientific examination from a context earlier than the mid-19th century.

The two crucible fragments that are the subject of this report (Fig. 21; Pl. 22) come from a closely datable context (16018), a deposit which must be earlier than 1790, and can be attributed to the period in the late 18th century when the Millsands steelworks was operated by John Marshall. The petrology and analysis of the fragments establishes the nature of the crucibles and of the flux used.

Requirements of the crucibles

The challenges presented by the Huntsman process were very considerable. First there was the obvious requirement that the crucible contain the molten steel at temperatures between 1500–1600° C in the furnace for times in the region of four to five hours and that it still be strong enough to be lifted from the furnace containing many kilogrammes of molten steel and safely carried and tilted at the teeming mould. The crucible must also resist erosion from the steel itself and any slags present. Thus a thick walled crucible of well-levigated and highly refractory clay was essential.

In addition the reduction conditions were crucial. In the Huntsman process cementation steel was melted and the very narrow range of carbon content (typically from 0.5–1.5%) had to be preserved. If the

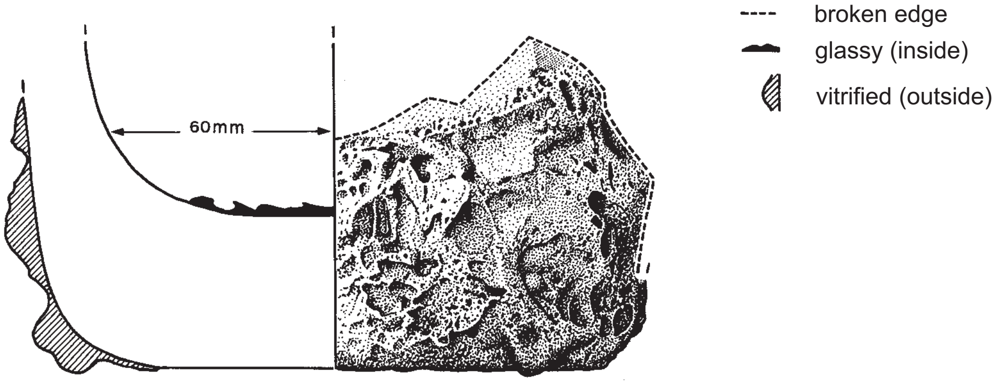


Figure 21 Base of late 18th-century Huntsman steelmaking crucible (from context 16018)

melting was attempted in a crucible just of refractory clay, such as the glassmakers used, there would be a danger that the steel would lose much of the carbon and become wrought iron. Conversely if the crucible conditions were too reducing, by tempering the clay with excess charcoal dust or organic matter for example, there was a danger of increasing the carbon content by as little as 1 or 2%, sufficient to turn the steel into ordinary cast iron. In the traditional South Asian steelmaking processes the crucibles were massively tempered with organic material (Freestone and Tite 1986). However, these processes were very different from the Huntsman process, either carburising wrought iron *in situ*, where a highly reducing atmosphere was essential, or by a co-fusion process where finely balanced quantities of cast iron and wrought iron were melted together to produce steel of the required carbon content.

Huntsman did not patent or publish any description of his process. This was partly because he was a Quaker and could not swear an oath, and also because he preferred to trust in secrecy. The eventual success of the crucible steel led to many enquiries as to the nature of the process, not least from the Swedes who were curious to find out what the English in Sheffield were doing with the Swedish iron that they were importing in ever increasing quantities. Their enquiries discovered much but they could get little certain information about the crucibles themselves. Only with the recent excavation of the crucible material from a sealed later 18th-century context has it been possible to directly investigate the nature of the early crucibles.

Plate 22 Base of late 18th-century Huntsman steelmaking crucible (from context 16018)

Methods

Samples (5371–1 and 5377–2) were cut from the fragments of two steelmaking crucibles with a diamond saw, cutting through the thickness of the crucible from inside to outside, thereby showing the complete structure. They were sent for polished thin sectioning. The polished thin sections were analysed using a Leica DMRX polarised light microscope for optical microscopy analysis and a Hitachi S-3700N variable pressure (VP) scanning electron microscope with energy dispersive X-ray spectrometry (SEM-EDX) for the study of the samples microstructure and their chemical composition.

Three bulk SEM-EDX analyses were carried out on each sample at 100x (*c.* 1.4 x 1.0 mm) (Tables 3 and 6), and spot analyses in different regions, using Oxford standards (Table 5). The SEM was used at a vacuum of 30 Pa with a 20 kV accelerating voltage; the samples were analysed uncoated at a 10 mm working distance. Thirteen elements (Fe, Al, Mn, Mg, Ti, Na, Si, K, Ca, P, S, Cu and Co) were quantified and the results were converted into oxide percentages. These percentages were normalised (oxygen by stoichiometry) to take into account the fact that oxygen and carbon are not measured (for more detail about the methods used, see Spataro 2014, 177–83). Three elemental composition maps were also run overnight (Pls 30–32).

One of the crucibles (5377–1) was also analysed by X-ray diffraction (XRD) with a STOE STADI MP.

Thin Section Petrographic Analysis

The two polished thin sections were analysed by optical microscopy. Both samples have a dark grey highly vitrified fabric, with abundant rounded voids left by the bloating pores (Pl. 23). The matrix is fine with a few inclusions (Pl. 24a). Sample 5377–1 includes abundant iron oxides and opaques, including some iron particles in the voids which could be due to secondary deposition of iron-rich compounds (Pl. 25a), and small amounts of shattered quartz grains (see also SEM Pl. 28a and b). Crystals of mullite, ($Al_6Si_2O_{13}$), are visible throughout the fabric (Pl. 24b; see also XRD results and SEM Pl. 26a). A fragment of sample 5377–1 was powdered and analysed by XRD, and the diffractogram confirms the presence of mullite. There are also some scattered graphite flakes and a spherical metal inclusion surrounded by corrosion products (Pl. 24d and EDX below). Sample 5377–2 is similar to the first fragment, but it is surrounded by a secondary deposit of iron-rich corrosion products very likely coming from the burial surroundings (Pl. 25b).

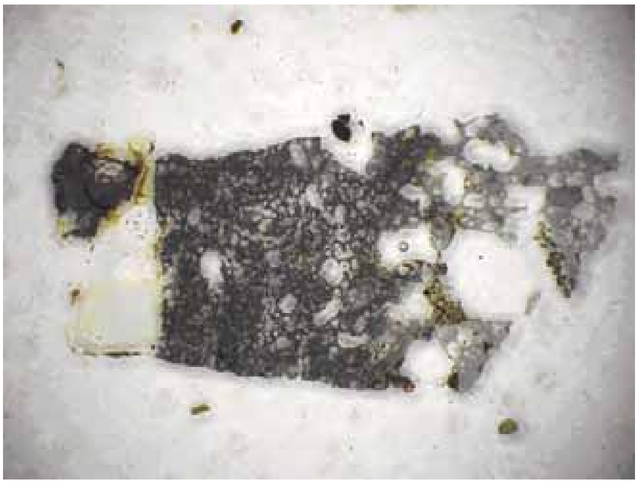


Plate 23 Crucible sample 5377–2: optical image of the thin section of one of the crucibles showing the solid core of the crucible (dark centre), the partly fused and bloated external surface (right side), and the glassy slag on an edge of the inner surface of the crucible. On the top left side a lump of corroded iron is visible (6x)

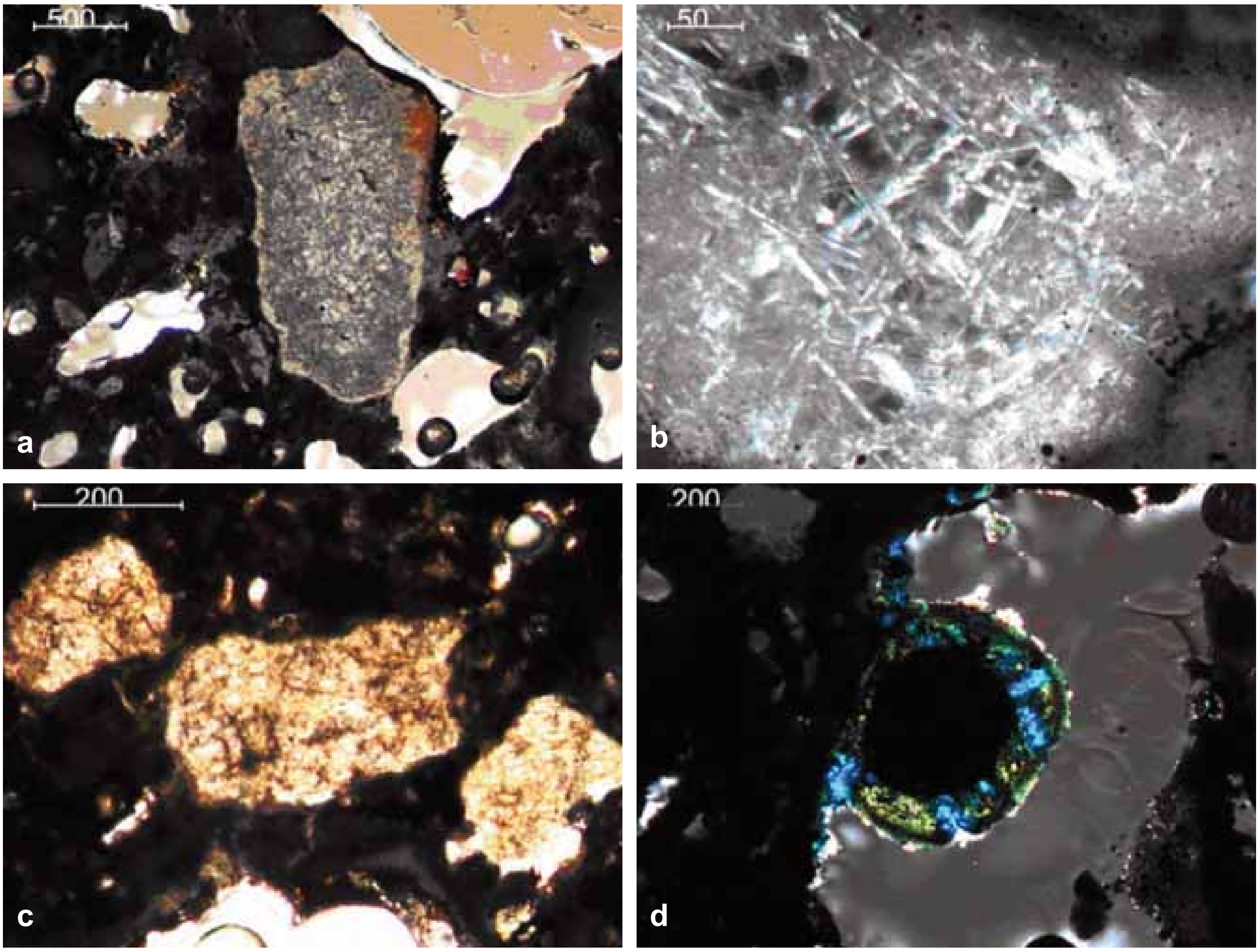


Plate 24 Photomicrographs of crucible sample 5377–1: a) fabric with bloated pores and coarse grain of shattered quartz; b) mullite crystals in the fabric; c) quartz grains in the paste (PPL); d) metal spheroid inclusion (copper corrosion product, see EDX). All micrographs were taken in cross polarised light (XPL, except for c) which was taken in plane polarised light (PPL)

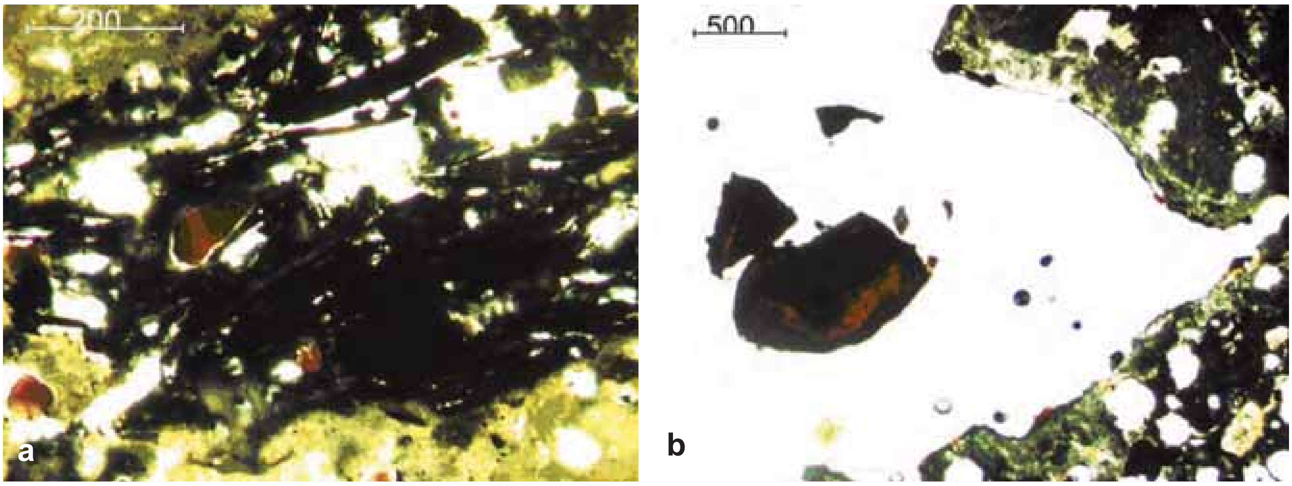


Plate 25 Photomicrographs of (a) crucible sample 5377–1 showing graphite (black lentoid) and iron-compounds (red) (PPL); b) crucible sample 5377–2 showing secondary deposition of iron-rich compounds (PPL)

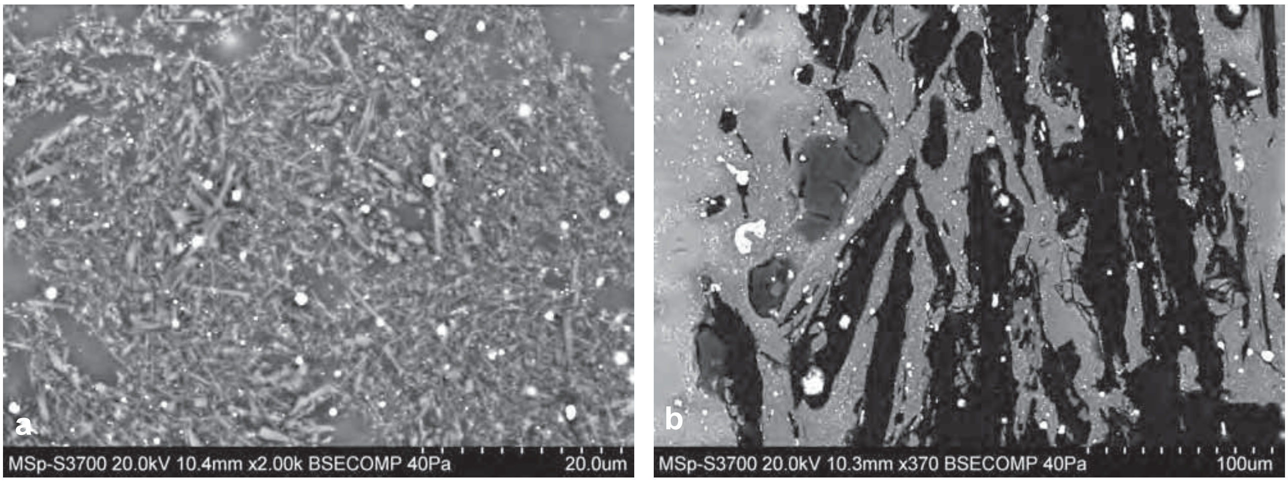


Plate 26 Crucible sample 5377–1: backscattered SEM images of the crucible fine fabric, showing (a) mullite crystals and metallic iron globules (white spots) and (b) graphite (black flakes) in the paste

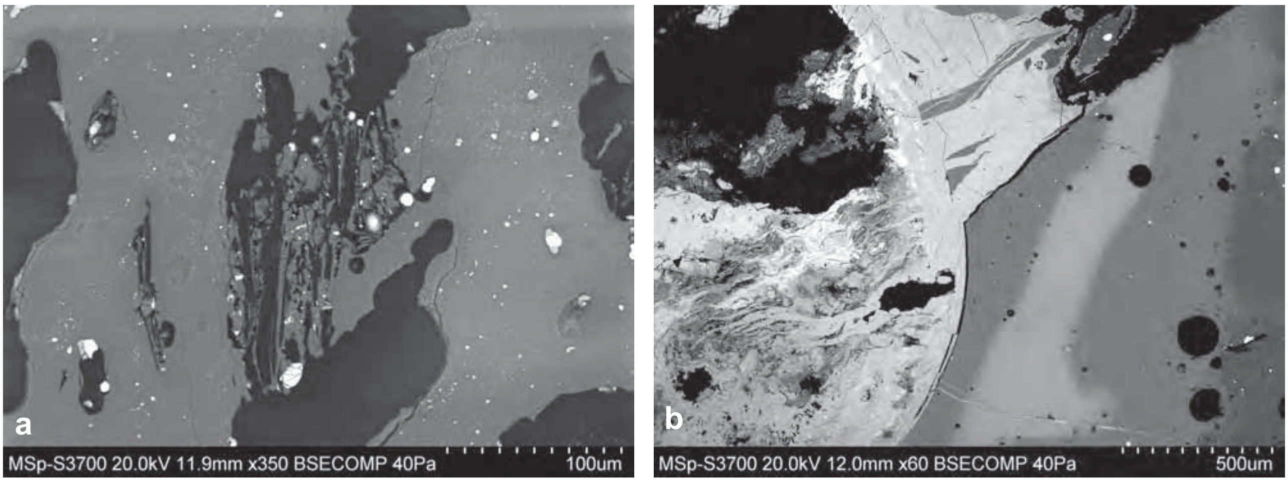


Plate 27 Crucible sample 5377–2: backscattered SEM images of (a) graphite (centre) and (b) corroded iron (left) adhering to the glassy phase

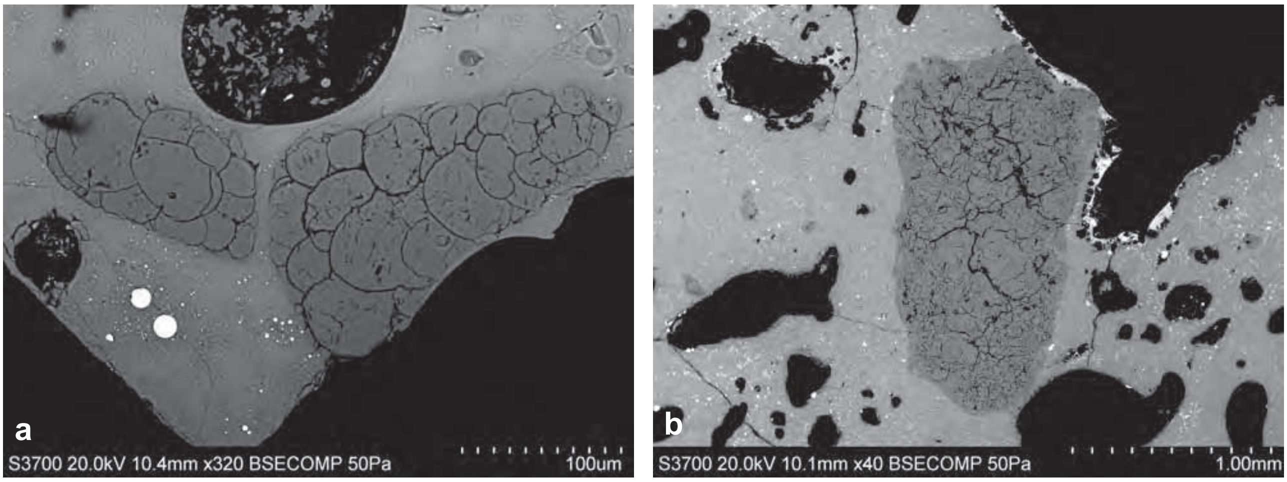


Plate 28 SEM images of crucible sample 5377–1 showing quartz grains shattered by the thermal stress; a) small size; b) very coarse inclusion

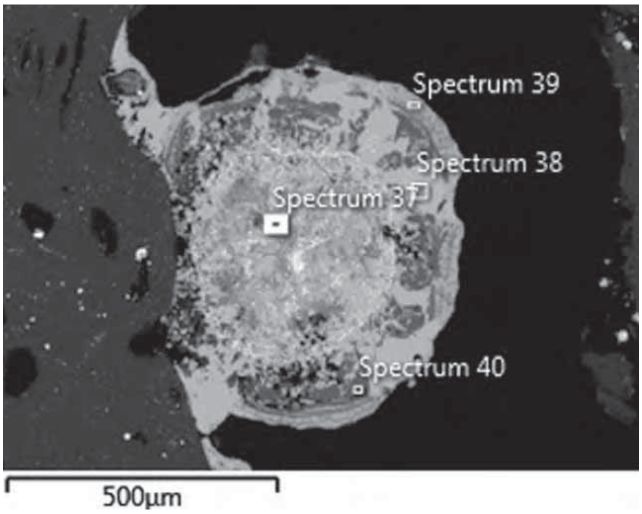


Plate 29 Crucible sample 5377–1. SEM image of spot analyses carried out on a copper-rich droplet (see Table 5)

Table 3 Compositional data from SEM-EDX analysis from the two 18th-century crucibles (mean of three bulk analyses at 100x). Results are reported as normalised oxides

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	FeO	CoO	CuO
5377-1	0.4	0.4	22.6	72.5	0.0	0.1	1.2	0.4	1.2	0.0	1.0	0.0	0.0
s.d.	0.1	0.2	7.3	8.6	0.0	0.1	0.3	0.2	0.1	0.0	0.4	0.1	0.1
5377-2	0.4	0.6	28.1	66.5	0.0	0.1	1.4	0.5	1.1	0.0	1.1	0.0	0.0
s.d.	0.1	0.1	2.8	2.1	0.0	0.1	0.1	0.1	0.2	0.1	0.5	0.0	0.1

Table 4 SEM-EDX results of a 19th-century Huntsman crucible (Freestone and Tite 1986, table IV)

Huntsman crucible	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_2	K_2O	CaO	TiO_2	FeO	Cl
Bulk	-	0.6	37.9	55.6	-	0.5	1.4	0.4	0.9	1.8	0.2
Matrix	-	0.8	37.4	57.1	-	-	1.7	0.3	0.6	1.0	0.2

SEM-EDX Microscopy and Analysis

The two polished thin sections were analysed by SEM-EDX to identify the different phases, such as the surface slag, crucible paste and metallic features. SEM images show the highly-vitrified fabrics with mullite crystals with metallic iron globules scattered through the fabric (eg, Pls 26, 27 and 28), added graphite (Pls 26b and 27a) and shattered quartz (Pl. 28a and b).

Three bulk analyses were carried out on each sample at x100 (each giving sample areas of *c.* 1.5×1.1 mm; Table 3). Both crucible fabrics contain mainly alumina and silica (glassy phase and mullite), with some potash, titanium and iron oxides. Most of the oxide concentrations are similar, except for alumina and silica, which have slightly different concentrations in the two crucibles. If these values are compared with those from a 19th century Huntsman crucible analysed by Freestone and Tite (1986; table IV), it can be seen that the 18th century samples contain more silica and slightly more titania, and less alumina and iron. In addition, the 19th century crucible fabrics contained coke and not graphite.

The fabric of sample 5377–1 includes localised traces of copper and tin, a particle of which is visible in optical microscopy (Pl. 24d, Pl. 29 and Table 5). Zinc and lead were also sought but were not detected. Elemental mapping of sample 5377–2 also detected a small concentration of copper and tin (Pl. 31c and j). Thus it seems that small particles of bronze became incorporated during the mixing of the clays for the two crucibles.

Sample 5377–2 has a glassy phase on the surface, probably related to its use, which was also analysed (Table 6; Pl. 23 on the left and Pl. 32g). The glassy region is very rich in manganese and iron oxides, richer in magnesia and calcium oxide, and poorer in silica than the paste of the crucible (see Tables 3 and 6).

Elemental Composition Maps

Three compositional maps of both samples were produced over about 15 hours to identify the elemental distribution (Pls 30–32).

Table 5 Crucible sample 5377–1: spot analyses of corroded copper deposit. Results are reported as normalised oxides

	spot 37	spot 38	spot 39	spot 40
Na_2O	0.0	0.0	0.0	0.0
MgO	1.9	0.7	4.7	2.9
Al_2O_3	1.9	2.2	2.4	1.8
SiO_2	27.9	6.2	11.6	47.3
P_2O_5	1.4	0.5	0.6	0.6
SO_3	0.8	0.4	1.1	0.6
K_2O	0.4	0.2	0.2	0.5
CaO	0.8	1.4	0.9	0.6
TiO_2	0.2	0.0	0.2	0.4
MnO	0.0	0.0	0.2	0.0
FeO	5.9	0.8	0.7	4.8
CuO	47.1	87.2	76.7	37.6
SnO_2	11.5	0.4	0.3	2.2
Sb_2O_3	0.0	0.0	0.0	0.5

Plates 30a–d show the fabric of sample 5377–1, rich in aluminium and silicon (mullite and glassy phase or vitrified paste) and some graphite (see Pl. 30d).

Two elemental composition maps were carried out for sample 5377–2: the first focusing on the paste (Pl. 31a–j), the second on the glassy region and the rest of the fabric (Pl. 32a–h).

In Plate 31 the fabric of sample 5377–2 is rich in aluminium and silicon (Pl. 31a and b; mullite and glassy phase), the iron droplets are clearly visible and do not overlap with titanium (Pl. 31d and e). Interestingly, copper and tin seem to be concentrated in a small area (Pl. 31c and j), but also manganese (Pl. 31h), and sulphur (Pl. 31i).

In sample 5377–2, the surface glassy phase (Pl. 32a on the left, lighter area) is rich in calcium, manganese and potassium, and lower in aluminium and silicon content than the body (Pl. 32b–e and g). The body (Pl. 32a on the right, darker area) is rich in aluminium and silicon and contains quartz grains (Pl. 32d and e) and scattered tiny iron and titanium-rich particles which are usually not associated (Pl. 32f and h).

Table 6 Glassy phase on the inner surface of crucible sample 5377–2. Two areas were analysed showing a lighter (spot 5) area richer in iron and a darker region (spot 4) richer in soda, alumina, silica, potash and calcium. Results are reported as normalised oxides

5377-2 glassy layer	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	FeO	CoO	BaO
Spot 4	1.0	1.6	22.6.	53.2	4.0	3.1	1.0	7.6	5.4	0.0	0.5
Spot 5	0.4	1.1	17.9	40.3	1.6	2.2	1.0	7.6	27.4	0.2	0.2

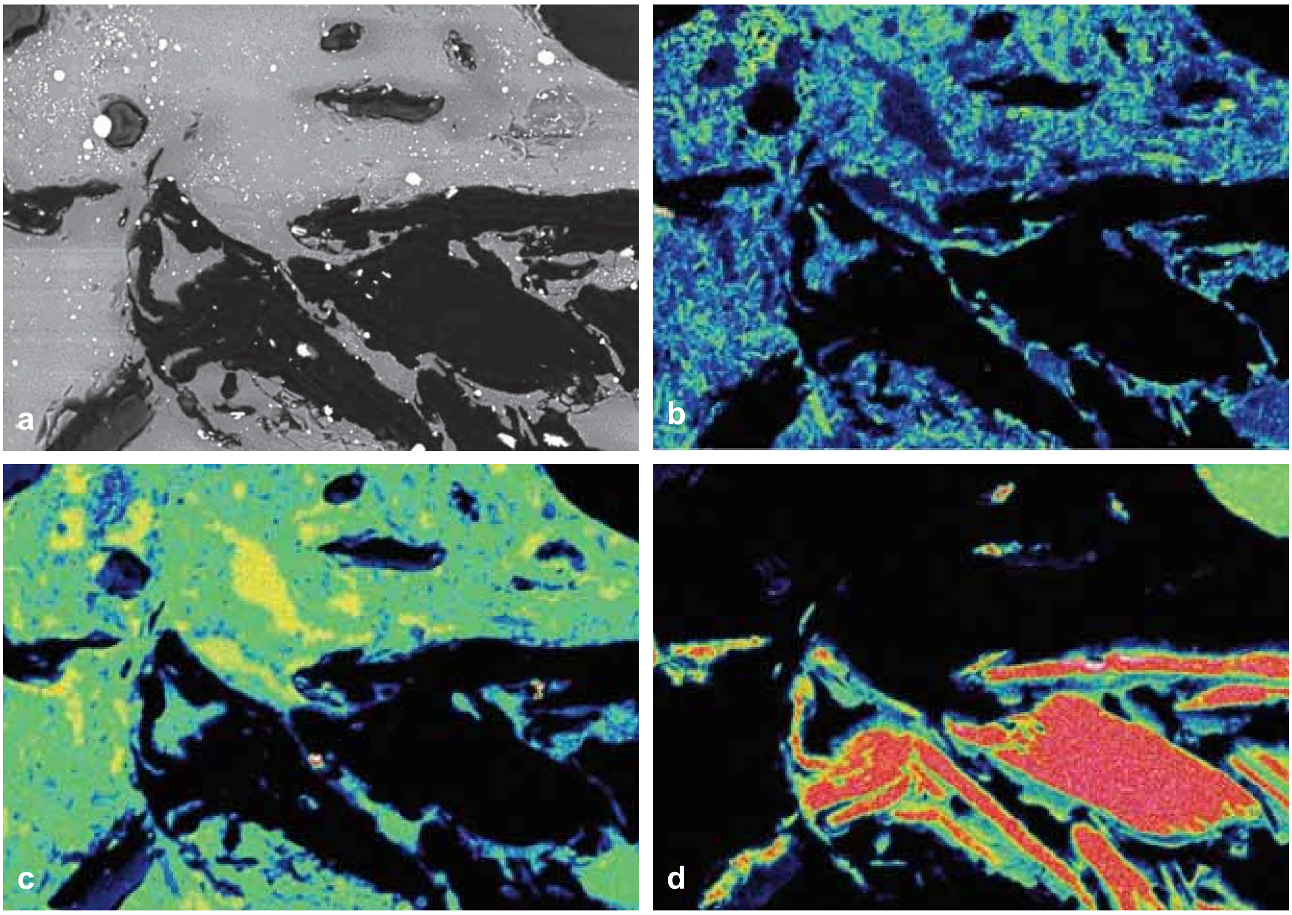


Plate 30 Elemental maps of crucible sample 5377–1: a) mapped area (0.35 x 0.25 mm) showing a fine matrix with graphite flakes; b) the elemental map for aluminium, which is abundant in the paste, except where the graphite flakes are; c) the elemental map for silicon, very abundant element in the paste; d) the elemental map for carbon concentrating where the graphite fragments are

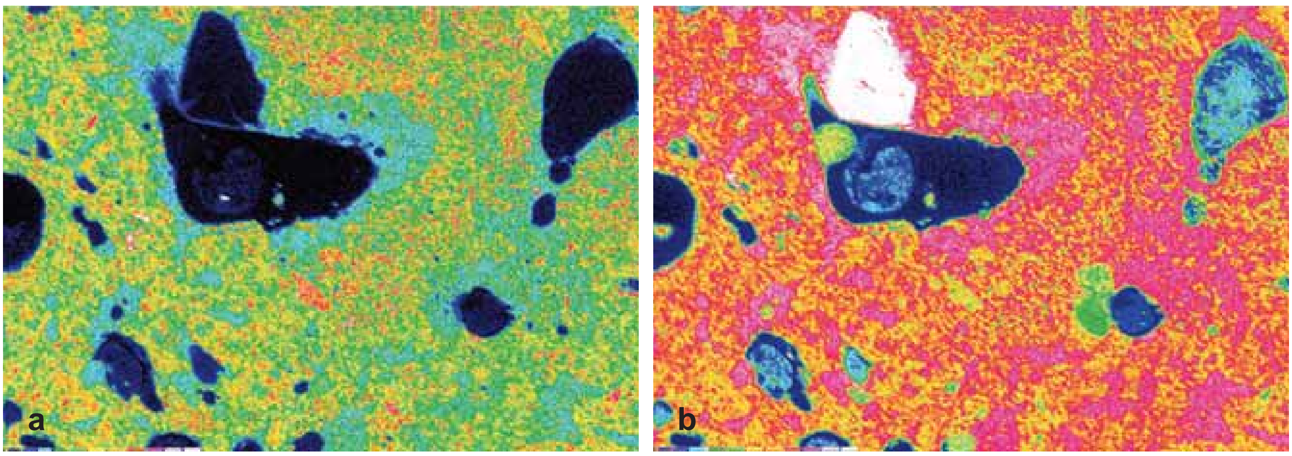
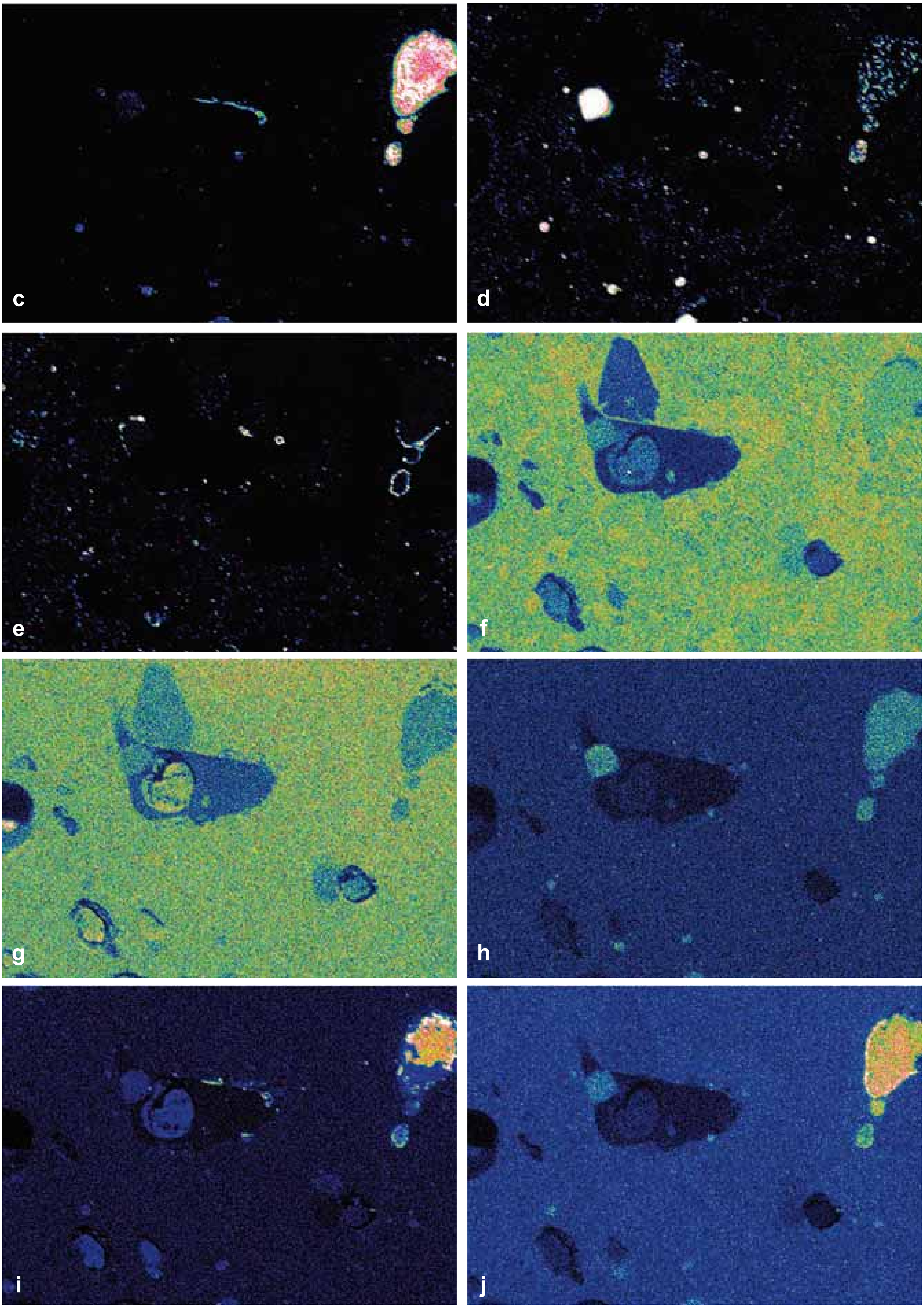


Plate 31 Elemental maps of crucible sample 5377–2: a and b) (above) showing the elemental composition of aluminium and silicon, largely present throughout the fabric of the crucible; (next page) c) the elemental map for copper, concentrated in one spot with tin (see map j); d and e) the elemental maps for iron and titanium, which do not overlap; f and g) the elemental maps for potassium and magnesium evenly distributed in the paste; h) the elemental map for manganese, which is concentrated in specific spots; i) the elemental map for sulphur, which is associated with copper; j) the elemental map for tin associated with copper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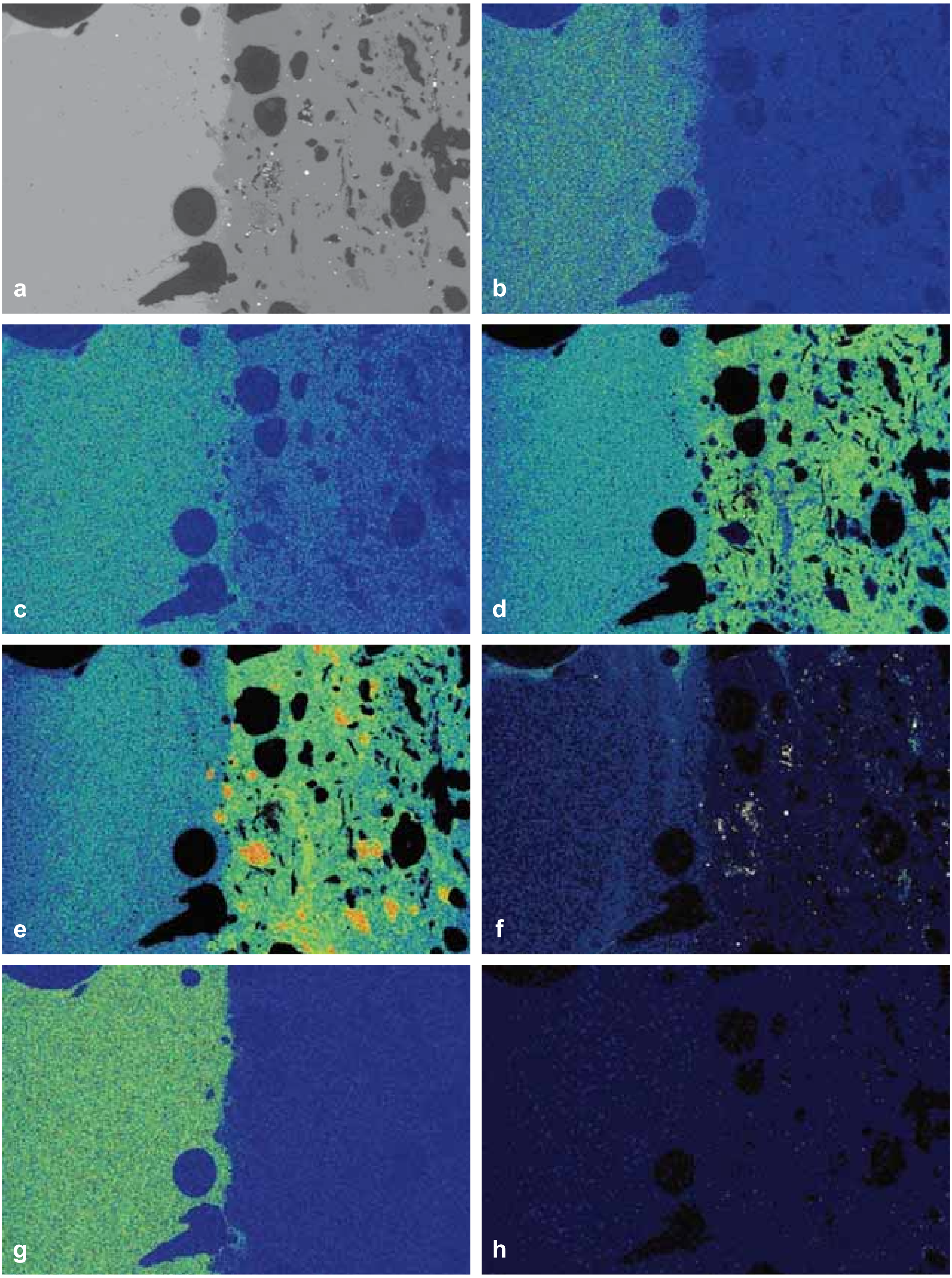

Plate 32 Elemental maps of crucible sample 5377–2: (a) mapped area showing on the left the glassy phase and the fabric on the right; b and c) the elemental maps for calcium and potash showing their concentration in the glassy phase; d and e) the elemental maps for alumina and silica which concentrate in the paste; f) the elemental map for iron, showing some droplets; g) the elemental map for manganese present only in the glassy area; h) the elemental map for titanium which does not overlap with iron (f)

Discussion and Conclusion

In summary, the Huntsman 18th century crucibles are refractory ceramics containing high proportions of mullite fibres in a vitrified matrix (see also Freestone and Tite 1986, 55), and tempered with graphite. The presence of manganese in the slagged layer in one of the crucibles suggests the addition of a manganese dioxide flux to the charge.

The crucibles were made from a refractory clay, possibly the original Stourbridge clay, favoured by the glassmakers, but quite likely containing similar clays from one of the local sources such as Bolsterstone or Stannington. The composition of such clays was already well understood in the 18th century. Thus in 1793 a French report on the production of crucible steel stated that 'the crucibles themselves are made from specially selected clays, which are pure mixtures of silica and alumina, free from lime and magnesia.' (quoted in Barraclough 1984, 33).

The clays of the Millsands' crucibles were tempered with between 10 and 20% of graphite by volume. Huntsman was adamant that his crucibles were just of suitable refractory clays, and Benct Andersson who visited Huntsman in the 1760s and then went on establish his own works back in Sweden, described the whole process in a detailed paper written in 1769, and stated that the crucibles were just to be made of Stourbridge clay (Pipping and Barraclough 1988). However, other of Huntsman's Swedish visitors were convinced that graphite was also present, probably contained in a temper of crushed goldsmith's crucibles which would themselves have contained graphite. Certainly there do seem to be reports of graphite-tempered crucibles being sent from 'Ypse' to Sheffield. Barraclough (1984, 11) believed this was likely to have been Ybb in Austria where graphite-containing crucibles certainly were made. Other production centres such as Obernzell in Bavaria are also possibilities. These crucibles had variable graphite contents from 20–70%, but usually in excess of 40% by volume (Martinón-Torres and Rehren 2009). However the Millsands' crucibles have no evidence of crushed ceramic grog material. It should be pointed out that Sheffield was also an important centre for silver production, especially of Sheffield plate, and precious metal refiners who would also have required specialist crucibles were already operating in the city (Wilson 1960). The possible sources of graphite for the steel-melting crucibles are not otherwise mentioned in the literature, but the Borrowdale deposits in Cumbria were being worked through the 18th and early 19th centuries and would seem a more likely source than central Europe.

As previously mentioned above there are no early accounts of the preparation and mixing of the clays and their temper or of the actual manufacture and firing of the crucibles. Huntsman is reported to have specifically refused to let some Swedish visitors see how the crucibles were made '.. not even if we had offered him £50.', although he was happy to show them the rest of the works (Barraclough 1984, 9).

Good descriptions do exist from the latter part of the 19th and early 20th centuries, amongst the best being that of Harry Brearley (1933, 23–35). The mixture of selected clays and temper (by then coke dust, known as breeze, had almost universally replaced graphite) were thoroughly kneaded, often spread out on a floor and treaded with bare feet for four or five hours to remove any remaining hard particles, homogenise the clays and squeeze out any entrapped air. It is known that from the 18th century on the crucibles were moulded in cast iron flasks. The Millsands' crucibles appear to have been moulded rather than thrown, and when John Marshall was operating the works in the 1770s they were reported as having a capacity of between 19 and 22lb of steel (Barraclough 1984, 41). The crucibles were carefully dried over a number of days, then stacked above the steel-melting furnaces for two to three weeks for further drying before finally being fired in a kiln to 'a good red heat' (see Fig. 25). Thus just prior to use the crucibles would have been a good stoneware, but only when the charged crucible was lowered into the steel-making furnace would the mullite begin to form at temperatures of between 1300°–1400° C. It probably formed out of the molten feldspar sand which was originally part of the paste (see Freestone and Tite 1986, 53) or other minerals (eg, decomposition of kaolinite) in the manufacturing process of the crucible. Mullite ($Al_6Si_2O_{13}$) is an almost ideal material for the crucibles (Martinón-Torres *et al.* 2008; Martinón-Torres and Rehren 2009). Not only does it have a very high melting point in excess of 1800° C, but it has a low thermal expansion, which confers resistance to thermal shock, a high creep resistance, as well as a strong resistance to chemical erosion at high temperature (Duval *et al.* 2008).

The role of the graphite was also important. As the unfired clays were quite plastic the body would need some more rigid filler. In crucibles where graphite or coke dust was not added then either a quantity of pre-fired clay or crushed used crucible were added as grog. In the 19th century, when both graphite and coke-tempered crucibles were used, it was clear that the graphite tempered crucibles lasted considerably longer (approximately 10 re-uses, compared to only two or three re-uses for the coke-tempered crucibles), and that heat transfer through the crucible was much quicker (Brearley 1933, 32). This was actually a problem for although the melting process proceeded a little faster, on removing the crucible from the furnace it cooled down more quickly. Brearley noted that if the molten steel was not to be poured immediately from a graphite-tempered crucible then it would be transferred to an ordinary crucible to conserve the heat. Searle (1940) stated that carbon "improves the heat resistance, reduces the tendency of the contents to oxidise, enables heat to pass more readily into the interior of the crucible, improves resistance to sudden changes in temperature so much that plumbago (graphite) crucibles may be subjected to very sudden changes without cracking and may be used repeatedly". More recently, Martinón-Torres and Rehren (2009, 61) also noted that the graphite in the dark crucibles from Bavaria (which contain up to 70% graphite) was a heat conductor and "being extremely stable at high temperatures, graphite would have contributed to the vessels' thermal refractoriness".

In the wall of the crucible the graphite flakes, if added as a mineral rather than as grog, tended to orientate parallel with the faces of the crucible and thus any heat crack developing in the clay from the inner face would be likely to run into a flake and stop. As graphite is much more resistant to oxidation than the alternatives, coke or charcoal, it would be present in the crucible for much longer (contributing to their greater life). It also seems that the slow oxidation at high temperature did contribute to the overall reducing conditions in the crucible and thus to the preservation and even increase of the overall carbon content of the steel (Barraclough 1984, table 1, 54).

As already noted in the introduction there was considerable debate and contradiction as to the composition of Benjamin Huntman's crucibles. There were varying claims that old crucibles used by goldsmiths (and which would have contained graphite) were used as grog, or that new crucibles were being sent to Sheffield from Holland, assumed also to be ground up and used as grog (Barraclough, 1984, 10). Huntsman's son William, who was also concerned in the business, denied this but did wish for a few tons of the clay from which the Dutch crucibles were made, and this has also been interpreted as a clue that they were importing crucibles. However, could he instead have been referring to the graphite-rich clays mined in Austria and Bavaria, used to make crucibles which were traded very widely including from Dutch ports to Britain? The export of these graphite-rich clays themselves was forbidden, hence it really would have been something that the Huntsmans could only wish for!

Benjamin Huntsman himself was after all a clock maker by training. When he started his experiments he would have had little experience of refractory materials and it is natural that he would investigate the properties of the gold refiner's crucibles that would have been used by the Sheffield precious metal refiners, some of which are likely to have contained graphite. Experimenting with mixing the ground up crucibles with Stourbridge and other refractory local clays, used by the glassmakers, would eventually have brought success. This would obviously have been a very expensive form of graphite and whilst Huntsman and probably some other steelmakers initially used ground up crucibles as their source of graphite, others such as John Marshall at Millsands were experimenting with adding mineral graphite to the clays. At just this time the crucible makers of Obernzell also changed from using natural graphitic clays to a synthetic mixture of mineral graphite and refractory clay (Martinón-Torres and Rehren 2009). The obvious source of graphite for Sheffield was from the deposits at Borrowdale in Cumbria. However, apparently none of the Sheffield sources mention Borrowdale and none of the Borrowdale sources mention Sheffield or crucible steel as the destination of their graphite.

Latterly coke-breeze very largely replaced graphite in the Sheffield crucibles. As the melting furnaces were always fired by coke it was an obvious and very much cheaper material. Possibly its greater reactivity meant that it burnt out too quickly from the inner surfaces, and the sulphur content of the coke could have made the early crucible steel makers wary of exposing their molten steel to such a dangerous element; note the 0.5% sulphur present in the body of the 19th-century coke-breeze crucible (Table 4). However these problems were resolved by the early 19th century at the latest, as Rees in the 5th volume of his *Cyclopaedia* (the parts issued in 1819–1820, Cossons 1972, 158) stated that the crucibles were made of Stourbridge clay and coke dust with no mention of graphite.

The Flux

As already noted many early foreign commentators believed that the success of the English steelmakers was in large part due to the secret fluxes that they added. It is possible that the steelmakers themselves also believed this, although in fact the real reason for their success was the purity of the Swedish iron that the Sheffield steelmakers always used (Barraclough 1984, 46, 65–6). Indeed some later writers, such as Barraclough, were sceptical as to whether anything other than the cementation steel was added to the crucible in the early days of the process, and that talk of nostrums and fluxes just served to throw the competition off the scent. However the discovery of large quantities of manganese in the slag layer on one of the Millsands' crucibles is significant and can only have arisen by deliberate addition of manganese dioxide.

Over half a century later in 1839, Josiah Heath patented his famous 'carburet of manganese' which was also claimed to contain oxide of manganese and tarry materials, although its function was very different from than that of the 18th century fluxes (Percy 1864, 840–7; Barraclough 1984, 59–61). In the preparation process it is likely that some of the manganese dioxide was reduced to metal and this was the effective agent in the carburet, although neither Heath nor his rivals seem to have realised this (Barraclough 1984, 59–63). The manganese could react directly with the other elements in the steel, particularly the sulphur and was thus much more effective than the oxide. The discovery of manganese in the Millsands' slags demonstrates that experimentation with manganese salts had been in progress for many years before.

The potential benefits that the steelmakers, back in the 18th century, thought addition of the flux would confer on their steel are not certain. The actual part played by the manganese dioxide in the process would almost certainly have been connected with the overall redox conditions and the removal of remaining oxides in the steel. The charge of cementation steel in the crucible inevitably still contained some slags from the original production of the iron. These would be principally of wustite (FeO) and fayalite ($FeO.SiO_2$). Some would have been reduced in the cementation process but some would remain. Whilst molten more of these oxides would be reduced to metal by the carbon in the steel, creating carbon monoxide gas which would rise though the metal and burn off at the top. However this process was quite slow and might well not be complete when the steel was removed from the furnace and poured into the teeming mould. Then the forming gas bubbles could not escape through the setting metal but were entrapped, a phenomenon known as honeycombing, which effectively ruined the ingot. Thus the steel had to be kept molten for a considerable time to ensure that all the iron oxides had been reduced, a process known as killing. This was clearly expensive and in the 19th century experiments showed that additions of manganese dioxide speeded up the killing process considerably. The reasons for this are obscure. Manganese oxide by itself is a stable oxide and unlikely to reduce the iron oxide levels in the metal directly. The most obvious reaction is with the clay of the crucible wall, forming the observed manganese silicate slag. This would have the effect of exposing some of the graphite from the wall of the crucible to the surface of the melt, increasing the local reducing conditions there, reducing the iron oxides which would also tend to concentrate on the surface of the melt.

Also the molten manganese silicate slag layer would be more stable than the comparable iron silicate slag and form a better protective layer over the molten steel further protecting it from oxidation from the atmosphere. Andersson, in the 1760s, recommended the addition of crushed glass to the crucible charge to protect the steel from oxidation (Pipping and Barraclough 1988).

Thus it is possible that the manganese was added as a protection against honeycombing of the ingot, but without any real understanding of the process at a time when the English steelmakers still had not fully accepted that it was the carbon content that determined whether the iron was wrought iron, steel or cast iron.

Overall the Millsands' crucibles document the early developments in the late 18th century of the crucible process from its inception almost half a century previously, already incorporating manganese oxide fluxing, but before the introduction of coke-breeze tempers.

Chapter 4
Discussion

The Development and Use of Waterpower

The History of the Goits

Sheffield developed as a major industrial centre in the location it did primarily because of waterpower. Although other necessary resources for steel and cutlery production, notably iron ore, coal, sandstone for grinding wheels and ganister for lining furnaces were all available locally, it was the plentiful supply of water which provided the power required to drive the grinding wheels of the cutlers and edge-tool manufacturers, tilt hammers and rolling mills, as well as corn mills and, later, textile mills. The Don, the Sheaf and the many tributaries of these rivers descended relatively steeply in the area around Sheffield and this made them ideal for driving waterwheels. This aspect of Sheffield's history has been extensively researched and is the subject of a comprehensive publication (Ball *et al.* 2006), and a plan showing the concentration of waterwheels in and around Sheffield at the beginning of the 19th century (Fig. 22) amply illustrates the use of waterpower at this time.

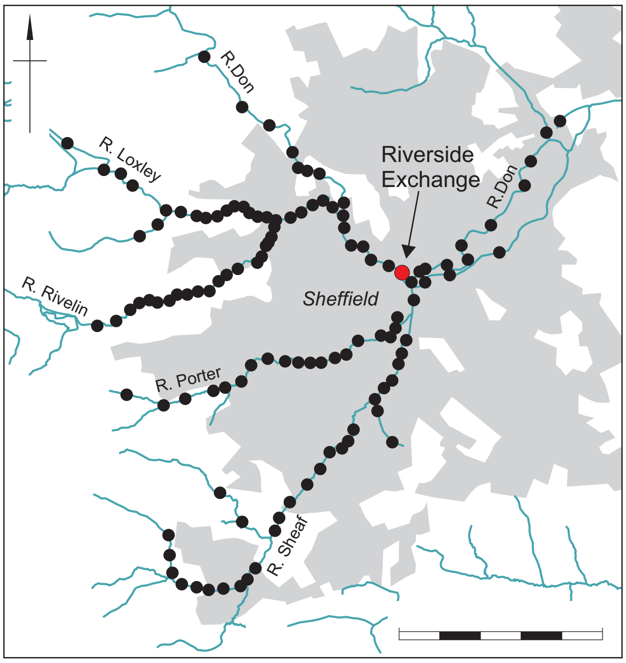

Figure 22 Plan showing location of waterwheels on rivers in and around Sheffield (after Ball et al. *2006, fig. 1)*

The development of the goits – artificial, sometimes modified natural watercourses – was part of the evolution of the harnessing of waterpower. These channels allowed further control and exploitation of the available supply of water, particularly within what became the built-up area of Sheffield itself. The Town Mill or Millsands goit may have been the earliest of these channels and provided power to the medieval Town Mill at Millsands, within the Riverside Exchange site (see Fig. 3). The canalised, perhaps largely artificial watercourse was diverted from the Don upstream of Kelham Island and ran approximately parallel to the river before rejoining it a kilometre or so downstream at Lady's Bridge. Later, a further goit was built which took water from the opposite, east side of the Don by Lady's Bridge, cutting off a southern loop in the river and providing power to the Wicker Wheel, recorded from the 16th century, and to the Wicker tilts (hammers) from the middle of the 18th century (Ball *et al.* 2006, 27–8).

Within the goits were dams and weirs used to control the flow of water, and there was a Town Mill dam within the goit just upstream of the Town Mill and Cutlers' Wheel at Riverside Exchange (see Fig. 4, inset). The goit here was approximately 20 m wide, but elsewhere was generally nearer 10 m across. The goits required maintenance and consolidation and there are records of improvements to the channels, forebays and wheel pits using newly quarried stone (Ball *et al.* 2006, 24), though timber is likely to have been extensively used, particularly early on. The 17th century probably saw the greatest period of development and use of the goits, but from the 1780s onwards and throughout the 19th century steam power came to supplant waterpower as the main source of power for the mills and 'wheels', leading to the gradual obsolescence of the goits. Eventually many of the goits were culverted and built over, and the flow of water in them much reduced as maintenance was no longer undertaken and they silted up.

In and around Sheffield the utilisation of waterpower continued into the early 20th century, though on a very small scale and in only a few locations, at nowhere near the level it had been a century or more before. For example, in 1794 there had been three steam-powered and 83 water-powered wheels in the Sheffield area, but by 1908 there were

300 powered by steam and only eight still powered by water (Linton 1956, 160). The introduction of steam power meant that industries were no longer tied to a location on a goit, stream or river and, perhaps more importantly, their operation was no longer governed by any fluctuations in flow. Such fluctuations might result from seasonal changes which, during a dry period, reduced the flow of water and thereby also the volume that could be stored in reservoirs. At the other extreme, excessive rainfall and the occasional failure of dams, for example that which occurred so catastrophically in 1864, could not only interrupt the supply of water but, as in 1864 at Riverside Exchange, inundate works and factories, causing considerable damage and temporarily halting production (Scott 1962, 11). There was also a problem with the increasingly large number of workshops and factories drawing water from the available supply, and in the case of the Town Mill there was a bye-law against diverting the water from the goit for other uses that might restrict the mill's operation.

Mills and Milling

Riverside Exchange is the site of the medieval Town Mill, which operated there in successive forms until the first half of the 20th century, over a period of 800 years. The excavations revealed nothing of the early mill used for grinding the flour of the Manor, but documentary sources have provided some information on its medieval and post-medieval history (Ball *et al.* 2006, 24–6).

Corn mills were only one, early element of the use of waterpower in and around Sheffield. There were, in addition, fulling and textile mills, whilst water was also essential for other local trades and industries which, at Riverside Exchange, included tanning.

However, it was cutlery making that was the major post-medieval industry that developed and took advantage of the ready supply of waterpower, using it to power tilt hammers and grinding wheels. At one time it was estimated that there was one cutlers' mill every 450 yards over 30 miles of rivers and streams, and there was room for no more. In the Sheffield area 'wheels' are recorded on 36 sites in 1700 and this had risen to 97 by 1800, when there were 1029 grinding troughs (Beauchamp 2002, 53–4).

Later, in the 19th century, more substantial machinery was also powered by water, including the Naylor Vickers rolling mill at Millsands. However, the advantages offered by steam power led to the move away from dependence on water of a number of industries and the eventual removal of the water wheels, as happened at the Town Mill, Cutlers' Wheel and the Naylor Vickers rolling mill at Riverside Exchange.

Cutlers and Knife Production

The beginnings of the cutlery industry in Sheffield can probably be sought in the 12th century. *Robertus le Cotelere* is the first documented cutler in the town, recorded in 1297 (Hey 2005, 91), and Sheffield subsequently developed as a medieval industrial centre renowned for the manufacture of knives. It was well-placed in having easy access to iron ore and locally produced iron, coal (for fuel), sandstone (for grindstones), waterpower (for grinding) and, initially, imported steel, with locally produced cementation and crucible steel replacing this during the course of the 18th century (*ibid.*, 93). Nevertheless, throughout the medieval and early post-medieval periods London continued to be the most important cutlery production centre in England, both in terms of quantity and quality, until superseded by Sheffield in the mid-18th century (Symonds 2002, 1–2). Cutlers' marks began to appear on Sheffield blades from *c.* 1560 and the Company of Cutlers was established in Hallamshire in 1624, although by the late 18th century unions and trades societies were becoming more important in the organisation and control of the trade (Unwin 2002, 15–17). The social structure and working practices of the local population also contributed to the expansion and success of the cutlery industry in Sheffield, characterised by a large number of small workshops, and by the mid-17th century 60% of men in Sheffield were involved in cutlery making (Wray *et al.* 2001, 6).

In the medieval period cutlers used locally produced iron, but steel was imported from Sweden, Germany and Spain, being superior to that then available in England (Hey 2005, 91–2). The cementation process, as far as is known, was developed in central Europe in the second half of the 16th century, and the product became known in England as 'German steel', because it was generally imported through there, though this came to be used as a generic term for cementation steel in the later 17th century (*ibid.*, 92). By the mid-17th century sufficient steel was being made in the vicinity of Sheffield to meet local demands for the town's growing cutlery industry, and by the second half of the 18th century Sheffield was famous for the quantity and quality of steel that was being produced by the cementation process, supplemented and later superseded by the production of crucible steel (*ibid.*, 93–4).

Steel was produced with a range of carbon contents to suit different requirements, and accordingly varied in hardness, brittleness etc. Shear steel was used for cutlery, and was hand forged to form knife blades, sometimes 'sandwiched' between layers of iron or with a steel cutting edge added to an iron back (Unwin 2002, 25–6). The blade was created

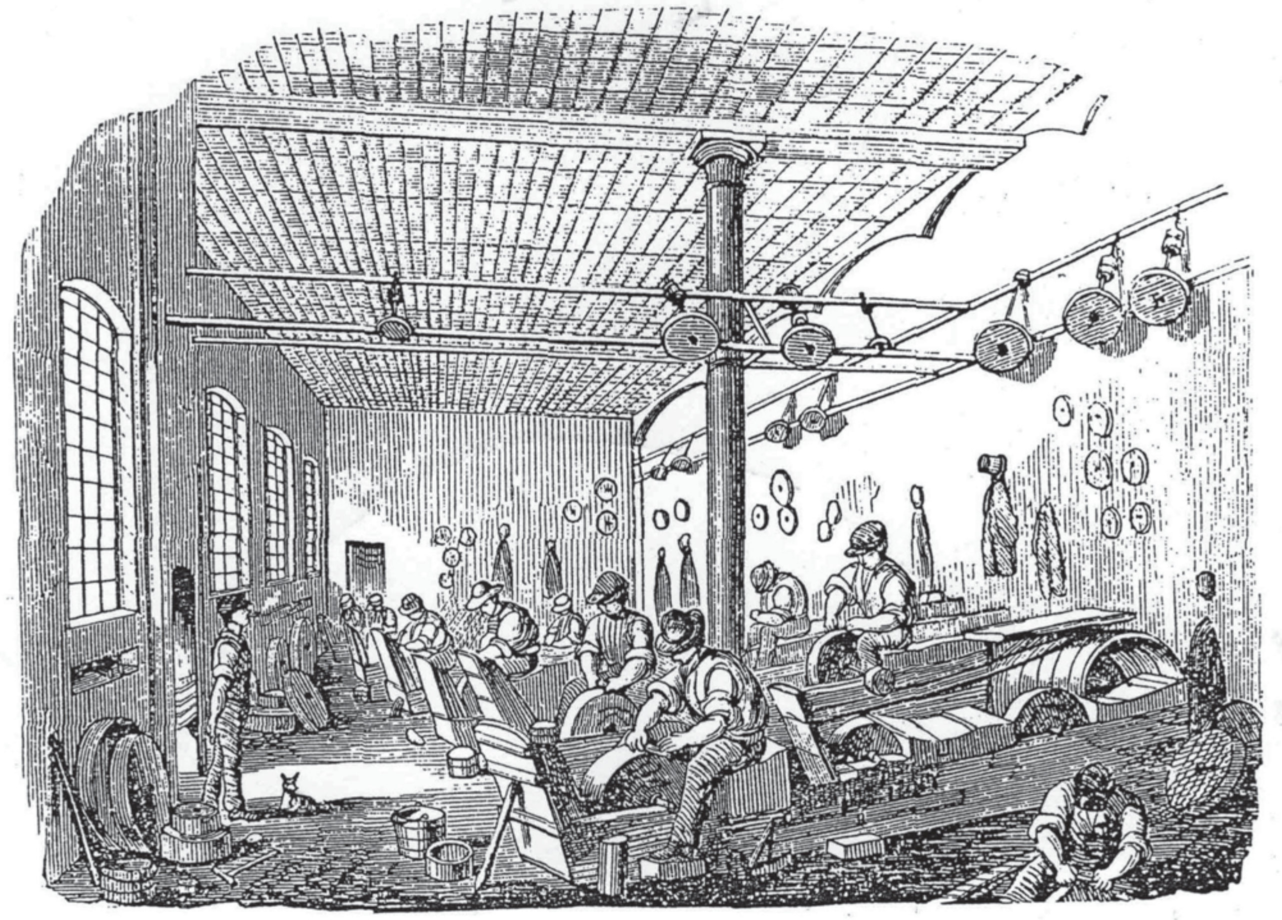

Plate 33 Contemporary view of interior of grinding hull (reproduced from Taylor 1879, with permission from Sheffield City Council, Libraries Archives and Information: Sheffield Archives)

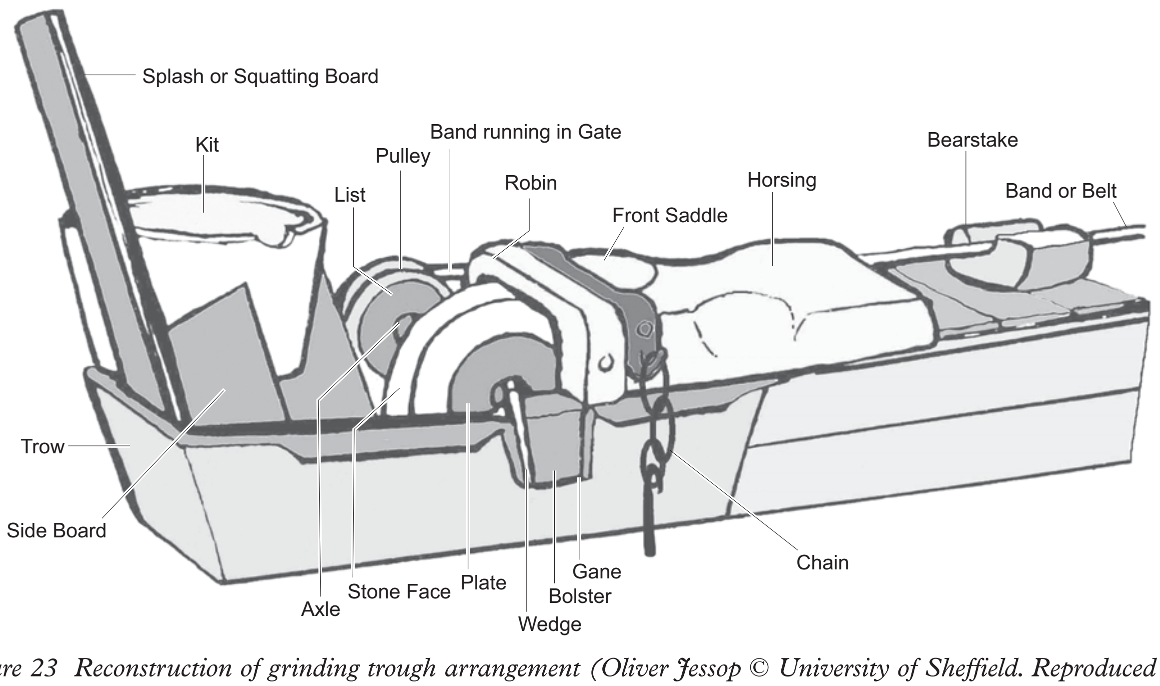

Figure 23 Reconstruction of grinding trough arrangement (Oliver Jessop © University of Sheffield. Reproduced by permission)

by the forger, who manipulated the hot metal, and the striker, who wielded the hammer, working together. After the blade had been hammered out, the bolster and tang were formed, and the cutler's mark stamped on the blade, which was then hardened and tempered by re-heating and quenching (*ibid.*, 26–7). The sharpening was done by grinders, specialists who seem to have emerged as a separate group in the early 18th century (*ibid.*, 28–9). Grinders operated within workshops or 'hulls' associated with the numerous water-powered 'wheels' that were set up, working up to three in a line, sitting above and behind the grinding wheel which rotated away from the grinder (Pl. 33). The grinding wheels were driven by leather belts from a waterwheel, each grinding wheel set in a trough of wood, stone, iron or concrete which contained water to cool the wheel and reduce dust (Beauchamp 2002, 55) (Fig. 23). The grinders gave the blades shape, a cutting edge and polish, using various grades of grindstone and other materials, and also ground the bolster and any decoration required (Unwin 2002, 29).

Tangs took two forms: scale-tangs, which were flat, and round tangs with, usually, two-piece and single-piece handles respectively. Handles from the mid-18th to the mid-19th century were mainly of bone or wood, though higher quality cutlery had handles of horn, antler, ivory or exotic wood. Later, metal, porcelain or other ceramic materials were also used, and it was usually the cutler who drilled holes and riveted the handles to the blades where required (Unwin 2002, 29–30).

In the 17th century there was a clear division between the different groups of cutlers, for example the scissorsmiths and scythesmiths, with each individual undertaking all stages of production, but these were later separated into more specialised tasks, in particular grinding, and undertaken by different craftsmen (Unwin 2002, 42–3; Wray *et al.* 2001, 10–11). Waterpower could be rented by grinders in a 'public' wheel, devoted exclusively to grinding, or within a 'private' wheel forming part of a larger factory where a range of operations were undertaken, usually cutlery production (Wray *et al.* 2001, 28). The change from water to steam power in the 19th century was the major innovation in the industry, nevertheless, despite some mechanisation in cutting and stamping, craft skills remained in demand.

In 1824 approximately 13% of Sheffield's population was involved in the cutlery and related trades, representing 97% of Britain's cutlers; these 8500 or so people included 2240 table knife manufacturers, 2190 spring knife manufacturers and 1284 file manufacturers (Beauchamp 2002, 54). The cutlers often worked on their own or with apprentices in small workshops and, in one description, it was noted that '*Most of the cutler's houses were small abodes, with a shop and forge in the yard behind*' (Hunter 173a). Craftspeople such as these, the so-called 'Little Mesters', undertook most of the cutlery production at this time, carrying out their own work and taking on commissions from the relatively few larger businesses (Unwin 2002, 14 and 19). Seventy years later, in 1891, there were still many small firms and only a few large factories; 416 firms employed 50 people or less and just 27 had between 200 and 800 workers (Beauchamp 2002, 55).

Riverside Exchange lay within one of six areas in and around Sheffield with a significant number of cutlery or tableware (forks and spoons) workshops (Beauchamp 2002, 55). The majority of these in the Riverside area were on a slightly larger scale than elsewhere in the town, and there were 380 entries in rate books in the 19th century, operating in 138 properties, reaching a peak in the middle of the century (*ibid.*, 58–9). Many of the workshops were rented, but there were more owner-occupiers in the Riverside area (*ibid.*, 60–1), and most workers lived close to their workplace, typically between 0.25 and 0.75 miles away, until at least the mid-19th century (*ibid.*, 62–3).

The Development and Technological Aspects of Steelmaking

Steel has a carbon content of 0.6–2% (Barraclough 1984a, 2–4), which gives it strength and hardness and enables it to be sharpened and given a cutting edge. Wrought iron in comparison has only 0.1% carbon, whereas cast iron has 3–5%, making it hard but brittle. Prior to *c.* 1800 the precise role that the carbon played was not understood and the production of steel depended on the practical skill and experience of the steelmaker rather than on any scientific understanding of the processes by which this took place (Belford 1998, 8; 2008, 90–1).

Cementation and Blister Steel

The process of cementation, which involves the diffusion of carbon into wrought iron to form steel, was probably a medieval, central European development, and practised in Nuremberg in the second half of the 16th century (Barraclough 1984a, 48). The principle was not new, for the medieval tradition of case-hardening iron objects by heating them in a bed of charcoal had been widely used when a 'shell' of hard metal was required (Crossley 1990, 171). However, only small objects could be treated in this way and the scale of production was limited.

Producing steel by cementation on an 'industrial' scale involved a furnace being used to heat bars of

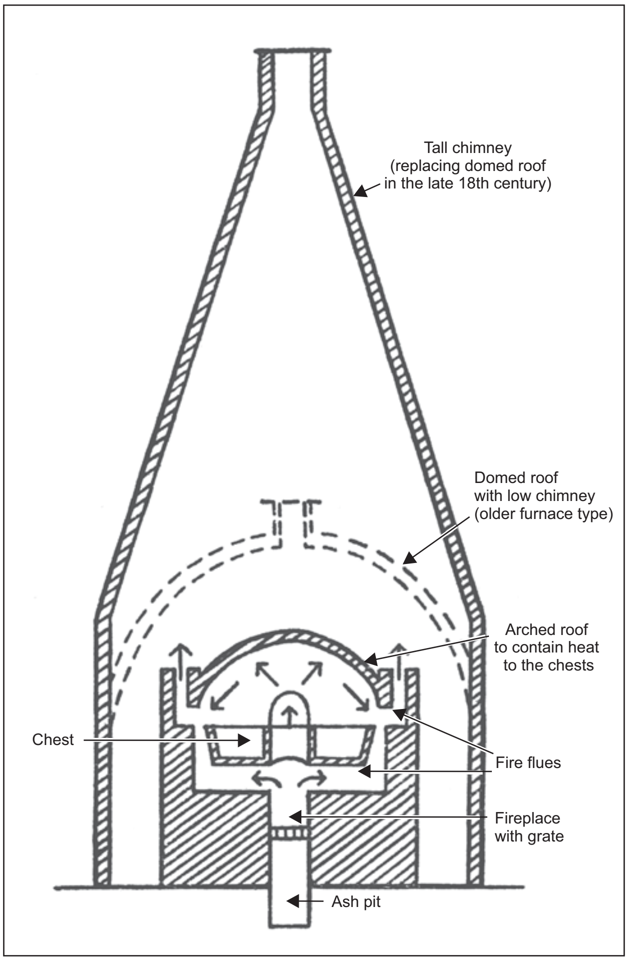

Figure 24 Section of double-chest cementation furnace at Sheffield (after Schubert 1957, fig. 36)

Plate 34 Interior of double-chest cementation furnace (Sheffield City Council, Libraries Archives and Information: Sheffield Local Studies Library, Sheffield and Rotherham Illustrated, 1897)

wrought iron and charcoal in one or, more usually, a pair of closed sandstone or (later) brick chests, and this method became widespread in Europe from *c.* 1600 (Barraclough 1984a, 48–55). An axial ash pit, also acting as a flue, ran below a fire grate, above which other flues carried flames from the fire grate around and over the chests, which lay beneath an arched roof forming a reverbatory chamber, with the smoke and gases subsequently escaping via the furnace cone and chimney (Fig. 24).

The process used rectangular-section bars (½”–¾” thick) of wrought iron to maximise the surface area and, therefore, the diffusion of carbon into the bars. From the late 17th century Swedish iron was considered the most suitable, by virtue of it being produced in charcoal-fired furnaces and largely free of sulphur and phosphorus (which inhibited the absorption of carbon); by the mid-18th century nearly all English steel was produced from Swedish iron (Barraclough 1984a, 101; Belford 1998, 8). The bars of wrought iron and charcoal were heated together in the chests at 1000–1100° centigrade in the absence of air over a period of up to 14 days, allowing the carbon atoms to diffuse into the surface of the iron, after which another week was allowed for cooling. Cementation was fuelled by coal and the chests were packed with charcoal, usually oak in England as this was most readily available in large quantities (Barraclough 1984a, 36). The chests were sealed with sand, clay, or as was later the case in Sheffield, wheel swarf (debris from grinding – a mix of sandstone particles and steel grindings) which made an effective refractory cement, known locally as ‘crozzle’ (Barraclough 1984a, 121; Belford 1998, 8). In Sheffield, the relatively small double-chest cementation furnaces of the mid-18th century appear to have had a capacity of just under four tons (Barraclough 1984a, 82), but by the mid-19th century capacities of between 20 and 30 tons were common (Pl. 34).

The cementation process produced what came to be known as ‘blister steel’ (Barraclough 1984a), so-called because of the small blisters which formed on the surface as a result of carbon monoxide being produced as the carbon penetrated the wrought iron bars. However, this steel was brittle and the carbon was concentrated at and near to the surface rather than percolating through the entire bar, leading to an uneven steel in terms of the carbon content. The blister steel had, therefore, to be hot-worked and reduced in section, by forging under a water-powered hammer or, later, by rolling to produce different ‘tempers’ (carbon levels) for different products, for example ‘shear’ or ‘double shear’ steel, for cutlery and edge tools.

It is not certain when the cementation process was first successfully practised in England, but the most

Plate 35 Remains of double-chest cementation furnace excavated at Jessop's Brightside works (scales = 1 m) (© University of Sheffield. Reproduced by permission)

recent evidence indicates that it may have been as early as the second decade of the 17th century, at Coalbrookdale (Belford and Ross 2007). Certainly by the second half of the 17th century there is documentary evidence for early cementation steel production in several areas including the Forest of Dean, Bristol, Birmingham and, subsequently, the North-East, in particular the Derwent Valley (Barraclough 1984a, 54 and 61–3; Belford and Ross 2007, 108; Cranstone 2008, 105). Closer to Sheffield, Charles Tooker of Thrybergh, near Rotherham, was granted a patent for making steel in 1664 (Hey 2005, 92–3), and was probably the first producer in what was later to become this major steelmaking centre. Around Sheffield, early cementation furnaces were constructed in increasing numbers after the mid-17th century by members of the local gentry, and by the late 17th–early 18th century several had been erected in parishes to the south-east of Sheffield (Hey 2005, 93). Nearer to the town, John Fell made steel at Attercliffe Forge and Samuel Shore made steel at Darnall and Woodhouse before moving into Sheffield, and in 1737 there were two steelworks operating cementation furnaces within the town, at Steelhouse Lane and Balm Green (*ibid.*, 93). However, no pre-18th-century steelmaking installations have been found, and the earliest cementation furnace to survive is at Derwentcote, County Durham, in existence possibly as early as 1720 (Cranstone 1997; 2008, 105).

The cone-shaped cementation furnaces became a common feature of the Sheffield landscape from the 18th to the early 20th centuries. However, the declining use of cementation, replaced by new methods of bulk steel production, led to their obsolescence and demolition (Pl. 35). Today only Doncasters' cementation furnace in Doncaster Street survives upstanding in the city, and is a Scheduled Monument (Wray *et al.* 2001, 16–17), whilst two partially surviving examples (both scheduled) remain at Bower Spring.

Crucible Steel

Blister steel could be worked to achieve different 'tempers' and then forged into shears and cutlery, for example, but imperfections (eg, concentrations of slag inclusions) and variations in carbon content made it unsuitable for fine work (Belford 1998, 8). However, the discovery, attributed to Benjamin Huntsman (but see Evans 2008), of a method of making high quality steel in crucibles, solved this problem. Huntsman, formerly a Doncaster clockmaker, moved to Handsworth on the east side of Sheffield in 1742, and later set up a crucible steelworks at Attercliffe (Belford 1998, 8; Hey 2005, 94). Early steelmakers had been unable to achieve high enough temperatures to melt steel, but Huntsman's long series of experiments to produce good quality, uniform steel

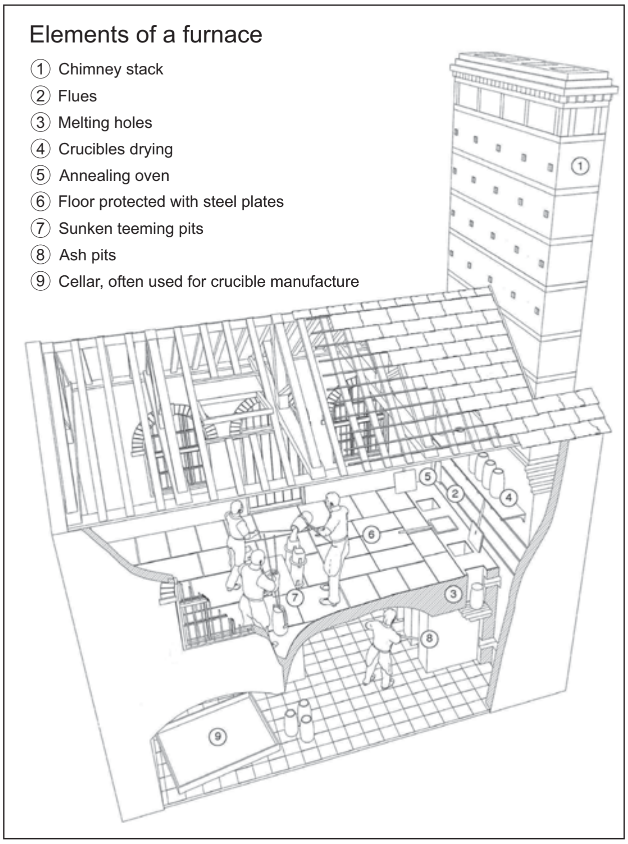

Figure 25 Cutaway view of a typical crucible steel furnace (Oliver Jessop and Marcus Abbott © University of Sheffield. Reproduced by permission)

were eventually successful, and enabled pieces of blister steel, cut from bars, to be melted ('refined') in crucibles and the resulting molten steel to be poured ('teemed') and cast into an ingot of more homogeneous steel with an even carbon content and fewer impurities (Barraclough 1984b). A key feature in this process was the use of highly refractory clay for the crucibles, which enabled them to be heated to at least 1500° centigrade for around four to five hours without cracking or breaking up. One mixture comprised high alumina clay, obtained from near Stourbridge and also at Bolterstone close to Sheffield, to which was added iron-free sand, crushed fragments of used crucibles and coke dust or graphite (Wayman and Craddock 2000, 17), whilst another was 'a mixture of white china clay, Derby clay, common clay and coke dust' (Vessey 1984, 317–8). Analysis undertaken on fragments of two of the late 18th-century crucibles from Riverside Exchange, which are the earliest yet identified, have shown these to comprise mullite and graphite, and of different composition to the 19th-century crucibles, with no coke dust or crushed fragments of used crucibles present (see above).

Huntsman did not obtain a patent on his process but instead relied on secrecy. Even so, several attempts were made to discover the composition of his crucibles and copy the crucible refining process, and by the late 1760s a number of firms had set up in Sheffield, although the process was not widely adopted until the end of the 18th century (Hey 2005, 94). Marshall's was one of these firms, and analysis of fragments of two of the late 18th-century crucibles from Riverside Exchange has identified a manganese-rich slagged layer in one, suggesting that manganese dioxide was a deliberate addition. This is likely to reflect experimentation with manganese salts to improve the efficiency of the crucible steel making process, at a time when this was not well understood. Manganese dioxide may have been one of the mysterious fluxes mentioned in early literature, around which there was much secrecy and speculation. However, cementation continued to be the major steelmaking process in use up to the end of the 18th century in Sheffield, with the rapid growth in crucible steel production not taking place until the first half of the 19th century. Nevertheless, the superior quality of Huntsman's steel became well known and respected overseas (Barraclough 1984a, 123), and several observers visited Sheffield from continental Europe and Scandinavia during the second half of the 18th century. It transformed the character of steelmaking, and Sheffield became a major steel producing centre, the crucible steel process dominating the industry until Henry Bessemer's invention of a converter in 1856 allowed far larger quantities of steel to be produced at a much cheaper price (Hey 1991, 68). However, Bessemer steel had a lower carbon content than crucible steel and was not suitable for tools, blades and cutlery, for example. For these purposes crucible steel continued to be produced, but not from cementation steel or by the Huntsman process.

No 18th-century crucible steel furnaces are known to survive, but several remain from the 19th century and their structure and operation are well understood (Barraclough 1984b; Belford 1998, 8; Wray *et al.* 2001, 18–20; Powell 2014) (Fig. 25). The buildings containing the furnaces are characterised by tall, broad, rectangular brick stacks, usually with iron bands near the base to strengthen them against heat damage. At ground or sub-basement level were cellars which provided access to the ash pits and, coupled to the height of the chimneys, facilitated a strong draught to raise the temperature required for melting the blister steel in the crucibles. If there was no separate pot shop then the cellars might also be used for making the crucibles, which were then dried on shelves on the wall of the chimney stack on the melting shop floor above. Prior to use the crucibles were heated in an annealing oven, then 'charged' with pieces of blister steel and other raw materials, all having been ready prepared and weighed in advance.

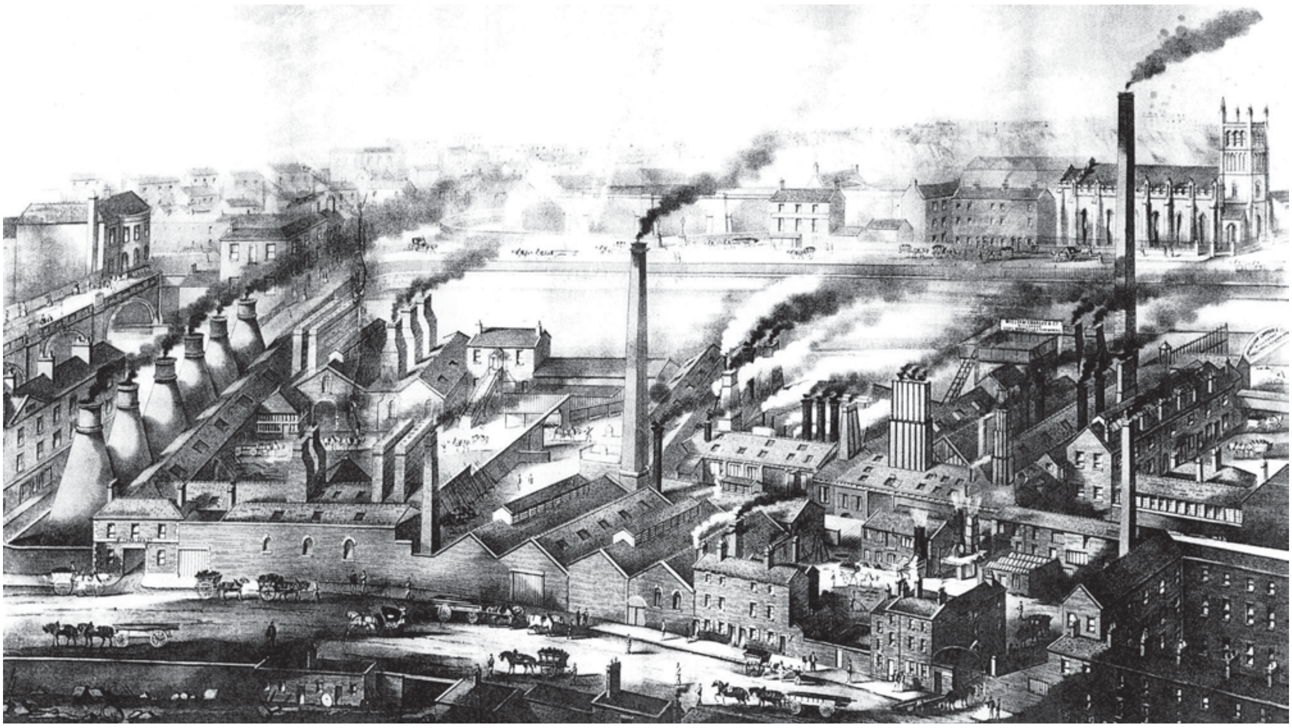

Plate 36 Artist's view (from west) of former Naylor Vickers works, after its purchase by William Charles and Co in 1865 (source unknown)

Knowing what mixture of materials, the size of crucible and the melting time necessary to produce a specific type of crucible steel required specialist knowledge, only gained through long experience. In the 18th century it was usual for each melting hole or furnace to accommodate a single crucible along with fuel, set above an ash pit and linked to a flue, but by the end of the first half of the 19th century two crucibles in each melting hole was common; more than this proved inefficient for heating with coke. The melting holes were lined with ganister, a highly refractory clay sourced in the Sheffield area, and re-lined every few days during working periods, with the crucibles usually surviving for three melts (a day's work) before erosion rendered them unusable. The earliest, mid-18th-century crucibles had a capacity of around 13 lb, doubling in volume by the end of the century, and doubling again to around 50 lb by the mid-19th century, the maximum that could be manually handled during teeming.

Integrated Works and Later Innovations

The Marshall's works were established in the mid-1760s, just a few years after Benjamin Huntsman had perfected the crucible process for melting or 'refining' and then casting what had begun as blister steel. Prior to Marshall's, only Huntsman himself and the Cutlers' Company had the capacity to convert wrought iron into steel and then refine it to cast steel on the same premises, but Huntsman's facility was small and rural, whilst that of the Cutlers' Company was also small scale as well as short-lived, set up to produce steel solely for the Company's own use (Belford 1998, 14). Marshall's was the only commercial firm with a comparatively large output which was consistently described with both converting and refining capacity until the end of the 18th century (Barraclough 1984a, 90), making the Millsands works the world's earliest integrated steelworks of this type. Thereafter, the integration of the two steel processes increased and Gell and Bennett's Directory for 1821 lists a relatively large number of firms who undertook both.

For more than a century, from the mid-18th to the mid-19th century, the expansion of the Sheffield steel industry was mainly a result of many relatively small businesses, and in 1856 there were 135 steelmaking firms in the town, most of them founded by cutlers or other steel users who wanted good quality steel (Linton 1956, 156). Between around 1800 and 1865 cementation and crucible steel production developed and there was a rapid growth of capacity from 3000 to 100,000 tons per annum (Barraclough 1976, 8–9) (Pl. 36), steelmaking becoming the major industry within the city and the basis of its prosperity (Hey 2005, 96).

Bulk steelmaking processes utilising the newly developed Bessemer and Open Hearth production methods created an extensive new market for steel, and were introduced into Sheffield during the second half of the 19th century, largely to meet the demand for steel rails (Barraclough 1976, 8–9). Henry Bessemer moved from London and established a works in Carlisle Street in 1858, and others took out licences to install converters from around 1860 (Hey 2005, 96). However, Bessemer's own efforts were not successful in Sheffield, and the greatest boom in steel production from the 1870s took place in other places with better access to raw materials, especially iron ore. Sheffield never became a major bulk steel producer using these new methods of making cheaper steel, and the high carbon, high quality, crucible steels for tools and cutlery, for example, for which the town was famous worldwide, remained its major product, with approximately 120,000 tons of crucible steel produced in 1873 (Barraclough 1976, 8–9). Further important technical developments between the 1850s and 1870s also enabled crucible steel to be made directly, either by co-fusion or direct carburisation, cutting out the need for cementation steel, and the Huntsman process had been superseded by the close of the 19th century (Barraclough 1990).

Chronology and the Ordering and Use of Space

The Diversification of Craft and Industry on the Site

Up until the middle of the 17th century Millsands was a relatively low-lying area on the periphery of Sheffield, with the medieval Town Mill the only significant industry located within the site at Riverside Exchange. However, from then on this area, largely given over to garden allotments, began to change rapidly as Sheffield developed as a major industrial centre.

A tannery was established, probably in the second half of the 17th century, a noxious industry located away from the main area of settlement. The archaeological evidence suggests that this was concerned primarily with 'light' tanning, in particular the preparation of sheep and goat hides. Tanning and leatherworking remained a feature of this area until after 1850, and at least two fellmongers or tanners (William Marsden and Richard Yeomans) operated there at the end of the 18th century.

In 1750, the Cutlers' Wheel was built close to the Town Mill, one of many water-powered grinding workshops set up during this period as Sheffield became the pre-eminent centre of cutlery production in England.

The middle of the 18th century also saw the first recorded evidence for steelmaking on the site, John Marshall taking advantage of the space and relatively low rental afforded by this generally undeveloped area close to the centre of Sheffield. In the 1860s he constructed an innovative integrated steelworks with the capacity for both converting and refining steel on a sufficiently large scale for commercial production of cementation and crucible steel.

Towards the end of the 18th or early in the 19th century, the Vickers family, who operated the Town Mill, began to take an interest in metal manufacturing. In 1825 they built a rolling mill, subsequently going on to buy the Marshall's steelworks and later establish the Naylor Vickers works at Millsands as a major steel producing business, also renowned internationally for the production of cast steel bells.

The presence of the Cutlers' Wheel, Marshall's and later Naylor Vickers steelworks helped to attract cutlers and toolmakers to the undeveloped parts of the Millsands site. At the end of the 18th and beginning of the early 19th century these included table knife and spring knife manufacturers, a scissor maker, a razor maker, an awl blade manufacturer, screw makers, two file makers and an edge tool manufacturer. At around the same time, the 'Isle' to the south became a focus for saw making, a major industry in Sheffield from the later 17th to the 20th century, supported by the ready availability of crucible steel (Barley 2008).

Towards the end of the 19th century, several foundries for both brass and iron (including at least one grate works) and a spindle works were established, and there is otherwise undocumented evidence for the manufacture of copper alloy dress pins (not all craftsmen or occupiers were listed in trade directories). There is less evidence for steelmaking, the Millsands works occupying the former Naylor Vickers site now a forge and rolling mill. However, the old Marshall's site at the southern end of Riverside Exchange survived as the Millsands Steelworks and the Prometheus Works lay at the north end, the latter including the row of old Naylor Vickers cementation furnaces, these being probably demolished some time between 1905 and 1923, perhaps after World War I (Sean Bell pers. comm.). Other trades were not metal-related, and there is archaeological and documentary evidence for the production of bone handles for knives, glass cutting and lens manufacture. From the middle of the 19th century the establishment and subsequent expansion of Tennants' (later Whitbread's) Exchange Brewery and bottling plant succeeded at least one earlier brewery (Croft's) and, following the closure of the rolling mills in the second half of the 20th century became, for a short period, the dominant industry on the site.

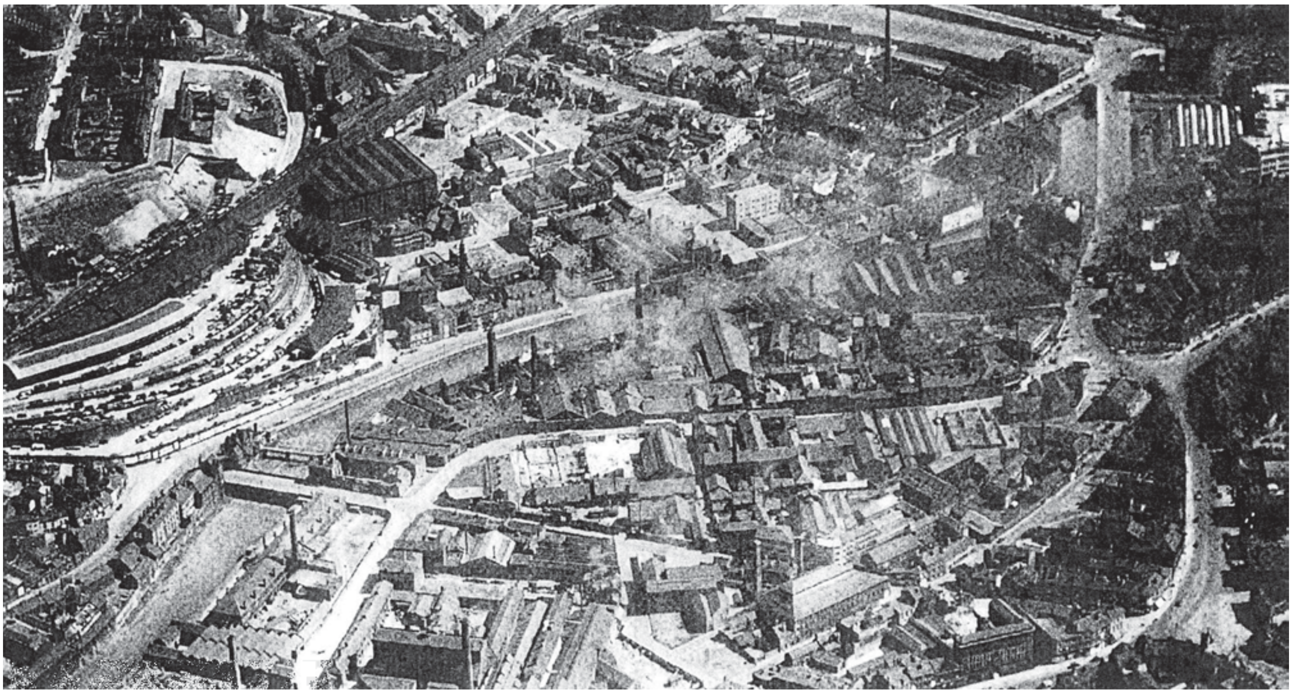

Plate 37 Aerial view (from the north) of Millsands and the surrounding area prior to World War II (Sheffield City Council, Libraries Archives and Information: Picture Sheffield S12355)

The Pattern of Crafts and Industries

To a great extent both the nature and layout of the crafts and industries at Riverside Exchange were determined, initially, by the proximity of water and, in particular, the availability of waterpower provided by the Town Mill goit. At the heart of this area lay the medieval Town Mill that occupied the central part of Millsands, between the River Don to the east and Bridge Street to the west until the mid-17th century. The remainder of the site stayed largely open land covered with garden allotments, that to the west of the Town Mill goit forming part of Colson Crofts and that to the east bisected by a route (subsequently known as Millsands) which ran northwards from Under the Water (Bridge Street).

The availability and relatively low cost of land at Millsands, held by the Norfolk Estate and the Town, provided the potential for expansion and allowed development to take place largely unfettered by the constrictions of space, a major factor on other sites near the centre of Sheffield. Initially, tanning and leatherworking were attracted to the central part of the site, and continued here for around 200 years until at least the mid-19th century. However, from the mid-18th to the mid-20th century it was the steelworks which came to dominate the area, first Marshall's at the south end and later Naylor Vickers and its successors at the north end, which together came to comprise the Millsands steelworks.

During the latter part of the 18th and the first half of the 19th century a variety of crafts and industries were established and operated alongside the expanding steelworks, often in small factories or in workshops (some of which also provided domestic accommodation), interspersed with public houses, various merchants' and shopkeepers' premises and housing. Late 18th-century maps show relatively large properties associated with some of these activities, in particular tanning and leatherworking, alongside the Town Mill and the Cutlers' Wheel, with John Marshall's steelworks by then a significant part of the local landscape. However, there was clearly some re-organisation of properties in parts of the site at the end of the 18th century (see Figs 16 and 18).

The greater pressure on space (see Fig. 4) partly resulting from the continued development and increasing output of the steelworks eventually led to Vickers (as it had by now become) relocating to a more spacious site at Brightside, on the north-east fringe of Sheffield, in the mid-1860s. Nevertheless, a major steelworks continued to operate in the same premises at Millsands for just over another hundred years, latterly as a forge and rolling mills only (Pl. 37). It was towards the end of the 19th century that the Exchange Brewery, established on the Isle at the south end of the site in 1852, became Sheffield's largest brewery, and later this came to occupy a large part of the site following the closure and demolition of the steelworks in the early 1980s. By this time, most of the smaller crafts and industries had disappeared, and the brewery complex itself was largely demolished following closure in the mid-1990s.

Throughout the period of industrial development at Riverside Exchange in the 19th and 20th centuries, a similar transformation was taking place in the surrounding area, though nowhere with a complex of steelworks on the scale of that at Millsands. To the north-west lay the major textile mills at Kelham Island, while immediately to the west of Bridge Street, opposite the former Naylor Vickers works, the extensive Soho Grinding Wheel complex was built. Across the river to the east in Nursery Street was another cementation furnace, wire works, saw mills and further corn mills.

The Place of the Riverside Exchange Site in Sheffield

Riverside Exchange at Millsands developed from a peripheral, semi-rural location in the 17th century to a major industrial site in the 19th and 20th centuries. The availability of waterpower and the proximity to the centre of Sheffield in the 18th and first half of the 19th centuries, providing a nearby market and redistribution centre, as well as a pool of skilled craftsmen and labour, were important factors in its development, initially as the location of the Town Mill and particularly later in its association with steelmaking. There were several areas of Sheffield that featured urban steelmaking, but this area, which included Millsands, was where some of the earliest, longest lived and most innovative works were established (Belford 1998).

Improvement of the area, which was prone to flooding, was achieved through the dumping of material in order to raise and level the ground, then making access easier and culverting parts of the goits. Industrial development and urbanisation of this newly available land took place in a relatively ordered fashion, and it was the new, integrated and large-scale steelworks, initially Marshall's and later Naylor Vickers, which influenced the subsequent development of the area and made it internationally famous. Naylor Vickers became a multi-function works for not only did it have a rolling mill, in addition to steelmaking facilities, some taken over from Marshall's, but it had a file works, spring works and its own grinding wheel.

The expansion and success of what by the mid-19th century had become the Vickers works at Millsands led to its move to the new River Don Works at Brightside on the east side of Sheffield in 1863. By this time steam was rapidly replacing the dependency on waterpower, and a newly built railway provided much improved access to this extensive new site, allowing iron and coal or coke to be brought in and finished goods, by now primarily steel for railways and machine tools rather than cutlery, to be taken out. The Sheffield to Tinsley canal, completed in 1819, making the Don navigable as far as the centre of the city, was not a significant factor in the history of Riverside Exchange.

Vickers went on to become one of the largest manufacturers of heavy engineering products and armaments in the world. Although no longer based in Sheffield, the Vickers Company is still involved in the construction of ships, submarines and tanks. From the 1960s onwards increasing competition and imports from abroad have led to a major decline in the British steel industry, but Sheffield Forgemasters International, the result of a merger in 1983 between part of British Steel and Firth Brown, remains an important steelworks and dominates the lower Don Valley in Sheffield, with a global reputation for large and complex forgings and castings.

Patterns of Consumption

The Nature of the Finds Assemblages

Finds largely comprised pottery, glass, clay tobacco pipes, ferrous metalwork and animal bone, the vast majority of 18th- and 19th-century date, and some possibly brought in from elsewhere with material used to raise ground levels or else simply disposed of as rubbish there. Earlier finds were restricted to a few sherds of medieval and early post-medieval pottery and small quantities of 17th-century material of various types. Other categories of finds were sparse, as might be expected on what for the most part had been an industrial site since the 18th century, and allotment gardens before this, with the Town Mill probably the only medieval structure on what was a peripheral low-lying site.

The relative paucity of metal finds of interest can in large part be explained by the sequence of activity on the site, particularly in the later phases. As firms and factories closed down, machinery would be removed and finished or part-finished products sold on to other manufacturers or sent for scrap to recover at least some of their value. It also appears that some material not disposed of in these ways was dumped into the goit and abandoned wheel pit of the Town Mill. The assemblage from here was mixed, of different dates deriving from different parts of the site, hence the presence of two mid-18th-century knives in a deposit containing largely 19th-century material.

Most of the information about metalworking comes from the archaeological remains and documentary sources, since the metal finds themselves were somewhat limited in number and range, though the metallurgical materials, particularly the pieces of blister steel and the early crucible fragments, have proved to be of considerable technological interest.

The Social and Economic Significance of the Finds Assemblages

Overall, the identifiable objects, particularly the metalwork, do little to reflect the scale of industrial activity carried out at the site, especially after 1750, and generally there is little in the finds to suggest the types of buildings, the locations of various processes, products made and tools or machinery used by craftsmen and manufacturers. Nevertheless, the finds complement the documentary and archaeological evidence and provide further insights into the nature of the site and who worked and lived there.

The clay tobacco pipes indicate that workers had access to and were using pipes that were of good quality and also fashionable, with a variety of designs. It appears that most of these came from outside Sheffield which, surprisingly perhaps, did not have a significant pipemaking industry until the 19th century. There is also the 'industrial doodling', reflected in the ground stems, these pipes probably coming from the Cutlers' Wheel, the workers there taking a few moments out from the arduous routine in the dust-filled grinding workshop.

The pottery, some of it deriving as rubbish from elsewhere in Sheffield, reflects a domestic assemblage, with local potteries contributing as much as Staffordshire until the mid-19th century, after which the everyday products of the former suffered declining use. As with the clay pipes, from the early 18th century onwards more fashionable and relatively expensive pottery gradually appears, in part reflecting greater prosperity and probably also the formalisation that took place in domestic cooking, eating and drinking arrangements.

The glass also appears largely to be domestic debris, but there is a small quantity of industrial waste from glass cutting and lens grinding, as well as bottles perhaps originating from the breweries. This can be added to the other evidence for crafts and industries, in particular the discarded, unfinished cutlery and broken grinding stones, the animal bone assemblage deriving from tanning and the bone-working waste from scale-handle production.

Conclusions

The Riverside Exchange project is a landmark in Sheffield city-centre excavations. For the first time, access to a large site with a known metalworking history, has enabled the results of archaeological excavation to be combined with documentary evidence and finds.

The site at Millsands has a long history from at least the 12th century, when the Town Mill is first recorded. The waterpower for the Town Mill was drawn from the River Don along a goit which ran through the middle of the site, and probably because it was low lying and prone to flooding, the site was not extensively developed for housing and workshops until the middle of the 18th century, being partly taken up by allotment gardens and a tannery (or tanneries) before this time.

There were few finds or archaeological remains from the medieval and early post-medieval periods, probably reflecting the nature of use at this time as well as the impact of extensive later industrialisation on earlier deposits. Nevertheless, a group of tanning pits did survive from the mid-17th century and more substantial remains of the mid-18th-century Cutlers' Wheel. Metalworking on the site was carried out for at least 250 years and was principally concerned with steelmaking and related operations. The size of the metalworking concerns ranged from small workshops of individual craftsmen to the large integrated factories of Marshall's and later Naylor Vickers. These included the primary production of steel, utilising both the cementation and crucible processes, and also the manufacture of edge tools and cutlery, as well as associated crafts such as grinding. There is no doubt that the discovery of remains of three early cementation furnaces is of national significance, particularly in the context of Sheffield and the first integrated steelworks. There used to be some 260 cementation furnaces in Victorian Sheffield, but now there are upstanding remains of only three, two at Bower Springs, both partially destroyed, and another at Hoyle Street. Since the investigations at Riverside Exchange, other cementation furnaces have been recorded on excavations in the city, five at the north end of the Naylor Vickers site (investigated as part of the Inner Relief Road project (Bell in prep)) and four at Jessop's Brightside works in Attercliffe, though these examples are of later 19th-century date.

While the excavations did not provide many identifiable metal objects which can be used to reconstruct the metalworking activity over the centuries, the two 18th-century knife blades are of note, and the steel bars, crucibles and refractory material contribute important technological evidence. In particular, the late 18th-century Huntsman steelmaking crucibles represent the earliest yet discovered and analysed, and are of considerable significance. Not only has their composition been established, but something more has been learned of what, at the time, was a process subject to much secrecy and misinformation.

Overall, the value of this excavation can be seen in providing a method of assessment and analysis by combining the rather poor material finds with documentary sources and archaeological evidence. As one of the first large-scale investigations on an urban metalworking site, it is important in providing a bench mark against which other sites, particularly in Sheffield, can be measured. Notably, the excavations at Riverside Exchange have allowed a better understanding of the development of a specific site in terms of the growth, diversification and pattern of crafts and industries, as well as changes over time. Compared to other sites in Sheffield it has also provided moderately large assemblages of pottery, glass and clay tobacco pipes, the latter a rare example of a late 18th- and early 19th-century clay pipe assemblage from Yorkshire. The pottery also is likely to repay further study, with comparisons made to assemblages from different sites across the city with a view to establishing how the topography of the city and the lives of its inhabitants are reflected in the character of the pottery assemblages.

Finally, the evidence from Riverside Exchange can be viewed against a wider background of population growth, urbanisation and industrial development between the late 17th and the 19th centuries. This was a period when Britain had a vigorous commercial economy, with a rapid growth in home and overseas markets, in the case of Sheffield for steel, cutlery and edge tools, especially in America between the Napoleonic War and the American Civil War. Yet, despite the introduction of steam power and increasing number of factories, each employing a relatively large number of people, many goods continued to be made in workshops with little or no machinery long after 1850, and the distinction between domestic craft and factory production was probably not clear cut. This was a pattern that could still be seen at Riverside Exchange well into the 20th century, with individual businesses and workshops adjacent to a major steelworks. Dramatic economic changes in the second half of the 20th century led eventually to the closure of the rolling mill in 1981, the last surviving element of the old Naylor Vickers works, and the end of the brewery and bottling operation in 1995. Subsequently, all were swept away as a part of a major phase of inner city regeneration and replaced by the offices and housing of the early 21st-century Riverside Exchange development.

Appendix
Concordance of phases of archaeological work undertaken

ARCUS no.	**Trench/Area no.**	**Date**	**Description**
240A	–	1996	Desk-based assessment
240B	Evaluation trenches 1–3	1996	Evaluation
240C	–	–	Excavation – not undertaken
240D–G	Trenches 1, 2, 10 (Area 1)	1999–2003	Evaluation/Excavation/Watching brief
240D–G	Trenches 4, 5, 6, 11 (Area 2)	1999–2003	Evaluation/Excavation/Watching brief
240D–G	Trenches 7, 8, 9 (Area 3)	1999–2003	Evaluation/Watching Brief
240H	Trench 14 (Area 2)	2000	Evaluation
240I–K	–	–	–
240L	'Green area' 1/Trench 16 and 'Green area' 2 (Area 1)	2002–3	Excavation/Watching Brief
240M	–	–	–
240N	Trenches A–D (Area 1)	2002–3	Excavation/Watching Brief
240O–P	–	–	–
240Q	(Area 1)	2003–4	Excavation/Preserved *in situ*

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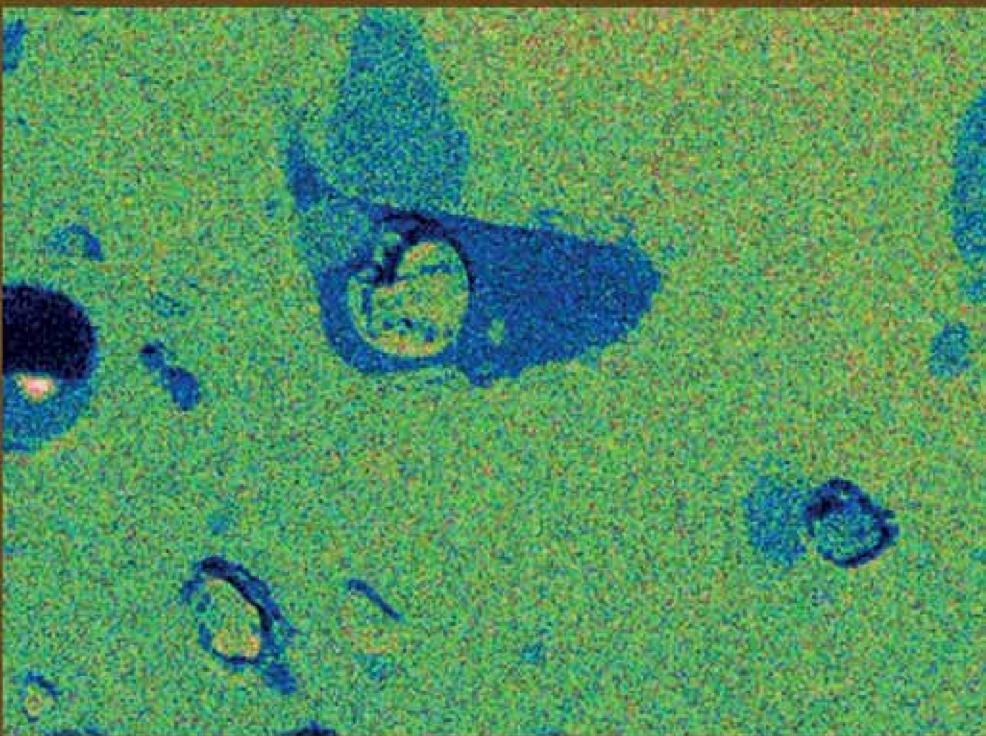
Excavations at Riverside Exchange in the centre of Sheffield revealed significant evidence of the city's post-medieval industrial expansion and, in particular, unique remains relating to early steelmaking.

Nothing of the medieval Town Mill survived but the goit which supplied water to the mill remained an important element within the site. Mid-17th-century tanning pits were followed by the Cutlers' Wheel, built in the mid-18th century to provide a water-powered grinding workshop. Notable assemblages of cutlery, pottery and clay tobacco pipes were recovered.

Marshall's steelworks was established in the mid-1760s, an innovative, integrated works which combined cementation furnaces and the newly developed crucible steel process. The remains of three early cementation furnaces are of national significance and have been preserved *in situ*. Analysis of two crucibles has provided the earliest evidence for their composition and the Huntsman process, at a time when these were a closely guarded secret.

From the 19th century, documentary, map and archaeological evidence combine to give a picture of the development of the Naylor Vickers works, which took over Marshall's and later became one of Sheffield's major steelworks.



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