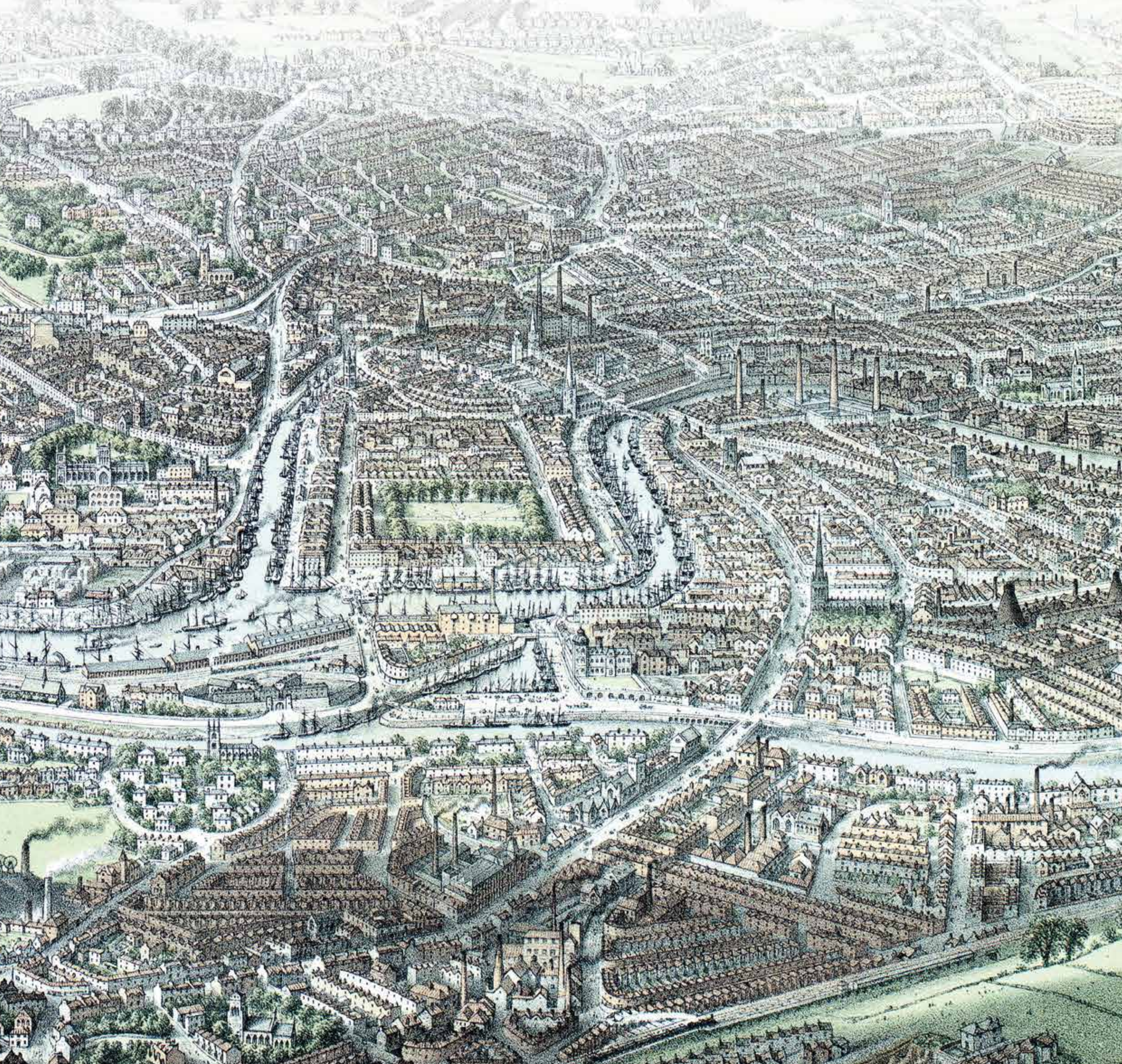
Capper Pass & Son's Bedminster Smelting Works

EXCAVATIONS AT DALBY AVENUE AND WHITEHOUSE LANE BEDMINSTER GREEN, BRISTOL

Cai Mason
with contributions by
David Dungworth and Richard Smith



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Illustrations by:
Will Foster

Wessex Archaeology Occasional Paper
2025

Published 2025 by Wessex Archaeology Ltd
Portway House, Old Sarum Park, Salisbury, SP4 6EB
www.wessexarch.co.uk

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-1-7391876-9-9

Designed and typeset by Will Foster
Cover design by Will Foster
Copy-edited by Dr Tess Millar
Printed by Bookvault

Cover
Edward Colston Lavar's Bird's Eye View of Bristol, 1887
Image courtesy of Bristol Museums

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ACKNOWLEDGEMENTS

Wessex Archaeology would like to thank Bristol and Bath Heritage Consultancy Ltd and Wring Group Ltd for commissioning the work and Watkin Jones plc for funding the project. Wessex Archaeology would also like to thank Simon Cox (Bristol and Bath Heritage Consultancy Ltd) and Sam Barber (Wring Group Ltd) for their assistance throughout the works. Thanks are also due to Peter Insole (Principal Historic Environment Officer), who monitored the project on behalf of Bristol City Council, and to Dr Richard Smith and Dr David Dungworth for their expert advice on the technological aspects of the smelting works.

Fieldwork was directed by Cai Mason, who was assisted by Amy Pannell, Chiara Sabato, Chris Hambleton, Isabelle Kennedy, James Goodall, Jamie Gibbons, Josh Bower, Luke Jervis, Roy Krakowicz, Simon Flaherty, Steve Froud and Victor Jerjotoma Ortin. Photogrammetric recording was undertaken by Chris Hambleton. The site survey and photogrammetry were processed by Rebecca Havard and Sally Jones. The fieldwork was managed for Wessex Archaeology by Bruce Eaton, and the post-excavation programme by Kirsten Dinwiddy. Finds photography by Tom Westhead. This report was edited by Phil Andrews, copy edited by Dr Tess Millar and typeset for publication by Will Foster.

ABSTRACT

Archaeological excavations in 2022 at Metal Works, in the Bedminster district of Bristol, uncovered extensive remains of a 19th-century non-ferrous smelting works known as the Bedminster Smelting Works. It was established in 1840 by a local metal refiner named Capper Pass, who refined lead, copper and zinc from scrap metal and cheap waste materials like metal ashes, slags and poor-quality ores. He also experimented with extracting gold and silver from Sheffield plate and gilded buttons. For many years the company barely broke even, but in the 1866, Capper Pass and his son Alfred finally found a product, solder, that proved to be highly profitable. Solder is a lead–tin alloy used for sticking all manner of metal objects together, most notably tin cans and metal pipework, the demand for which grew in response to increasing urbanisation. In the 20th century, new applications for solder emerged, notably the burgeoning electrical and automotive industries. By the end of World War I, the market for solder had become saturated, and the company turned to tin smelting, for which it developed several innovations that were never patented.

The smelting works expanded throughout the later 19th and early 20th centuries, but by the 1920s, it was clear that the Bedminster site, constrained on all sides by houses and other industrial premises, was too small. A new site was eventually found in Melton, Yorkshire, and from 1937 onwards production gradually shifted to the new works. The Melton works was focused on tin smelting, primarily from Bolivian ore, while the Bedminster site was reconfigured to focus on solder production. The Bedminster Smelting Works closed in 1963 and the site was subsequently levelled to make way for a new road and car park.

The excavations uncovered the remains of various types of coal- and oil-fired furnaces and associated underground flue systems, a bank of three large Lancashire boilers that provided steam for the engines that powered the works, and rows of industrial workers' houses. Most of the excavated remains date from *c.* 1870–1914: a period known as the Second Industrial Revolution. The methods of production and furnace technology used at the Bedminster Smelting Works was typical of the period, but the company's focus on scientific analysis of the raw materials allowed them to work with materials that other smelters were unable to successfully process. This constant checking also meant that the metals they sold had a reliable composition and predictable behaviour. This type of standardisation was essential for the industries they supplied and was one of the features that distinguished materials of the Second Industrial Revolution from those of the preceding era.

Figure 1.1 Location plan showing places in the surrounding area referred to in the text

CHAPTER 1
INTRODUCTION

Project Background

Bedminster is an inner-city district of Bristol, located 1 km to the south of the city centre (Figs 1.1, 1.4 and 1.5). Today, its identity has been largely subsumed by its larger neighbour, but it is in fact a much older settlement with a distinct and separate identity. The name of the settlement, meaning the '*monasterium* of *Bedæ*', suggests that it was the site of an important Anglo-Saxon church. By the medieval period, it had developed into a village with its own mill and a small hospital dedicated to St Katherine.

Bedminster lies within the Bristol and Somerset Coalfield, the deeply buried seams of which were first exploited in the late 17th century. By the turn of the 19th century, mining had become a significant local employer and the ready availability of fuel attracted other industries, one of which was a non-ferrous smelting works. This metal refinery, established by Capper Pass II in 1840 and later known as the Bedminster Smelting Works, grew throughout the 19th century and become one of the area's largest employers. Its chimneys dominated the local skyline, and the near-constant sound and light of its furnaces were a defining feature of the district from the mid-19th to mid-20th centuries.

Industrial development attracted workers to the area, and by the mid-19th century, Bedminster had developed its own rapidly expanding suburbs. The houses on the low-lying land close to the factories and industrial works had a strongly working-class population, while those on the surrounding high ground had more affluent inhabitants. The buildings around the smelting works were to be its downfall: hemmed in on all sides, it was unable to expand to meet the increased demands for its products in the 20th century. In 1937, Capper Pass & Son Ltd opened a new refinery in rural East Yorkshire. This eventually became the dominant site and in 1963 the Bedminster works closed for good. The redundant site was soon cleared of buildings and a new road (Dalby Avenue) was constructed across the former smelting works. The area to the west of Dalby Avenue was redeveloped as an office block and shopping centre, while the land to the east was tarmacked over for use as a carpark.In 2019, plans were drawn up for the wholesale redevelopment of underused land and buildings between East Street and the Bristol to Exeter railway line. This development, known as Bedminster Green, was divided into five plots, one of which, Plot 3 (Figs 1.2, 1.3 and 1.6), incorporated part of the former Bedminster Smelting Works and adjacent plots of brownfield land and light industrial units fronting Whitehouse Lane.

Figure 1.2 Aerial view of the western half of the site (Plot A) during evaluation (photograph reproduced with the permission of Bristol & Bath Heritage Consultancy Ltd)

Figure 1.3 Aerial view of the eastern half of the site (Plot B) prior to evaluation, looking north-east (photograph reproduced with the permission of Bristol & Bath Heritage Consultancy Ltd)

Proposals for the mixed-use redevelopment of Plot 3, comprising student accommodation and ground-floor business space, were submitted in 2020 and approved in 2022 (BCC 2024). The new student residences, which opened September 2024, have been named Metal Works in recognition of the site's industrial past (Bristol University 2024).

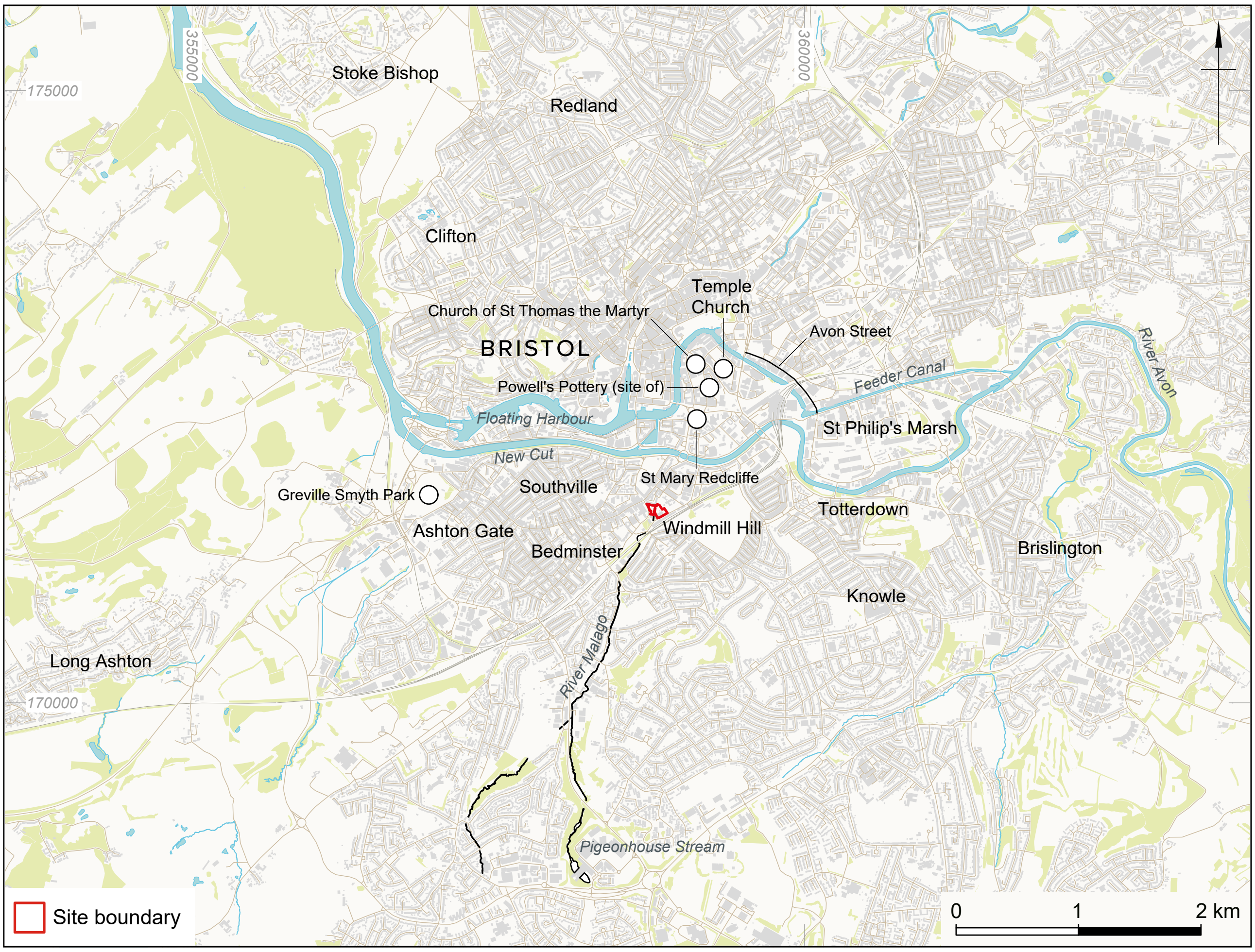


Figure 1.4 Site location and places in Bristol referred to in the text

Two archaeological desk-based assessments of the site highlighted the potential for remains of a post-medieval channel of the Malago river, 19th-century clay extraction pits, 19th–20th-century industrial remains of the Bedminster Smelting Works, and Victorian workers' housing (Cotswold Archaeology 2018; Bristol and Bath Heritage Consultancy Ltd 2020). Preliminary works for the redevelopment of the site, comprising demolition of standing buildings along Whitehouse Lane, removal of subsurface obstructions throughout the site, mitigating the risk of unexploded ordnance, and soil remediation works, began in January 2022. These works were undertaken in conjunction with a programme of archaeological mitigation, comprising the excavation of ten evaluation trenches; a watching brief during geotechnical works; and a large open area excavation focused on the oldest parts of the Bedminster Smelting Works (Wessex Archaeology 2022; Figs 1.6–1.10). The archaeological fieldwork was carried out between 10 January and 5 April 2022.

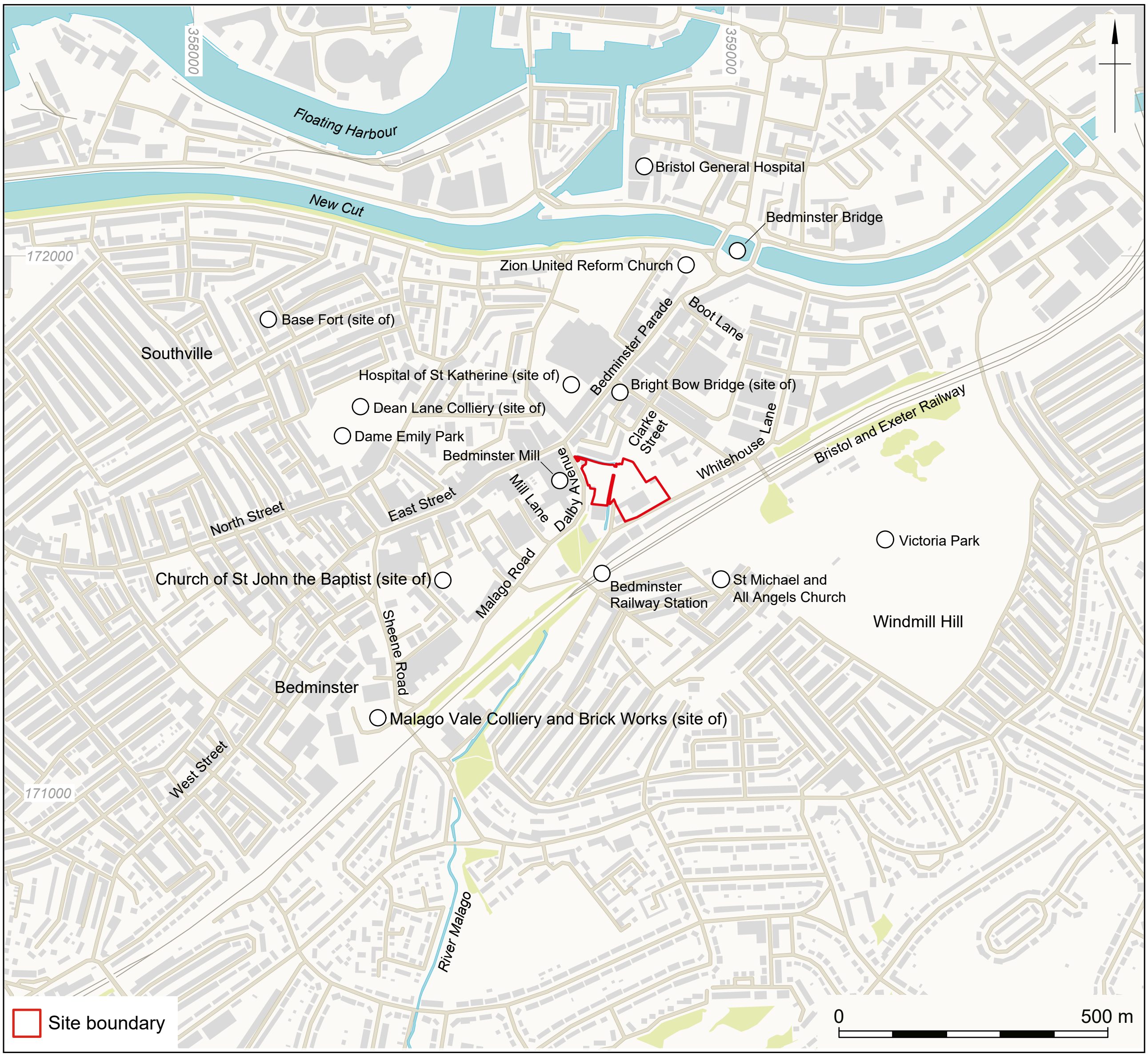


Figure 1.5 Site location and places in Bedminster referred to in the text

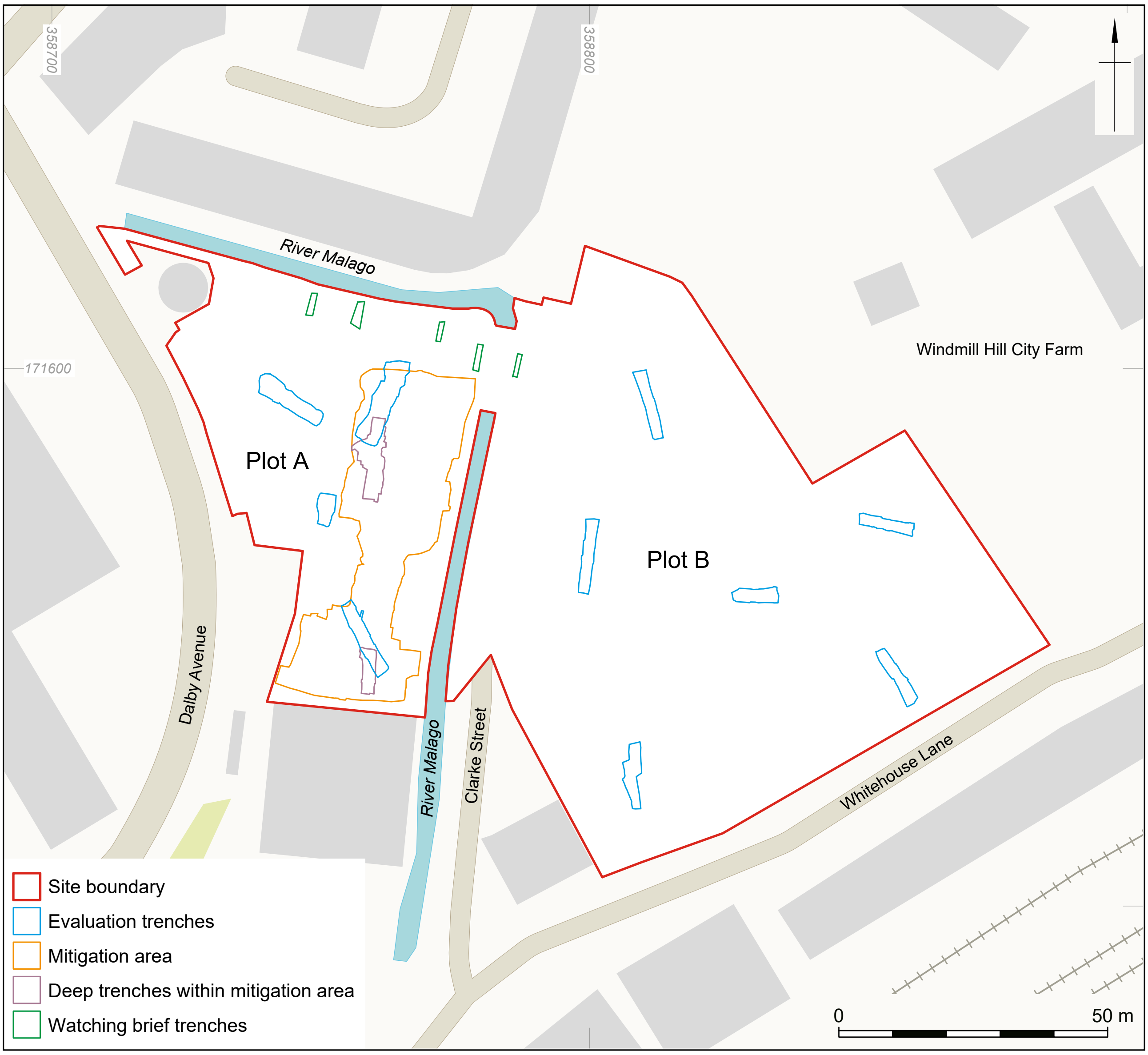


Figure 1.6 Site plan, showing evaluation, excavation and watching brief areas

Figure 1.7 Aerial view of the Plot A during excavation (photograph reproduced with the permission of Bristol & Bath Heritage Consultancy Ltd)

Figure 1.8 Aerial view of the Plot A during excavation, looking south (photograph reproduced with the permission of Bristol & Bath Heritage Consultancy Ltd)

Figure 1.9 Southern part of Plot A during excavation, looking south-east

Figure 1.10 Aerial view of the northern part of Plot A, showing solder pots S50 (photograph reproduced with the permission of Bristol & Bath Heritage Consultancy Ltd)

Organisation of this Report

The results of the archaeological work are presented by period, with the relevant historical background outlined at the beginning of each chapter and, where relevant, integrated into the chronological narrative (Chapters 2–7). Each chapter concludes with a period-specific discussion. Chapter 8 presents the technological background and analysis of the metalworking debris recovered. Chapter 9 outlines some aspects of the site's material culture, and the final chapter presents a discussion and conclusions of the broad themes investigated by the project. The historic background is drawn from previous histories of the Bedminster Smelting Works by Little (1963), Penny (2005) and Vincent (2022), primary records held by Bristol Archives, Bristol Central Library, Bristol Museum and Art Gallery, and historic newspapers.

The basic unit of reference throughout the archaeological archive is the context number. This is a unique number given to each archaeological event (e.g., layer, cut, fill, wall, etc.). In this report, archaeological features (groups of contexts) are described by land use type, which are abbreviated as follows:

B	Building
OA	Open area (e.g., field, yard or garden)
S	Structure. This category includes all other man-made features, such as free-standing walls, drains, ditches, quarries and pits.

Other abbreviations used in this report:

OD	Ordnance Datum
BA	Bristol Archives
BCC	Bristol City Council
BCL	Bristol Central Library
BEP	Bristol Evening Post
BHER	Bristol Historic Environment Record
BM	*Bristol Mercury*
BMi	*Bristol Mirror*
BMAG	Bristol Museum and Art Gallery
BP	*Bristol Post*
BTM	*Bristol Times and Mirror*
CRFP	*Clifton and Redland Free Press*
HBRMDFP	*Horfield and Bishopston Record and Montpelier & District Free Press*
SEM	Scanning electron microscope
TNA	The National Archive
WDP	*Western Daily Press*

This report includes various chemical and technical terms related to metallurgy and smelting. To assist the reader, a glossary of these terms and a list of chemical symbols referred to in the text is provided below.

Glossary

Arsine	Flammable, toxic and gaseous arsenic hydride, produced as a by-product of some tin, lead or solder refining processes.
Baghouse	Dust-collecting apparatus using cloth bag filters to recover metal-bearing fume and dust for reprocessing. Superseded by the *electrostatic precipitator* in the early 20th century.
Ball mill	Type of grinder used to mill ore, comprising a rotating drum partially filled with steel balls.
Blast furnace	Type of metallurgical furnace. Ore, flux and coke or charcoal were loaded from the top, with air blown into the lower section through *tuyeres*. Metal and slag were tapped out at the base.
Blowing furnace	Shaft furnaces using charcoal as fuel, with air introduced by a single *tuyere*. Used to smelt tin but superseded by reverberatory furnaces in the early 18th century.
Bordeaux Mixture	Mixture of copper sulphate ($CuSO_4$) and quicklime (CaO) used as an agricultural fungicide.
Coke	Coal-based fuel with a high carbon content and few impurities. Made by destructive distillation, e.g., heating coal in the absence of air.
Dead roasting	*Roasting* ore until all sulphur has been removed.
Dross	Mass of solid impurities that float on the surface of molten metal.
Electrorefining	Process of purifying metals by passing an electric current between an anode of impure metal and a cathode immersed in an electrolyte solution containing dissolved metal ions.
Electrostatic precipitator	A gas-cleaning device which collects dust and fume by electrostatic attraction onto highly charged metal plates or rods
End member	Mineralogy term for a mineral at the extreme end of a mineral series in terms of purity of its chemical composition.
Eutectic	Homogeneous mixture of elements or compounds that has a lower melting point than any of its individual components.
Fayalite	Iron-rich *end member* of the *olivine solid-solution* series.
Firebrick	Bricks with a high alumina (Al_2O_3) content, often made from Coal Measures clay, making them more resistant to high temperatures than common bricks. Also known as refractory bricks.

Hardhead	Compound of tin, iron and arsenic.
Gunmetal	Alloy of copper, tin and zinc.
Litharge	Lead oxide.
Manometer	A type of pressure gauge.
Malachite	Copper carbonate hydroxide mineral.
Metalline	Coppery tin alloy.
Olivine	Magnesium iron silicate.
Prill	Small globule of solidified metal or slag.
Printing metal	Alloy of lead, antimony and tin used in hot-metal typesetting machines such as the Linotype, Intertype and Ludlow Typograph.
Pyroxene	A complex group of silicate minerals.
Reverberatory furnace	Type of metallurgical furnace that reflects combustion gases and radiant heat from the roof of the furnace onto the materials being processed but keeps the flames and fuel of the firebox separate.
Roasting	Heating ore to a high temperature to remove impurities such as arsenic and sulphur.
Secondaries	Slags, flue dusts, metal drosses and scrap metal.
Sinter plant	Apparatus to agglomerate metal-bearing dust with other fine material at a high temperature to create nodules that can be smelted in a *blast furnace*.
Slag	By-product of smelting, normally a mixture of metal oxides and silicon dioxide.
Solder	Lead–tin alloy used to join metals. The term was used at Capper Pass to describe any tin/lead intermediate produced in the works.
Solid solution	Homogeneous mixture of two different kinds of atoms in solid state and having a single crystal structure (Abbaschian and Reed-Hill 2008).
Spinel	Cubic crystalline magnesium/aluminium mineral. Also used to describe any mixed metal oxide of a divalent and trivalent metal.
Smelt/smelting	A form of extractive metallurgy used to obtain base and precious metals.
Smelting furnace	Any type of furnace used to smelt metals.
Stibine	Very toxic gaseous antimony hydride, produced as a by-product of some tin, lead or solder refining processes.

Thermocouple	A type of temperature sensor formed from the junction of two wires with different metallic compositions. Used to monitor blast furnace temperatures from the late 19th century onwards.
Tuyere	Tube used to blow air into a furnace.
Whitemetal	Lead- or tin-based alloy, which may include antimony, cadmium, bismuth or zinc. Used as a base for plated silverware, as well as ornaments, jewellery, bearings and metal type.

Chemical Symbols

Al	Aluminium
Ag	Silver
As	Arsenic
Ba	Barium
Bi	Bismuth
Ca	Calcium
Cu	Copper
Fe	Iron
Hg	Mercury
K	Potassium
Na	Sodium
Ni	Nickel
Mg	Magnesium
Mn	Manganese
O	Oxygen
P	Phosphorus
Pb	Lead
S	Sulphur
Sb	Antimony
Si	Silicon
Sn	Tin
Ti	Titanium
wt%	Weight percentage (as opposed to atomic percentage).
Zn	Zinc

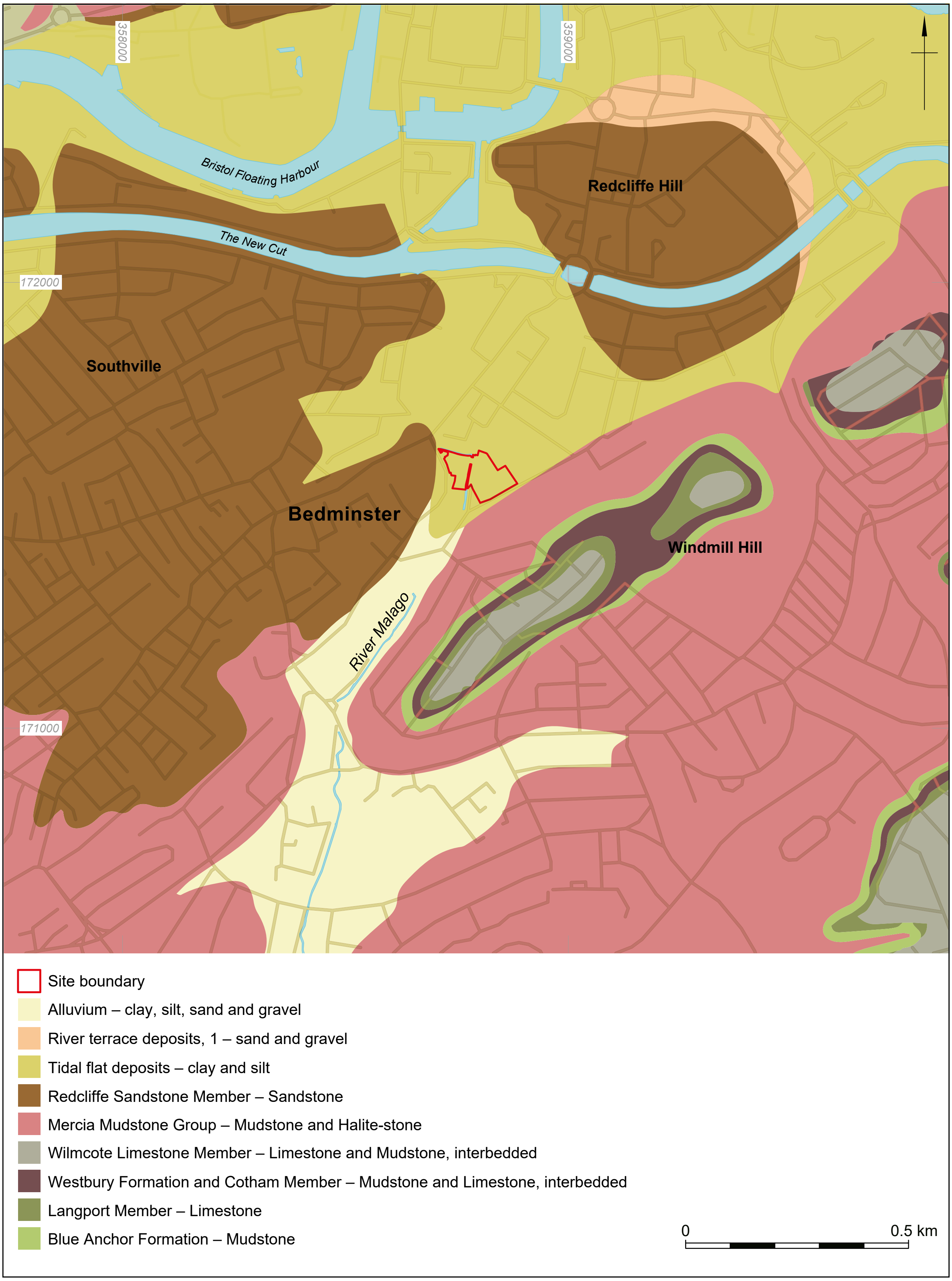


Figure 2.1 Surface geology

CHAPTER 2
BEDMINSTER BEFORE 1832

Topography and Geology

Bedminster lies within Malago Vale, which is named after a small river known as the Malago. This watercourse, and its tributary, the Pigeonhouse Stream, both rise from springs on Dundry Hill, 7 km to the south, and flow northwards towards their confluence with the much larger River Avon, 1 km to the north of Bedminster. The Malago cuts through a succession of Jurassic and Triassic Limestones, Mudstones, Halite-stones and Sandstones, the oldest of which, the Redcliffe Sandstone Member, is exposed across the western half of Bedminster and throughout central Bristol (British Geological Survey 2023). Below these lithologies, there are Carboniferous rocks, including Coal Measures of the Bristol and Somerset Coalfield. On the valley floor, the solid geology is overlain by Quaternary deposits of alluvium, and Holocene tidal flat deposits of the Wentlooge Formation (Fig. 2.1). These tidal flat deposits, which extend throughout the low-lying parts of central Bristol and along both banks of the Severn Estuary, are primarily composed of grey silty clays that were deposited in intertidal mudflat environments. Organic layers, representing stabilisation horizons where saltmarshes and alder carr vegetation formed, are known from several locations in central Bristol (Wilkinson *et al*. 2013, 27–9, 41).

The pre-modern ground level of the floodplain was approximately 7 m OD. This corresponds with the level of the spring high tide and, historically, the northern end of the Malago Vale has been susceptible to marine inundation and river floods. Natural deposits in this part of the valley are overlain by approximately 2 m of made ground dating from the 19th and 20th centuries (Wessex Archaeology 2022, 14). To the south-east of Bedminster, the valley sides rise steeply towards Windmill Hill, and more gently towards the low rise of Southville to the north-west.

Archaeological and Historical Background

Prehistoric and Romano-British

During the prehistoric and Romano-British periods, the excavation site is likely to have been marginal land characterised by intertidal mudflats: a type of environment not habitually exploited by humans (Wilkinson *et al*. 2013, 41). The surrounding land, which benefited from ready access to fresh water, woodland and land suitable for grazing, is likely to have been attractive to people from an early date. Geoarchaeological work in central Bristol has shown that some local woodlands were burnt during the Neolithic and Bronze Age (*ibid*. 2013, 49), probably to clear the land for agricultural use. It is likely that the higher ground around Bedminster was used for grazing or growing crops, though direct evidence for human activity during these periods is sparse.

Excavations along West Street, 0.7 km to the south-west of the site, uncovered cut features containing Early/Middle Bronze Age pottery. Several pieces of struck flint, including a Neolithic arrowhead and a Late Neolithic/Early Bronze Age scraper have also been recovered from this area. Middle to Late Iron Age features were found in the same area, as well as more substantial evidence for a small Romano-British settlement, probably a farmstead (Avon Archaeological Unit 2006a, 11, 16; 2006b, 14–16; Williams

2005, 128). The Romano-British settlement was probably focused along a road that followed the line of modern West Street. East Street and Bedminster Parade may follow a northward continuation of this postulated Roman road (Mason 2020a, 219). Residual Roman pottery has also been found at the south-western end of East Street (Avon Archaeological Unit 2006c), potentially indicating further Romano-British activity in this location.

Anglo-Saxon and Medieval

During the Late Anglo-Saxon period, Bedminster was a royal estate that belonged to the kings of Wessex. The name Bedminster, '*monasterium* of *Bedæ*', suggests that there was an Anglo-Saxon minster (a royally founded Christian community) within the settlement, probably in the same location as the medieval parish church of St John the Baptist (Costen 2011, 65; Mason 2020a, 219). The Domesday Survey of AD 1086 records the manor of Bedminster (*Beiminstre*) as a community of 51 households and a mill (Williams and Martin 1992, 231). Finds of 11th-century pottery from two sites near to the church (Bristol and Region Archaeological Services 2014, 2; La Trobe-Bateman 1999, 7–8) and along West Street (Avon Archaeological Unit 2005, 12) confirm the documentary evidence for Saxo-Norman occupation in Bedminster (Mason 2020a, 219).

After the Norman Conquest, Bedminster continued to be a royal possession, though William I did grant 112 acres of its meadow and woodland to Geoffrey de Montbray, Bishop of Coutances (Williams and Martin 1992, 231). In 1093, William II granted the feudal barony of Gloucester, which included the lordship of Bristol and two hundred manors (one of which was Bedminster) to Robert Fitzhamon, Lord of Glamorgan (Ford 2017, 10). Fitzhamon died in 1107 and the manor passed to his daughter Mabel, who married Robert FitzRoy (also known as Robert of Gloucester, and probably the eldest of King Henry I's many illegitimate children) in 1119 (Sanders 1960, 6). In the early 12th century, FitzRoy granted the north-eastern part of the manor to the Knights Templar and sold the land immediately to the west to a wealthy local merchant named Robert Fitzharding: these areas subsequently became the medieval suburb of Redcliffe (Ford 2017, 13; Teague 2017, 125).

Fitzharding was a supporter of the Empress Matilda and her son (the future King Henry II) during a civil war known to modern historians as The Anarchy (1138–54). After Henry II's victory in 1154, the King granted Fitzharding the feudal barony of Berkeley, which included the manor of Bedminster (Sanders 1960, 13; Smyth 1883, 23). Fitzharding's descendants, known as the Berkeleys, retained ownership of the manor throughout the medieval period.

In *c.* 1216–19, Robert de Berkeley, 3rd feudal baron of Berkeley, founded a small hospital, dedicated St Katherine, on a riverside plot on the north-west side of East Street, close to the medieval Bright Bow Bridge. Archaeological excavations on the site of the hospital identified part of a 14th-/15th-century stone building, which was associated with pottery dating from the late 13th to 15th centuries (Mason 2020a, 228).

Beyond the hospital, there were *foci* of medieval occupation around the parish church of St John the Baptist; the junction of East Street, West Street and North Street; and along West Street and Mill Lane. Medieval pottery has been recovered from all these locations, while more substantial remains comprising pits, gullies and ditches dating from the 12th to 15th centuries have been recorded along the south-east side of West Street (Avon Archaeological Unit 2006b, 20; 2006c; 2009, 49; Bristol and Region Archaeological Services 2014, 10; Cotswold Archaeology 2017, 12; Mason 2020a, 219).

By the end of the 12th century, there were several chapelries in the Redcliffe suburb, three of which (Temple, St Mary Redcliffe and St Thomas the Martyr) subsequently became separate parishes. In 1373, these parishes became part of the newly created

City and County of Bristol (Harding 1930, 146–65), leaving St John the Baptist as the only church in the slightly reduced parish of Bedminster.

The death of Thomas de Berkeley, 5th Baron Berkeley in 1417 led to a long legal dispute over his estate between his only child, Elizabeth Beauchamp, and her cousin James Berkeley, 1st Baron Berkeley. Elizabeth won the case and her husband Richard Beauchamp, 13th Earl of Warwick, became lord of Bedminster (Ward 2008). Beauchamp died in 1439, and the manor passed to his second daughter Eleanor. She married Edmund Beaufort, 2nd Duke of Somerset, and the manor was subsequently inherited by their fifth child, Margaret Beaufort. Margaret married Humphrey, Earl of Stafford in 1455 and their son, Henry Stafford, 2nd Duke of Buckingham, inherited the manor in 1458 (Hudd 1888, 263).

In 1483, Henry Stafford took part in a failed rebellion against King Richard III, for which he was beheaded without trial in Salisbury marketplace (Tait 1898, 450). Despite this ignominious end, his son, Edward Stafford, 3rd Duke of Buckingham, was allowed to inherit his father's lands and title.

Post-medieval

Edward Stafford was one of the few peers with substantial Plantagenet blood. This attracted the suspicion of his cousin, King Henry VIII, and in 1521 he was tried for treason and executed. This time, his descendants were disinherited, and their lands, including the manor of Bedminster, were confiscated by the Crown. The manor was then granted to Henry Bouchier, 2nd Earl of Essex. He died without a male heir in 1539 and the manor again reverted to the Crown (Hudd 1888, 263–4).

In 1553, Queen Mary I granted Bedminster to Edward Nevill. The Hospital of St Katherine survived the Dissolution because it was a secular foundation: its last recorded master, Francis Nevill (probably Edward Nevill's son), was appointed in 1573 (Collinson 1791, 282; Mason 2020a, 225; Page 1911, 154).

In 1574, Queen Elizabeth I visited Bristol. For entertainment, two mock forts were erected to the south of the city: one in Redcliffe, and a smaller one, known as Base Fort, in the fields to the west of Bedminster village. The forts were used as sets for a three-day mock assault by the Bristol Milita. Base Fort comprised an earth mound, approximately 28 m wide, which was extant until at least 1828 (BHER 2793M).

In 1578, the Hospital of St Katherine was sold to Henry Nevill, 6th Baron Bergavenny, who subsequently converted the buildings for residential use (Collinson 1791, 282; Mason 2020a, 225; Page 1911, 154). Henry Nevill's acquisition of the hospital completed his family's ownership of property in the manor of Bedminster. The manor passed through two more generations of Nevills and was then sold to Sir Hugh Smyth of Ashton Court in 1605 (Hudd 1888, 264). The Smyths were already one of the largest landowners in north Somerset and their purchase of Bedminster created a contiguous landholding that extended from Long Ashton in the west to Whitchurch in the east. Beneath this land there were extensive deposits of coal: something that became an important source of income for subsequent generations of the Smyth family (Bettey 1978, 14).

At the outbreak of the English Civil War in 1642, the lord of Bedminster, Thomas Smyth, 1st Baronet, raised a troop of horse to fight for the Royalist cause. Later that year, he contracted smallpox and died, leaving his ten-year-old son Hugh Smyth as heir (*ibid*., 20–1). The City of Bristol, which was held by Parliament, was protected by a ring of forts and earthworks. In 1643, Parliament suffered a crushing defeat at the Battle of Roundway Down (near Devizes, Wiltshire), the aftermath of which presented Prince Rupert of the Rhine with an opportunity to capture Bristol. The city capitulated after a four-day assault. Prince Rupert subsequently enhanced its fortifications and ordered his men to burn the outlying settlements to deny cover to the enemy. Most of Bedminster, including the parish church of St John the Baptist, was destroyed (Latimer 1970, 197). The church was rebuilt sometime after 1651 (Bates Harbin 1912, 202) and by the late 17th century a row of large gable-fronted buildings had been erected at the south-western end of East Street, all of which have since been demolished (Mason 2020a, 225).

Bedminster lies within the Bristol and Somerset Coalfield, which was first exploited on a small scale during the Romano-British and medieval periods. Licences for digging coal in the Forest of Kingswood were issued in the 13th century, and some mining was taking place in Brislington, Queen Charlton and Burnett by the 16th century. The deeper reserves below Bedminster were first exploited in the second half of the 17th century (Anstie 1873, 9; Buchanan and Cossons 1969, 80–1; Hatcher 1993, 178–84; Ramsey 2003, 3). More significant mining occurred in the 18th century, and by the early 19th century, there were 15 coal pits in Bedminster and Ashton Vale (La Trobe-Bateman 1999, 3; Wessex Archaeology 2022, 4). The Smyth family, who owned most of Bedminster, were heavily involved in mining from the mid-18th to mid-19th centuries (Ramsey 2003, 24).

The abundance of coal provided a source of cheap fuel for local industries, the earliest of which include a *c.* 1730–90 glassworks on the site of the Hospital of St Katherine (Collinson 1791, 282; Hudd 1888, 259, 276; Mason 2020a, 225; Strachey 1731, 654); and a small redware pottery on Boot Lane, which produced utilitarian domestic crockery, flowerpots and sugar moulds between c. 1784 and 1854 (Bristol and Region Archaeological Services 2004; Jackson 2019; Kent 2017). By 1809, the glassworks had been replaced by a large tannery (*BM*, 16 December 1809, 3; 13 May 1826, 3).

Figure 2.2 Plan of the manor of Bedminster, late 18th century. Reproduced with permission of Bristol Archives

Part of Bedminster (to the north of Bright Bow Bridge) is depicted in John Roque's 1742 *Plan of the City of Bristol* (not illustrated). This map shows a continuous strip of ribbon development across Redcliff Hill, with more intermittent development along the east side of Bedminster Parade. The west side of this street remained undeveloped until the early 19th century. To the east of Bedminster Parade, there was a large brickyard dotted with water-filled clay pits.

In 1804–9, the natural topography of north Bedminster was heavily modified by the creation of the New Cut: this was an artificial watercourse which channelled the water of the River Avon to the south of Redcliff Hill. It formed part of a system of locks, dams and canals that were built to create a new port facility known as the Floating Harbour. This work was authorised by the *Bristol Harbour Act 1803*, which also specified that land between the New Cut and the River Avon be transferred from the jurisdiction of the parish of Bedminster to the City and County of Bristol.

Late 18th- and early 19th-century plans of Bedminster (Figs 2.2–2.4) show that the site was formerly divided into two fields, referred to here as Plot A (west) and Plot B (east), separated by the easternmost channel of the Malago. The owners of these fields, which are numbered, are identified in series of accompanying surveys and terriers (BA AC/E/21; AC/M/11/32; AC/M/11/35; Table 2.1).

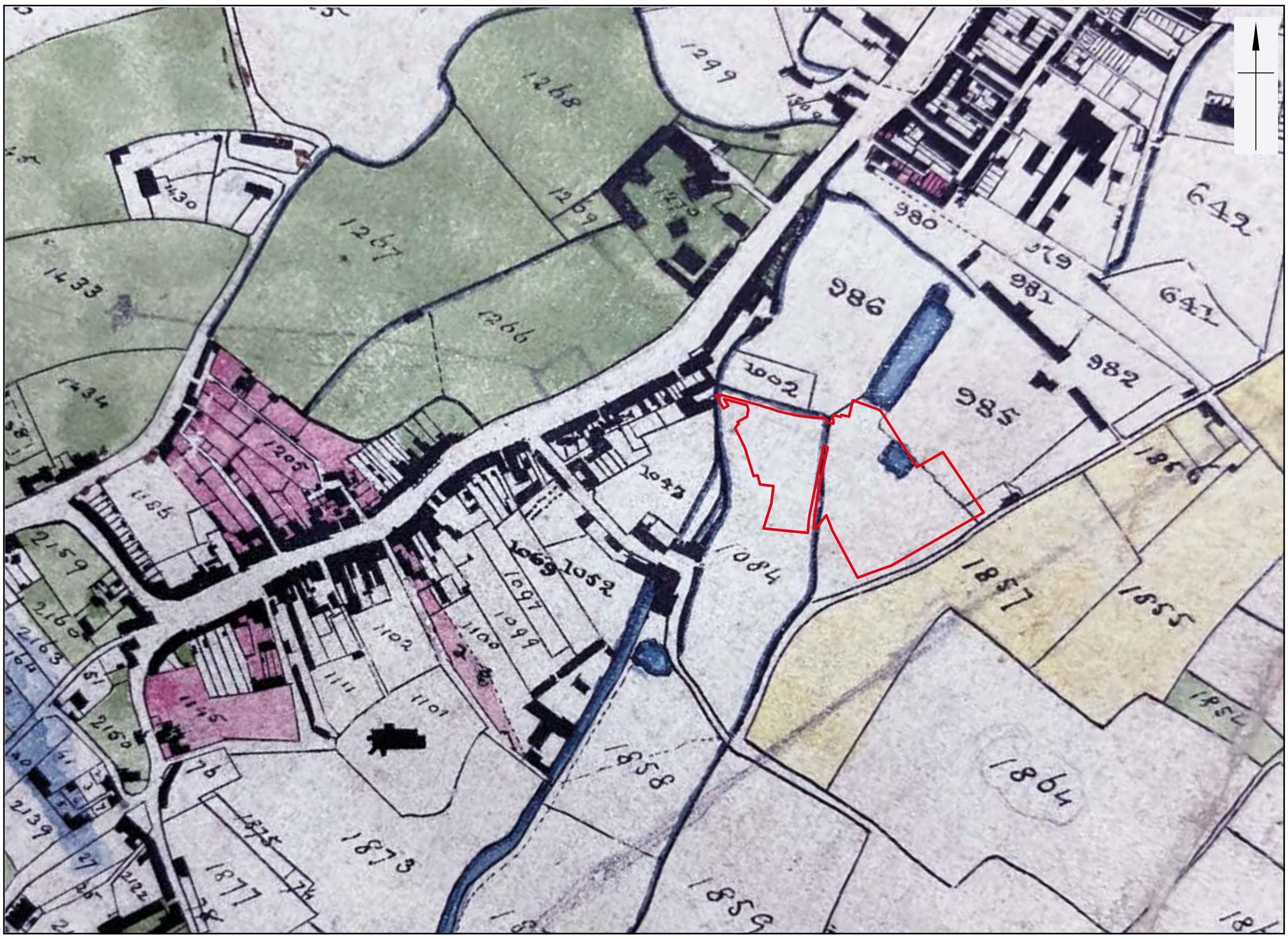


Figure 2.3 Map of the Parish of Bedminster, 1827. Reproduced with permission of Bristol Archives

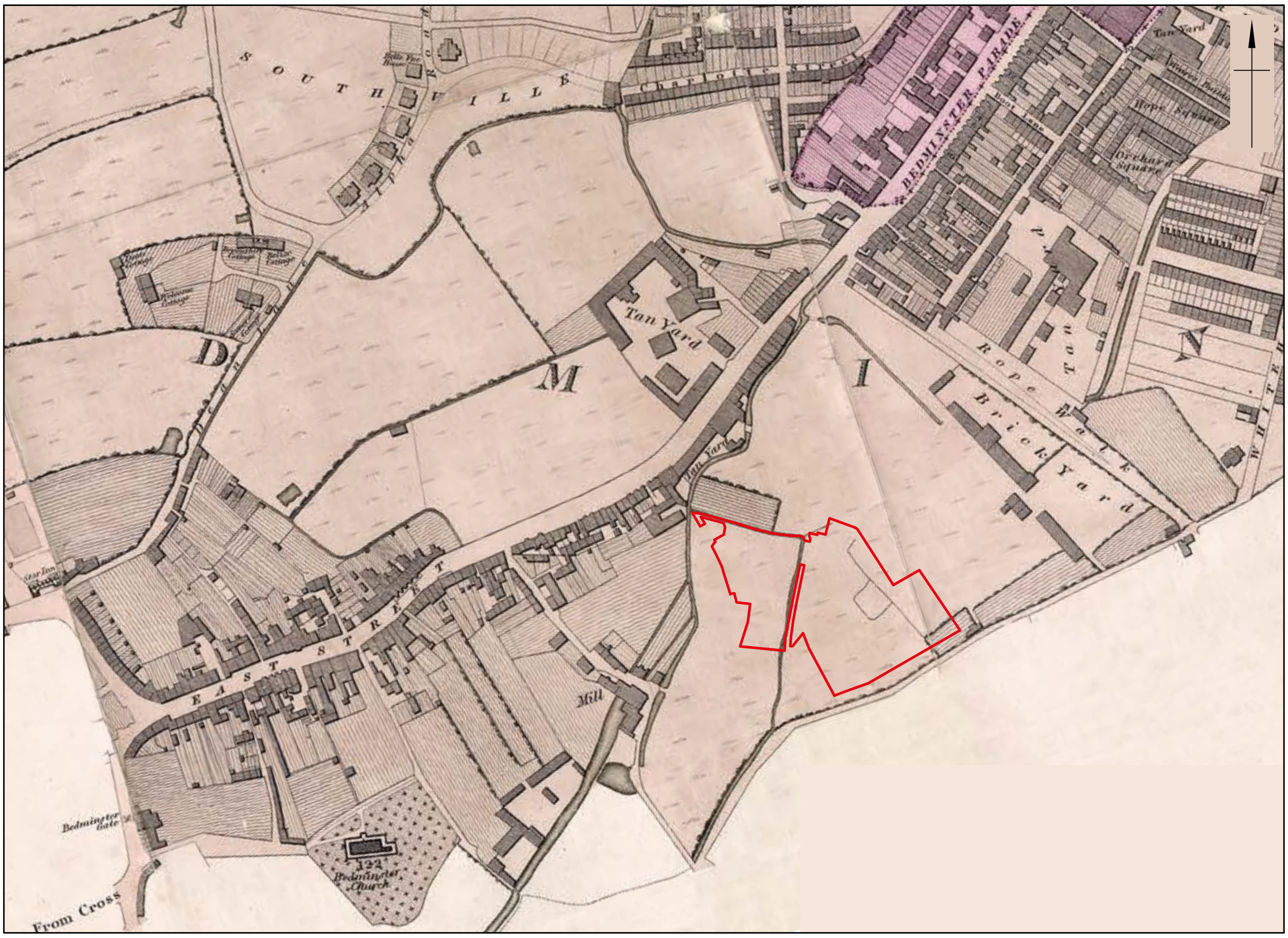


Figure 2.4 Map of Bristol, begun by John Plumley and completed in 1828 by George C. Ashmead. Reproduced with the permission of Bristol Archives

Table 2.1 Late 18th- and early 19th-century land ownership and use

Plot	*No.*	*Field name*	*Description*	*Owner*	*Occupant*
Plan of the Manor of Bedminster, late 18th century					
A	682	Lower Paddock	-	Mr Davis	-
B	685	Little Leaze	Brickyard and lands	E. Elton Esq.	-
Map of the Parish of Bedminster, 1827					
A	1084	-	House	Mrs Stagg	Sundry tenants
B	985	-	Brick kiln and yard	Nehemiah Bartley Esq	William Coombs & Co.

In the late 18th century, Plot A was owned by Mr Davis, who also owned several adjoining properties, including Bedminster Mill. Plot A was subsequently acquired by Mrs Stagg, who sublet it and a house at the end of Mill Lane to various unnamed tenants. Plot B was owned by Edward Elton Esq. of Greenaway House, Devon, and like the fields to north, it was used as a brickyard, a use that was continued by its subsequent owner, Nehemia Bartley Esq. (see Chapter 7).

The area immediately to the south of the New Cut was rapidly developed soon after its construction, and by the 1820s, the area around Bedminster Bridge was heavily built up with streets of terraced houses, shops and industrial premises (Fig. 2.5). The latter included the Bedminster Brewery, established c. 1821 (West Country Bottles 2023); four large tanneries; a ropewalk; and a brickyard.

Figure 2.5 Extract from Thomas Leeson Rowbotham's Panoramic View of Bristol from Pile Hill, Totterdown, c. 1829. BMAG ref. Mb497. Image courtesy of Bristol Museums

There was also a small steel works on Mill Lane (BM, 16 August 1828, 2). In 1830, Bedminster gained its first large non-conformist chapel, the Zion United Reformed Church (Lockie 2013). The surrounding land contained numerous market gardens that supplied fresh produce to city, but the largest employer was coal mining (Lewis 1831, 152). The growth of Bedminster can be seen in population statistics: when the New Cut was created, the parish had 3278 inhabitants; by 1821 there were 7979; and by 1831 the population had virtually doubled to 13,130 (Anon. 1884a, 73).

Archaeological Remains

Natural tidal flat deposits of silty clay, likely to be of post-medieval or earlier date, were recorded across the site (Fig. 2.6). Darker areas of organic clay, sometimes filling shallow-sided hollows, were noted in places: these probably represent silting in slow depositional environments, such as relict backwater creeks, stream channels, marshland, or ponds. Post-medieval/modern clay tobacco pipe stems and glass were noted in these features, indicating a relatively recent date of deposition.

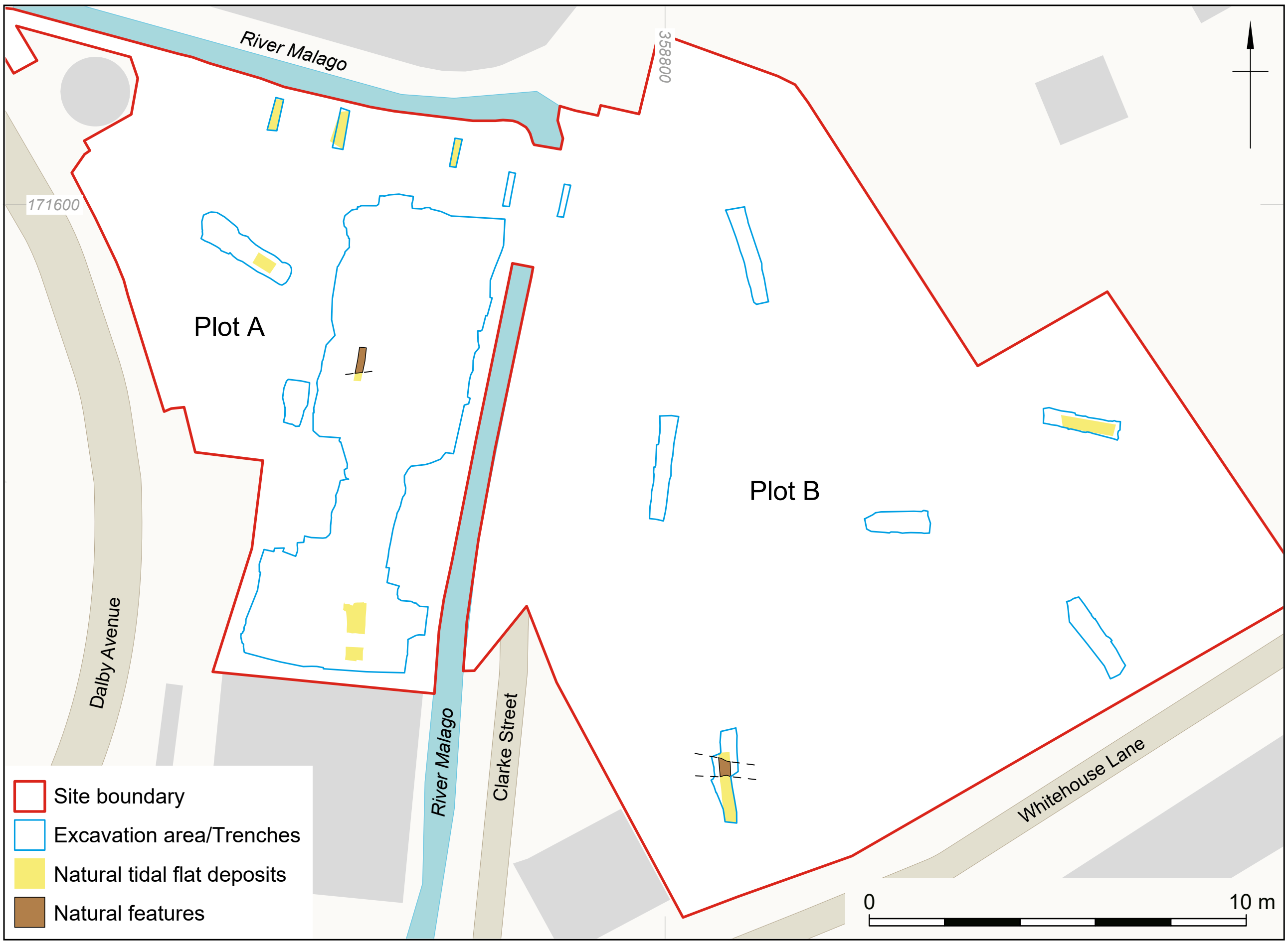


Figure 2.6 Site plan showing pre-1832 features and deposits

Plot A, to the west of the River Malago, is likely to have remained undeveloped until 1832. The only earlier remains comprise the buried surface of the riverside meadow, which was recorded at a height of approximately 7 m OD. The buried land surface was overlain by land reclamation dumps dating from the 1830s onwards. Remains associated with the 18th–19th-century brickyard in Plot B to the east are detailed in Chapter 7.

Discussion

The archaeological work confirmed that there was little human activity, apart from agriculture, on the site prior to the early 19th century. Areas of darker organic clay, some of which contained post-medieval/modern finds, are tentatively identified as the remains of natural waterbodies such as relict backwater creeks, stream channels, marshland, or ponds. The limited extents of the deep excavations preclude a confident identification of the nature or form of these inferred natural features.

Cartographic evidence suggests that Plot B was being quarried for clay by the 1820s. In subsequent decades, continued extraction expanded the clay pit across most of Plot B, thereby removing any remains of earlier activity. Plot A appears to have been completely undeveloped until 1832.

Chapter 3
Coronation Street and Adelaide Place, 1832–9

Historical Background

Bedminster

Between 1831 and 1841, the population of Bedminster grew from 13,130 to 17,862 (Anon 1884a, 73; Lewis 1835). Maps of the period show housebuilding on the low-lying land alongside Bedminster Parade and to the east of Mill Lane, including the hitherto undeveloped Lower Paddock meadow (Plot A). Bedminster had been a *de facto* suburb of Bristol since the late 18th century: this was formally recognised by the expansion of the city boundary to include the 'village' of Bedminster in 1835 (Little 1963, 8; Vincent 2022, 27).

There were various improvements to Bristol's transport infrastructure in the late 18th and early 19th centuries, notably the development of turnpike roads, the creation of the Floating Harbour, and the construction of the first railways in the late 1830s. On the 19 May 1836, the newly formed Bristol and Exeter Railway Co. obtained royal assent for the construction of railway between these cities (Tuck 1848, 217). Planning and construction of the new line, which ran along Malago Vale at the foot of Windmill Hill, was slow, and in 1839 the directors signed an agreement for the Great Western Railway Co. to complete the line and operate it on their behalf (MacDermot 1927, 151, 162; 1931, 130).

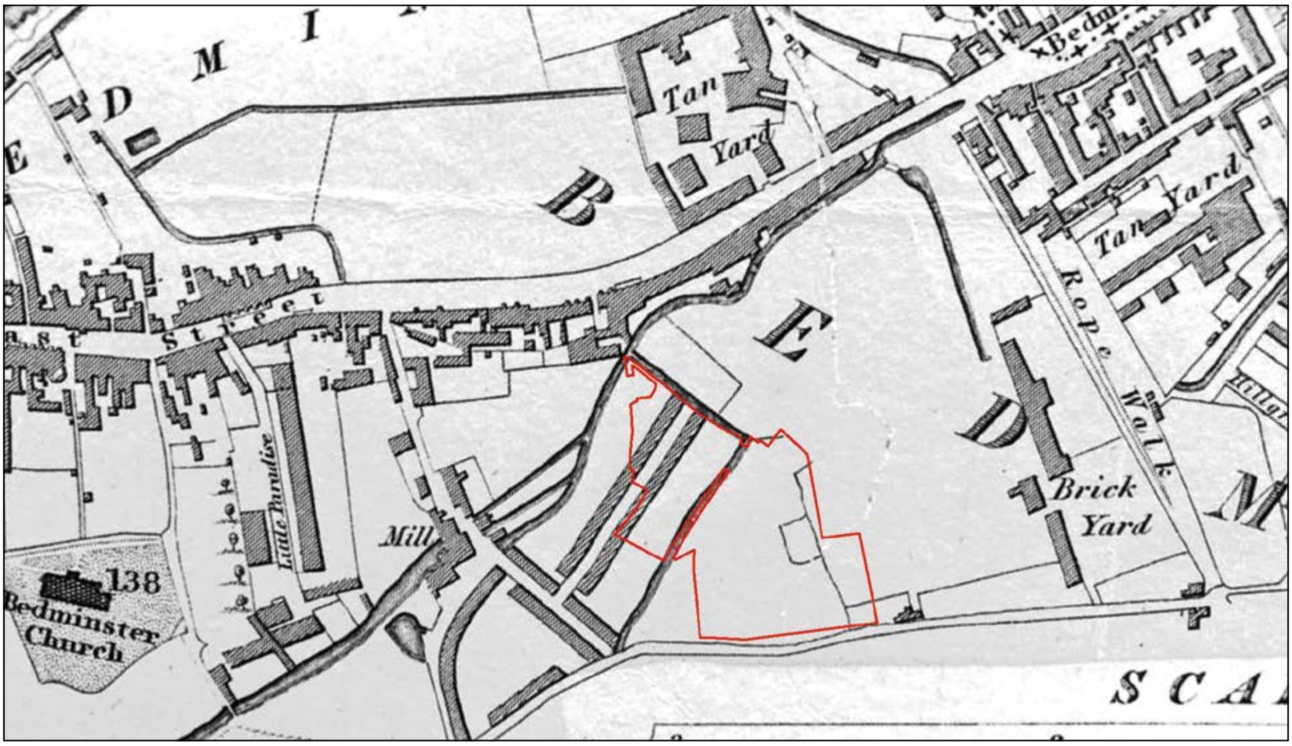


Figure 3.1 Plan of Bristol and its suburbs, reduced from the original survey of the late J. Plumley with additions by Geo. C. Ashmead, 1833. Reproduced with the permission of Bristol Museums

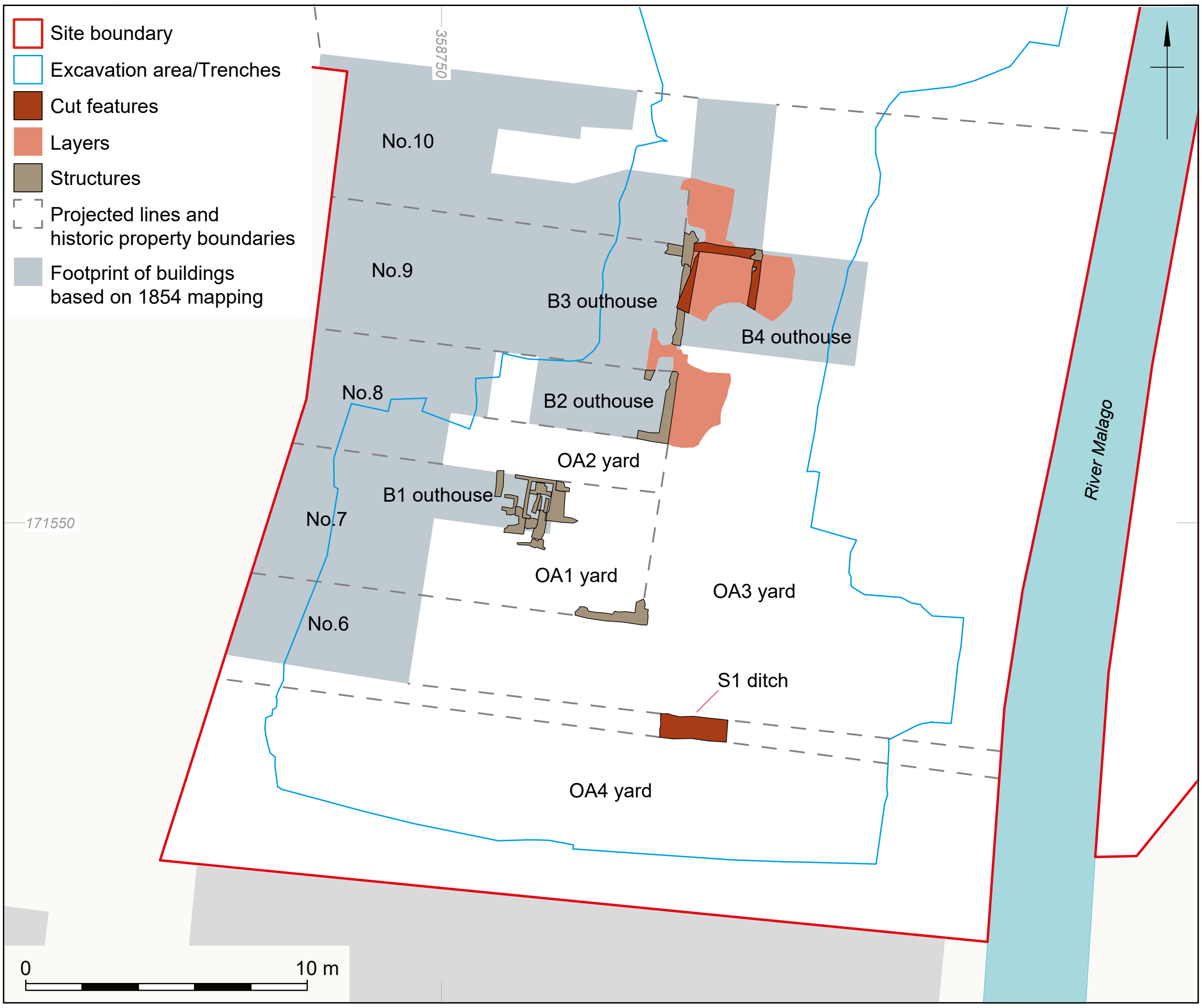


Figure 3.2 Archaeological features, 1832–9

Coronation Street and Adelaide Place

Development of Plot A began in 1832 with the laying out of a short cul-de-sac with a dog-leg at its northern end. The main part of the road was named Coronation Street; the north end was called Adelaide Place. Both were named after the coronation of King William IV and Queen Adelaide on the 8 September 1832. Ashmead's plan of 1833 (Fig. 3.1) shows terraced buildings along these streets. These are referred to in an 1832 advertisement for the sale of fee farm rents (annual rent charges) for '*several freehold messuages situate in Coronation Street, Bedminster*' (BTM, 15 Sept 1832, 2). The inhabitants of these houses are likely to have been poor: none were eligible to vote, and the names and occupations of the 1830s residents are unknown.

Archaeological Remains

The earliest archaeological features comprised the foundations of outbuildings and other structures to the rear of 7–10 Coronation Street (Figs 3.2 and 3.3). These structures, which were heavily truncated by later features, included an outhouse (B1) and associated brick-lined drainage system and garden wall to the rear of 7 Coronation Street; the walls of another outhouse (B2) behind No. 8; and an extension (B3) and outbuilding (B4) to the east of No. 9. The 1830s buildings were predominantly constructed of stone, with some brick details, all bonded with pale grey lime mortar. The buildings were aligned east–west and north–south.

Figure 3.3 Orthographic plan from photogrammetric model, showing archaeological features, 1832–9

Brick- and stone-built outhouse B1 measured 2.5 x 1.9 m wide and incorporated a contemporary stone-lined drainage system, probably for a primitive water-flushed privy and/or washhouse sink. There were no indications of any paved surfaces within the building. Building B2, which measured 2.5 x over 1 m, was built of stone and was probably also used as outhouse. There were unpaved yards (OA1 and OA2) to the south of these buildings.

Outbuilding B4 was divided into two rooms, measuring 3.2 x 2 m and 3.2 x over 1.3 m wide internally. It had stone walls and a clay 'beaten earth' floor. There were no industrial residues or other indications as to how the building was used, and it may simply have been a storage shed. The original foundations of outbuilding B4 were cut by the construction trench for a wall on the same alignment as the first; this probably represents a partial rebuilding of the structure, perhaps due to a structural failure of the original building. Outbuilding B4 was abutted to the west by an extension (B3) to 9 Coronation Street. Cartographic evidence suggests that the yard (OA3) in which building B4 was located was associated with 6 Coronation Street.

The southern boundary of 6 Coronation Street was defined by a 0.9 m wide and 0.35 m deep east–west aligned ditch (S1). The land to the south of the ditch (OA4) appears to have been undeveloped in the 1830s. Ditch S1 was infilled with a ground-raising dump associated with the development of the smelting works in the 1840s and early 1850s (see Chapter 4).

Discussion

The archaeological remains of the 1830s houses along Coronation Street were sparse and heavily truncated by later activity. The houses had shallow stone foundations and are likely to have been simple two-up two-down Georgian terraces with parapet frontages and butterfly roofs. There are no known documentary records related to the residents of these houses during the 1830s and the census returns of 1841 and 1851 do not clearly differentiate between the inhabitants of these streets and nearby Paul Street. Census returns of 1861 (Table 3.1) show that later inhabitants were of modest means, and it is likely that the occupants were always relatively poor (the most common male occupations in 1861 were labourer and coal miner, while the most common female occupations were laundress and servant).

No cesspits or wells were identified. This, coupled with the presence of a drainage system, possibly for a water-flushed privy, could be interpreted as evidence that the houses were linked to a piped water supply and sewage system from the outset. However, the provision of such utilities was far from universal in the 1830s, particularly for poorer residents in outlying districts such as Bedminster. The adjacent river would have provided a means of drainage and a ready, if potentially polluted, source of water.

Table 3.1 Adult occupations in Coronation Street and Adelaide Place in 1861

Male occupation	No.	Female occupation	No.
Baker	1	Laundress	7
Blacksmith	1	Parish relief	1
Coal haulier	2	Servant	3
Coal miner	6	Staymaker	1
Carter	1	Tailoress	2
Cattle dealer	2		
Costermonger	1		
Fireman at gas house	1		
Engine driver	1		
Lead and brass smelter (employer)	1		
Labourer	5		
Labourer (blacksmith)	1		
Labourer (brass works)	1		
Labourer (gas works)	2		
Labourer (tannery)	3		
Mason	1		
Milkman	1		
Railway porter	1		
Shoemaker	1		

CHAPTER 4
CAPPER PASS II AND THE BEDMINSTER SMELTING YARD, 1840–70

Historical Background

Bedminster

By the 1840s, Bedminster had become a large suburb with numerous streets of terraced houses, shops and industrial premises. The opening of the Bristol and Exeter Railway in 1841 provided a direct line from Bristol Temple Meads to Bridgwater, but there were no stations in Bedminster. Over the following decade, the population of the parish grew steadily from around 17,862 in 1841 to 19,429 in 1851 (Anon 1884a, 73). This growth is reflected by maps of the period (Figs 4.1 and 4.2), which show a gradual expansion of the settlement. Lavar's map of *c.* 1863 (not illustrated) shows a similar pattern of development, but from this date onwards, Bedminster began to expand at a very rapid rate, and by 1870, the suburb had changed beyond all recognition. Gone were the open fields and market gardens, and in their place were rows of terraced houses interspersed with large industrial premises with tall chimneys that blanketed the Malago Vale in coal smoke. The houses in the low-lying districts were mostly built in the late Georgian parapet-fronted style, whereas in Southville, away from the bustle of industry, there were more refined streets of detached and semi-detached Victorian-style villas. Windmill Hill became another focus for better-quality housing, though in this instance, the streets were lined with bay-fronted Victorian terraces.

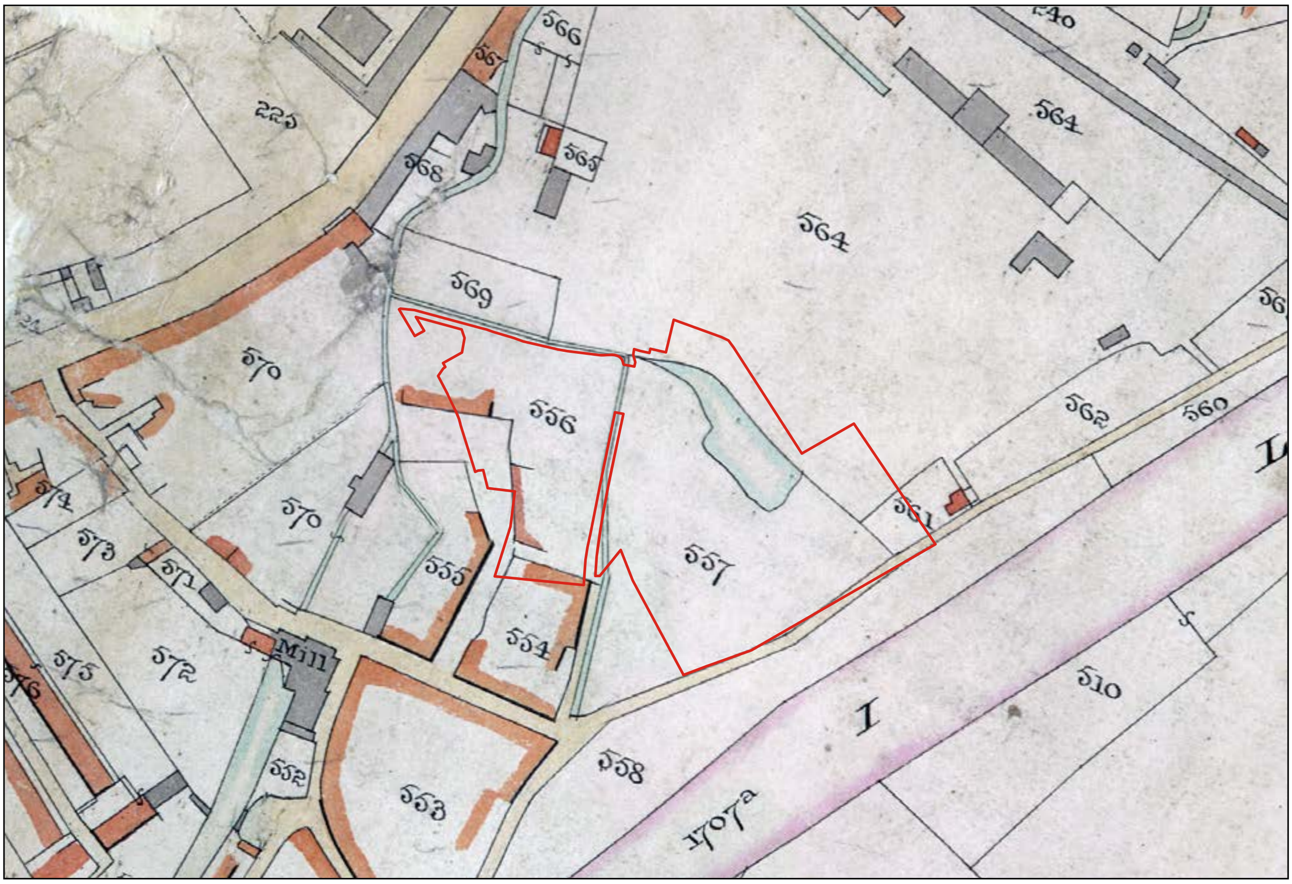


Figure 4.1 Bedminster Tithe Map, 1841. Reproduced with the permission of Bristol Archives

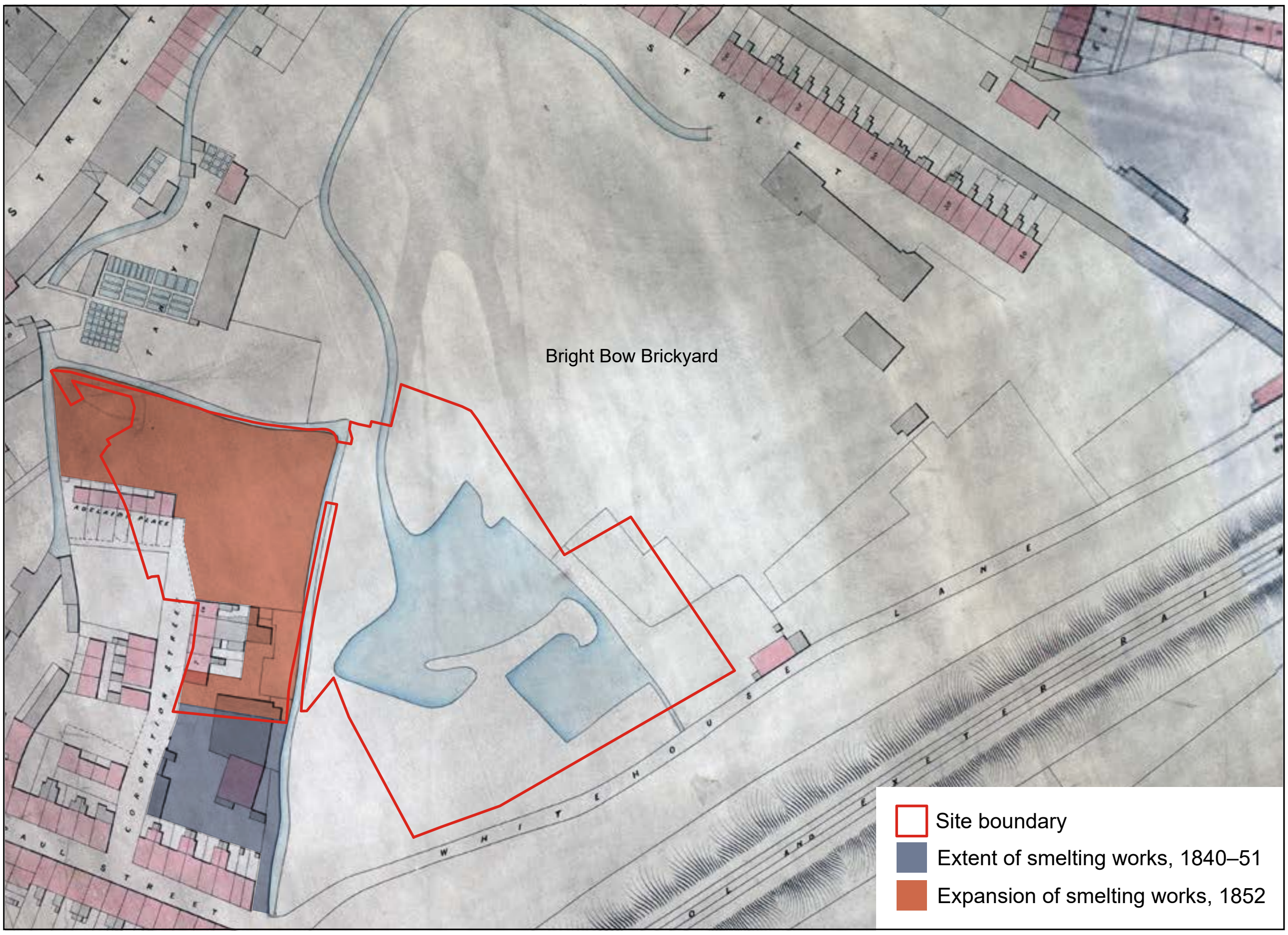


Figure 4.2 George C. Ashmead's Map of the City and Borough of Bristol, 1854. Reproduced with the permission of Bristol Archives

Bedminster Smelting Yard

In 1840, the metal refiner Capper Pass II (see Chapter 10, 'The Pass Family') purchased a vacant plot on the east side of Coronation Street. The property deeds state that the land measured 81 x 103 ft (24.7 x 31.4 m) and would be used for the construction '*of at least one substantial messuage or dwelling house*' and a smelting yard containing a '*lofty chimney with furnaces and workshops*' (Little 1963, 8–9). Pass's house, which was completed in August 1841, was a detached double-pile late Georgian-style cottage. Historic maps and photographs (Figs 4.3 and 4.4) show that the yard to the west of the house was used as a store for valuable metal ingots. To the east, there was a small garden with views over the Malago and claypits of the adjacent Bright Bow Brickyard.

During the 1840s, Pass processed various types of non-ferrous scrap metal and extracted lead from ashes and dross. He also refined silver from unwanted or damaged Sheffield plate (silver-plated copper) and gold from gilded buttons and utilitarian items like keys and seals. The smelting was probably undertaken using crucible and small reverberatory furnaces. In 1852, he purchased land to the north of his original workshop and subsequently erected his first blast furnace there. Initially, this was used to process Cornish lead ores, but the quality was variable and increasingly hard to source because of the decline of the Cornish lead mining industry. Pass subsequently moved on to processing residues and secondaries such as zinc slag, lead ashes, lead sulphate, leaded paper from tea chests, and scrap metal. The metals recovered (mostly lead and copper of inconsistent quality) were sold for a small profit. The business was still small at this date: in 1853, the workforce grew from six to seven (Little 1963, 9–12).

Ashmead's plan of 1854 (Fig. 4.2) shows individual buildings within the smelting yard, along with a row of seven houses along the north side of Adelaide Place and two rows of houses on Coronation Street: four on the west side and five on the east, with various non-domestic structures and Pass's house (to the south of the excavation area) set back from the road frontage. By 1855, the enlarged smelting yard had been named the Bedminster Smelting Works (*ibid*., 9).

During the late 1850s and 1860s, Pass experimented with the extraction of a variety of metals, including coppery materials of low metal content, scrap zinc and brass, and pan scum (a residue from softening tin). Solder ashes were also imported from Ireland and hardhead (a compound of tin, iron and arsenic) was brought in from Cornwall (*ibid*., 9–12). By the late 1860s, the company was importing raw materials from Europe: lead and zinc ashes and potash from the Netherlands, lead oxide from Belgium and lead sulphate from France (WDP, 26 June 1868, 4; 13 October 1868, 4; 29 January 1869, 3; 5 October 1869, 4; 30 November 1869, 4; *BTM*, 8 January 1869, 3). Some of the raw materials were treated in a reverberatory furnace, but the bulk was fed into the blast furnace, which operated 12 hours a day. Two working lists, both dating from 1870, give an insight into the operation of the blast furnace during Capper Pass II's tenure. Blast furnaces require a continual flow of blown air: this was provided by a steam-powered blower, operated by an engineman (paid 4*s* a day) and a boilerman (3*s* 6*d*). The furnace itself was operated by a furnaceman (5*s*), tapping man (3*s* 6d) and two slag men (3*s*). Feeding the furnace was a continual process, and men normally employed elsewhere in the works were tasked with bringing materials and fuel to the top of the furnace while the others had meal breaks. Cheap coal was available from local collieries, and similarly inexpensive coke could be purchased from the nearby Ashton Vale Iron Co. (Little 1963, 11).

Figure 4.3 West side of Capper Pass II's house, looking east. Built in 1840 and photographed c. 1910

Figure 4.4 East side of Capper Pass II's house, looking north-west. Built in 1840 and photographed c. 1910

Capper Pass II learnt his trade working in the family workshop. New processes were developed by trial and error with little in the way of scientific insight into the chemistry of the materials he processed. Pass's son Alfred benefited from a formal education, including lessons in chemistry, which he applied when he came to work with his father. By 1864, raw materials were being assayed by external firms of varying reliability, and in 1870 an assayer named Read was directly employed at the works (*ibid*., 10).

In September 1866, the Passes found a product, a lead–tin alloy used for solder, which could be reliably produced in commercial quantities and sold at a good profit. In recognition of his son's contribution to the business, the firm was renamed 'Capper Pass & Son'. Solder was produced by smelting pewter and solder ashes in a reverberatory furnace, with a little soda ash used as a flux (*ibid*., 10–12). This process, known as the 'P Tinalloy Process of 1866', allowed the company to produce a master alloy of guaranteed composition. It is described in the company's *Business Experiment Book*:

> *The metal produced from the above was drained as usual in the furnace and then treated as follows: melted in a pot containing about five tons, until a rim had solidified all round the pot. By watching until the right time arrived, and repeatedly pouring sample bars into a mould, it ultimately came to a certain quality of metal, very fluid and clean at a low temperature and uniformly the same. When this quality was reached, it was rapidly ladled out into pigs, and a quantity of thick stuff of very inferior quality remaining at the bottom and sides of the pot' (ibid., 10–12).*

Capper Pass II died in 1870, leaving his son Alfred as head of a successful business with 36 employees (census 1871).

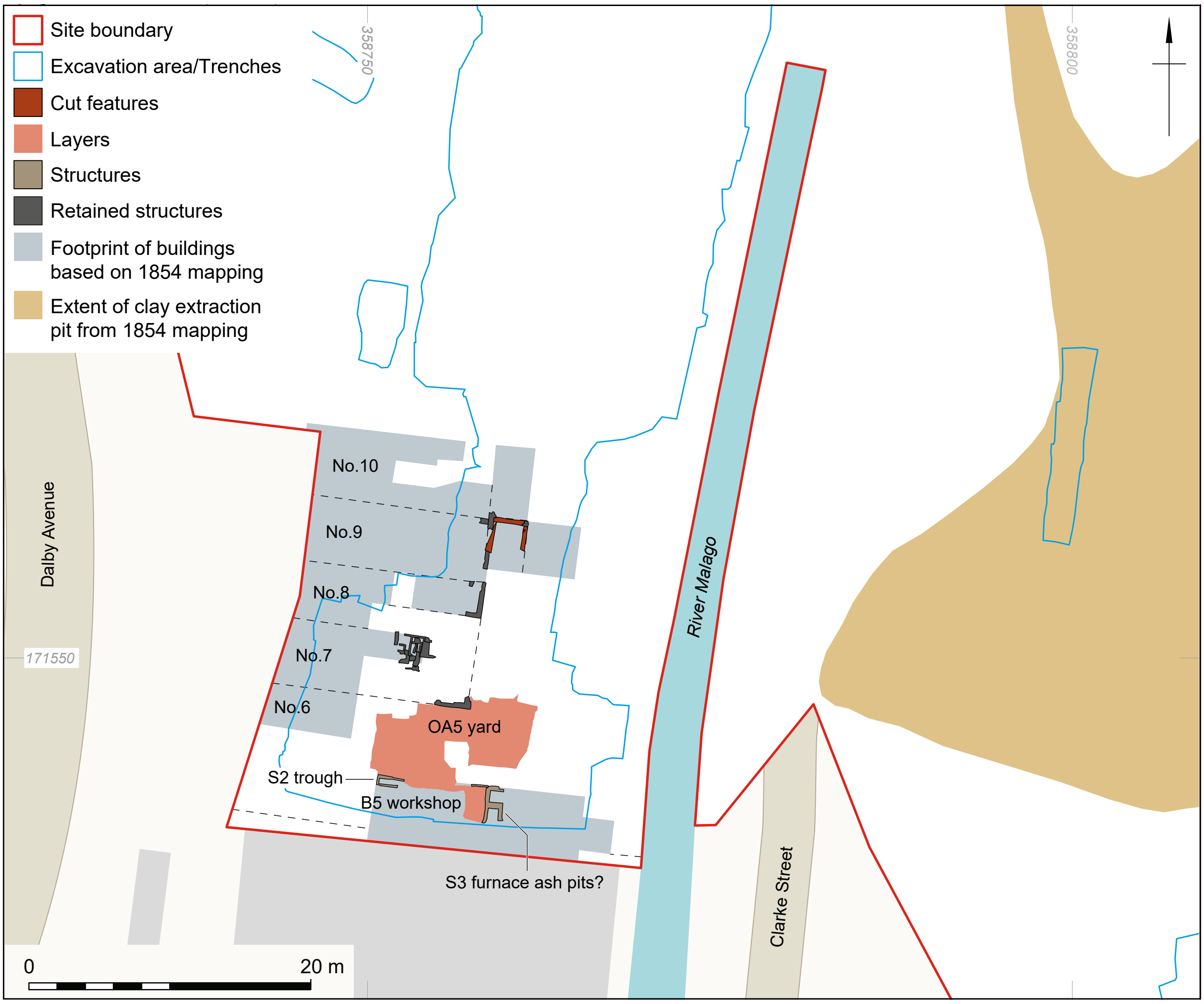


Figure 4.5 Archaeological features, 1840–54

Archaeological Remains

1840–54

The earliest part of Capper Pass II's smelting yard (i.e., the plot he purchased in 1840) was located to the south of the excavation area. In 1852, Pass purchased additional land to the north of his existing workshop. This area was initially used as a yard (OA5; Figs 4.5 and 4.6), which was surfaced with an extensive dump of clinker, stone rubble and industrial waste. The latter included a deposit of improved stoneware pottery wasters (see Chapter 9, 'Powell's Pottery Waster Dump').

By 1854, Pass had erected a small workshop (B5) within yard OA5. The fragmentary remains of this building comprised a shallow and insubstantial line of brickwork: possibly a plinth for a timber-framed wall. The north-west corner of the building was defined by a narrow (0.4 m wide by 1.75 m long internally) trough-like brick structure (S2), which had single-skin brick walls along its north, west and south sides, but none at the east end. The base was unlined. The function of this trough is unknown.

The only other structure within building B5 was a 0.6 m deep stone-lined pit (S3; Fig. 4.7), which was split into two cells, both of which measured approximately 1 x 0.8 m wide internally. The northern cell was open to the east; it is unknown if the southern compartment was open to the south, as its edge lay beyond the limits of excavation.

Figure 4.6 Orthographic plan from photogrammetric model, showing 1840–54 archaeological features

Figure 4.7 Twin-cell structure S3, with flue S4 to the rear, looking north-east. Scale: 0.5 m

The function of this structure is uncertain, but it is possible that the two cells were ash pits for small, above-ground crucible furnaces. This interpretation is supported by the presence of an accumulation of ash within structure S3. Analysis of the ash (see Chapter 8, sample 13), showed that it predominantly comprised particles of clinker, coal dust and partially burnt coal.

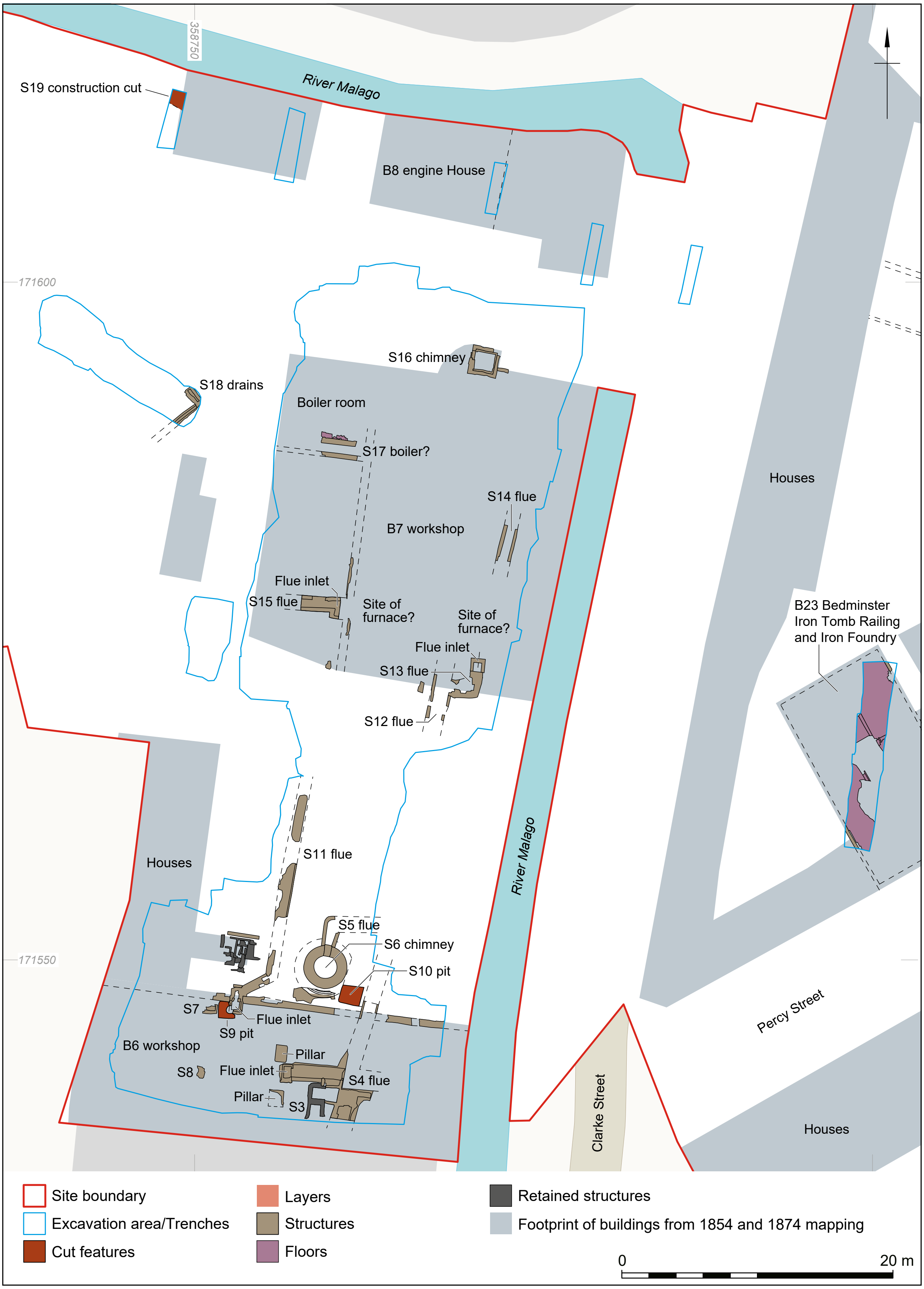


Figure 4.8 Archaeological features, 1855–70

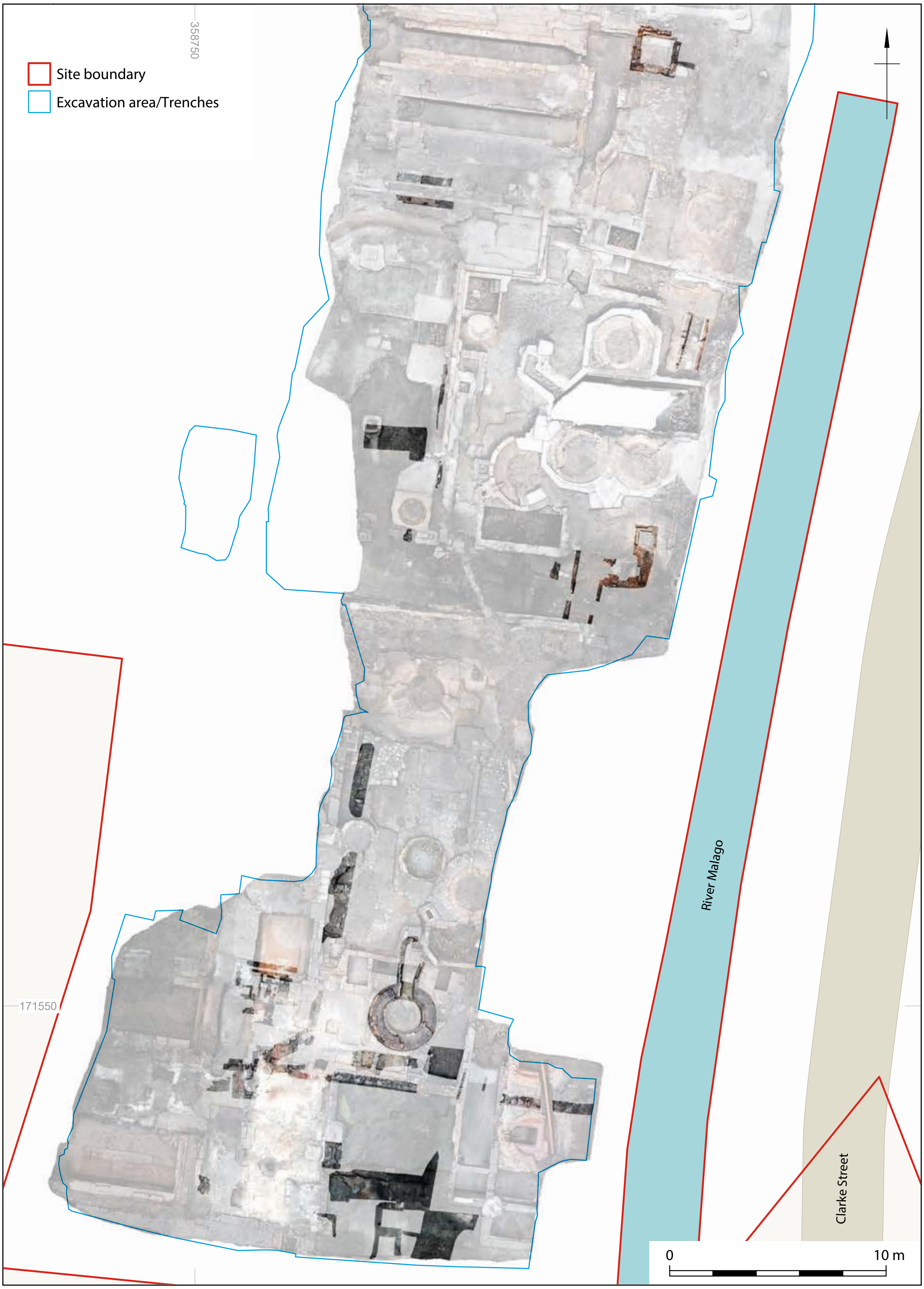


Figure 4.9 Orthographic plan from photogrammetric model, showing 1855–70 archaeological features

Figure 4.10 Flue system S4, looking south

1855–70

Cartographic and documentary evidence suggests that most of the land to the north of the 1840 workshop was developed after 1854. During this period, building B5 was demolished and replaced with a larger and more substantial workshop (B6; Figs 4.8, 4.9, 4.13, 5.13 and 5.14). A second large workshop (B7; Fig 4.8) was constructed to the north of 10 Coronation Street.

Building B6 measured 28 m east–west by over 10 m north–south. The northern edge of the building was defined by a 0.45 m thick sandstone rubble wall bonded with grey lime mortar. To the south of this wall, there were two large (1.2 x 0.85 m) rectangular sandstone rubble pillars. These would have supported the roof timbers and effectively divided the building into two rooms. To the east of the pillars, there was a subterranean brick-built flue system (S4; Figs 4.7 and 4.10). Flue S4 abutted possible furnace base S3 and had a ground-level inlet near the centre of building B6. This inlet is likely to have served an above-ground furnace immediately to the west of the pillars. All traces of this inferred earlier furnace were removed by a later reverberatory furnace (see Chapter 5). Flue S4 had a flat base, straight sides and an arched top. It was constructed of firebricks, bonded with red sand, and measured 0.8 m high x 0.7 m wide internally. The only direct dating evidence was a marked Rufford & Co. firebrick dating from 1802–1932. Flue S4 appears to have been used to channel smoke in a north-easterly direction and was probably linked to flue S5 and chimney base S6. Analysis of a vitrified firebrick from a relining of flue S4 (see Chapter 8, sample 14) showed that it contained oxides of arsenic, antimony, iron, lead, tin and zinc: all residues of metals that were refined on the site.

There were two other structures within building B6: a brick-lined pit (S7) and a brick foundation (S8). Both structures were heavily truncated, and their function is unknown. There was also a sub-rectangular pit (S9) of unknown purpose.

To the north of building B6, there was a substantial circular chimney base (S6; Figs 4.11 and 4.12). An annotation on the 1896 Goad Fire Insurance Plan (Fig. 5.4) shows that this chimney was 120 ft (36.6 m) high. The surviving elements comprised a 4.4 m wide circular foundation that supported the 3.2 m wide chimney, all built of curved red bricks bonded with grey lime mortar. The internal shaft had a diameter of 1.7 m and there was a single opening for a 0.53 m wide by over 0.5 m high flue (S5) on the north side. The east side of the chimney was partially cut by a sub-rectangular pit (S10) that measured over 3.7 m by over 1.8 m wide. The depth and purpose of this pit are unknown.

Figure 4.11 Chimney base S6, flues S5 and S22 and structure S31, looking south. Scale: 1m

Figure 4.12 Chimney base S6 and flues S5 and S22, with yard OA7, solder pot S30 and iron tank S43 in the background. Looking north

To the west of chimney S6, there was another subterranean flue (S11; Figs 4.13 and 4.14), with an opening on the northern edge of building B6. Flue S11, which measured 0.56 m wide and over 0.6 m high internally, would have channelled smoke northwards. The flue was probably originally linked to chimney S6 via a manifold, but the link between the two was truncated by later activity. There was a slight dog-leg at the southern end of flue S11, probably to avoid the outhouse (B1) to the rear of 7 Coronation Street. Documentary evidence indicates that this property was demolished *c.* 1873, which suggests that flue S11 and its associated furnace were constructed before this date. Flue S11 was partially truncated by flue S21 (see Chapter 5).

Building B7 was constructed sometime after 1854. Due to the intensity of later activity, very little of this building or the structures within it survived and those that did were very fragmentary (Fig. 4.8). The surviving remains comprised short lengths of external and internal walling, built of sandstone rubble and brick bonded with grey lime mortar; three subterranean flues (S12–S15); and a square chimney base (S16). The chimney, which is depicted on the 1896 Goad Fire Insurance Plan (Fig. 5.4) as a 100 ft (30.5 m) high structure, measured 2.1 m square externally and 1.5 m square internally and was constructed of red brick bonded with sandy lime mortar, with unmarked firebricks lining the interior. It was abutted to the west by a later flue manifold (S37) serving a pair of c. 1883–96 steam boilers (S36; see Chapter 5). Structure S16, which comprised a line of brickwork and a paved area, is interpreted as the fragmentary remains of a contemporary steam boiler base; most of structure S16 was truncated by steam boiler base S27 (see Chapter 5).

Figure 4.13 Buildings B1 and B6 and flues S11 and S21, looking north-east

Figure 4.14 Outhouse B1 and flues S11 and S21, looking north

Flues S12–S15 were all constructed of firebricks. There were openings at the east end of flue S15 and the north end of flue S13, which suggests there were furnaces in these locations, though all trace of them had been removed by later activity. Flues S12–S15 may have been linked to chimney S6 via flue S5, though this could not be confirmed. The flues were primarily built of unmarked and undiagnostic firebricks. The only marked example was a c. 1852–1968 firebrick made by Harris & Pearson, which provides some dating for flue S13. Analysis of the dust coating the interior of flues S11 and S13–S15 (see Chapter 8, samples 6, 9, 11 and 12) showed that it predominantly comprised particles of clinker, coal dust, partially burnt coal, and brick dust. Particles rich in a variety of non-ferrous metals were also present. When it became disused, flue S13 was infilled with large boulders of lead-rich blast furnace slag (see Chapter 8, sample 17).

Drains S18, which were situated in the yard (OA6) to the west of building B7, were constructed using bricks and limestone slabs bonded with a soft brown lime mortar. They channelled surface water towards a public sewer below Coronation Street, which is depicted on Ashmead's plan of 1874 (Fig. 5.1).

A construction cut (S19) for the Malago river wall was exposed at the northern end of the site (Fig. 4.8). The only direct dating for this feature were lumps of greyish lime mortar that were visible in the backfill. The river wall is tentatively dated to the period *c.* 1852–70 based on its height, which correlates with the elevated ground level associated with the expansion of the smelting works in this period.

At the northern end of the site, the surface of the pre-1852 meadow was overlain by a 0.45 m thick dump of concreted slag. This formed a base for the foundations of an 1850s engine house (B8), which was constructed of large stone blocks bonded with lime mortar.

Discussion

The earliest part of the smelting yard, dating from 1840, lay beyond the limits of the excavation. To the north of this, there was an open yard, which was purchased by Capper Pass II in 1852, along with a larger parcel of land to the north. Nos 6–10 Coronation Street may have been acquired as part of this deal, or during a later undocumented transaction. The earliest smelting works building (B5) was an insubstantial structure, probably single storey and timber-framed, which contained two structures of uncertain use: S2 appears to have been some sort of trough; S3 may have been an ash pit for a pair of small crucible furnaces. Building B5 was probably built in 1852.

Nos 7–10 Coronation Street were occupied until *c.* 1873 and their presence clearly influenced the positioning of smelting works buildings B6 and B7, which were built between 1854 and 1873. The remains of buildings B6 and B7 were heavily truncated by later activity and, in most instances, the only evidence for the furnaces within them were the subterranean brick-lined flues and associated chimneys. Building B7 is not shown on Lavar's map of *c.* 1863 (not illustrated). This map lacks detail and is not as reliable as Ashmead's plans of 1854 and 1874, but it provides some evidence that building B7 was erected after *c.* 1863. Capper Pass II started using a blast furnace for the initial processing of raw materials sometime between 1852 and 1870. The location of the company's first blast furnace remains unknown, but if it was in building B7, it might not have been built until the mid-1860s. Structure S24 (see Chapter 5) is tentatively identified as the base of a blast furnace, but the use of black ash mortar rather than grey or brown lime mortar suggests that it post-dates Capper Pass II's tenure of the works. The blown air needed by the blast furnace would have been provided by a steam-powered blower. The engine for this apparatus was located at the northern edge of the site (B8). A probable steam boiler base (S16) was identified in building B7, though most of it was truncated by a later boiler base.

CHAPTER 5
'WE MUST KNOW WHAT WE ARE DOING': BEDMINSTER SMELTING WORKS AND THE SECOND INDUSTRIAL REVOLUTION, 1870–1913

Historical Background

Bedminster

Coal mining continued to be an important local employer throughout the 19th century, but by the 1870s, other industries, including tanning, brickmaking, timber, brewing, smelting and building trades became increasingly important. The opening of Bedminster Railway Station in 1871 (Butt 1995, 20, 31) encouraged further housebuilding on the western slopes of Windmill Hill and provided a more convenient way for the district's suburban residents to travel. Some collieries had their own railway sidings, but there were no other passenger stations in Bedminster, which was a hindrance to further development, particularly in the western parts of the suburb. This situation was partially rectified by the opening of the Bristol Tramways & Carriage Co.'s horse-drawn tramway between Bristol Bridge and East Street in 1880 (*WDP*, 3 September 1880, 3). By 1899, the tramway had been extended southwards to Bedminster Down, and soon afterwards a second line was laid to Ashton Gate (*BM*, 21 October 1899, 1; *WDP*, 24 April 1902, 3). The trams were electrified soon after the opening of the tramway company's Temple Back generating station in 1900 (*BTM*, 2 November 1914).

By 1884, there were around 46,000 inhabitants in Bedminster parish (Anon 1884a, 83). Suburban growth continued throughout the late 19th and early 20th centuries, and in 1883, the district gained the first of its two large municipal parks: Greville Smyth Park in Ashton Gate. In 1888–9, most of the remaining undeveloped land on the east side of Windmill Hill was set aside for use as Victoria Park. The closure of the Dean Lane Colliery in 1906 and the redevelopment of its pithead as a park by Dame Emily Smyth provided another, slightly smaller, recreation ground. Development of suburbs broadened the social make-up of the area: while the low-lying districts amongst the factories of the Malago Vale were solidly working-class, the higher and less polluted areas, such as Windmill Hill, Southville and Knowle, had a mixed working- and middle-class population.

In 1886, the tobacconists W. D. & H. O. Wills opened their huge Factory No. 1 on the north side of East Street. This was followed by another large tobacco factory in Ashton Gate in 1900. The following year, W. D. & H. O. Wills and 13 other tobacco companies amalgamated to form the Imperial Tobacco Co. The new company built additional tobacco factories in Bedminster, and by the early 1900s, roughly 2000 people were employed by the local tobacco industry (Penny 2005, 105). In 1887, the tobacco factory was joined by another major employer: the paper, printing and packaging company E. S. & A. Robinson, who constructed a large factory at the south-west end of East Street. By the early 1890s, E. S. & A. Robinson had 800 employees (*ibid.*, 134–5).

In 1897, a further swathe of Bedminster parish, including large areas of undeveloped farmland, was formally incorporated into the administrative bounds of Bristol (La Trobe-Bateman 1999, 3–4). By the turn of the century, Bedminster, which had a population of around 70,000 (Taylor and Shapland 2012, 11), formed part of a contiguous area of suburban development that extended from Ashton Gate in the west and Bedminster Down in the south, to Knowle and Brislington in the east. There were factories throughout the district, but there were also areas of quiet suburban housing.

Tobacco, paper and printing, coal mining and tanning were all major employers, but there were also numerous smaller enterprises including a pigment works, glue factory, shipyard, sawmills and two iron works.

Bedminster Smelting Works

In 1870, Alfred Pass (see Chapter 10, 'The Pass Family') inherited his father's successful but still relatively small business with 36 male employees (census 1871). These men kept a single blast furnace operating 24 hours a day, and one or more reverberatory furnaces, which were used when needed. The main output of the works was lead and lead–tin alloy, used for solder. Tin was extracted from Cornish tin slag and hardhead (a tin-iron compound) and 'black slag' from South Wales. Lead was obtained from lead ashes, lead cupels, and most significantly, tailings and slimes from lead mines on the Mendip Hills in Somerset. The mines of Charterhouse-on-Mendip have Roman origins, and Alfred Pass discovered numerous Roman artefacts amongst the mining debris. During the 1870s, experimental work was undertaken on copper slags, regulus (metallic antimony or the end product of ore smelting), nickel, lead sulphate from alkali works, 'hard ashes', 'irony and tin lumps', 'calcined irony material', type metal (used in letterpress printing) and 'German arsenal stuff'. The latter comprised surplus munitions and weapons from the Franco-Prussian War of 1870–71. A material known as 'Greek fume' was also processed to produce lead and nickel. This was probably imported from the mines of Laurion, in the Kingdom of Greece (Little 1963, 12, 14–15, 17–18).

In 1871, the Pass family briefly moved to Weston-super-Mare, and it was here that Alfred's sister, Lydia Pass, married one of her brother's employees: a metal smelter named Alfred Trapnell. He would go on to become an important figure in the company, and eventually became a co-partner in 1894 (census 1871; Little 1963, 18; Vincent 2022, 21–2).

The houses along the east side of Coronation Street and Adelaide Place were still occupied in 1871, and the census of that year provides detailed information about their inhabitants (Table 5.1). The houses were all occupied by single family households of between two and nine individuals. Only one of the men, furnaceman William Barnfield, was an obvious employee of the smelting works, though other records show that labourer George Tapp (who lived in Capper Pass II's old house) was the works foreman. Three of the other men are recorded as labourers and may also have been employees of the smelting works. The rest of the men had a variety of manual occupations: saddle and harness maker, glue maker, painter, blacksmith, joiner and two hauliers. Half of the women had no listed occupation, indicating they were doing unpaid domestic work at home; the other half worked in a variety of low-paid jobs (in addition to domestic chores). Their recorded occupations are charwoman, dressmaker, milk seller, paper seller, tailoress and two laundresses. Most of the under-12s were in school, though one 11-year-old was employed as an errand boy.

Male occupation	No.	Female occupation	No.
Blacksmith	1	Charwoman	3
Bootmaker	1	Coal seller	1
Cabinet maker	1	Dairywoman	1
Coal miner	2	Dress maker	1
Coal seller	1	Invalid	1
Cordwainer	1	Laundress	4
Furnace man	1	Machinist	2
Glue maker	3	Milk seller	1
Haulier	2	Paper sorter	1
Joiner	1	Servant	2
Labourer	5	Tailoress	1
Mason	1		
Painter	1		

Table 5.1 Adult occupations in Coronation Street and Adelaide Place in 1871

Ashmead's map of 1874 (Fig. 5.1) shows that all the houses along Coronation Street and Adelaide Place had been demolished by this date, and the northern part of the street had been subsumed into the smelting works. In 1875, Pass purchased the land between Coronation Street and the tail race of Bedminster Mill to the west. The 1874 plan shows this land as part of the smelting works, which suggests that it may have been leased prior to purchase. The plan also shows two large industrial buildings within the smelting works, with a large circular chimney between them and a smaller square chimney attached to the northern building. There was a further range of buildings (identified on later plans as an engine house and smithy) at the northern edge of the site, along with a cluster of industrial buildings around Capper Pass II's house to the south of the site. Interestingly, this house is depicted as an industrial rather than domestic building, perhaps indicating that it was not occupied when the works were surveyed.

In 1880, Pass had a new stable block and a two-storey metal store and office constructed on the east side of Coronation Street, just inside the works entrance (BA Building_plan/Volume_17/21b; Building_plan/Volume_17/44c). The office, which had a canted bay window on the first floor, is depicted in the background of a late 19th-century photograph of the company's workforce (see Fig. 5.7). Two years later, Pass purchased a tannery on the east side of Bedminster Mill tail race (Little 1963, 16). The tannery buildings are shown on the 1885 OS Town Plan (surveyed in 1883; Fig. 5.2). The 1885 plan also shows further development within the smelting works, notably large extensions on the north side of the southern building and the west side of the northern building, along with various tanks and ancillary buildings to the north-west. Edward Colston *Lavar's Bird's Eye View of Bristol* (Fig. 5.3) gives a general impression of the appearance the smelting works (in the foreground) and its environs in 1887. While some details of this illustration are inaccurate, it is notable that all the smelting works buildings are depicted with pitched roofs rather than the curved corrugated iron roofs depicted on the 1896 Goad Fire Insurance Plan (Fig. 5.4) and 1920s aerial photographs (Figs 6.2 and 7.5).

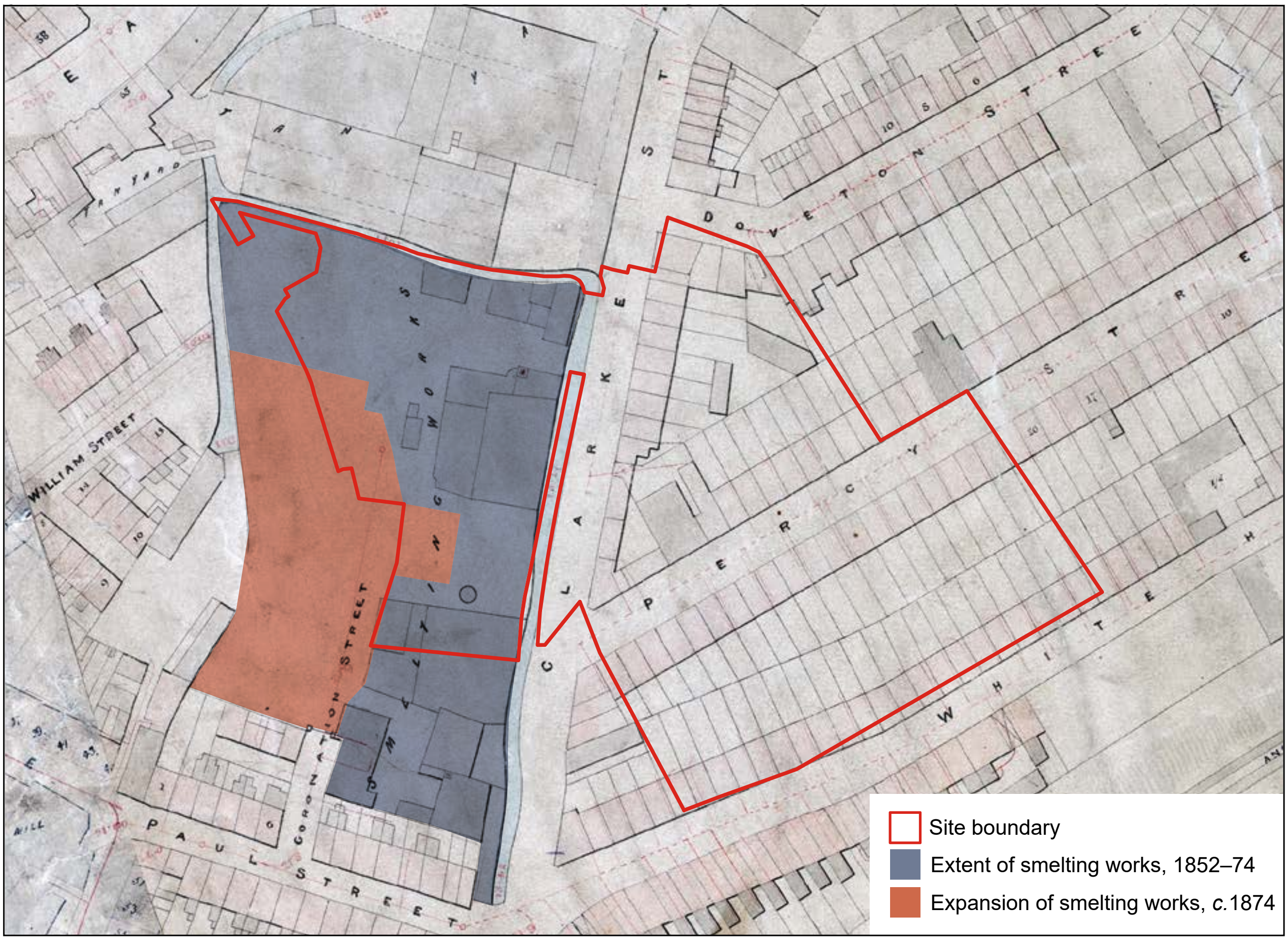


Figure 5.1 George C. Ashmead's Map of the City and Borough of Bristol, 1874. Reproduced with the permission of Bristol Archives

In 1883, Alfred Trapnell's nephew, Henry Caleb Trapnell, was appointed as the company's solicitor. Two years later, Henry Trapnell's brother-in-law, Stanley Hugh Badock, was employed to work on the technical aspects of the company's work. Badock was a young chemistry graduate from a wealthy family, who apparently rode to work on 'the highest penny-farthing in Bristol' (Little 1963, 18; Vincent 2022, 22). Henry Trapnell and Stanley Badock may be amongst the group of white-collar workers depicted in an 1880s/1890s photograph (Fig. 5.8).

The lower Malago Vale has always been prone to flooding, and in 1883 and 1889 there were particularly bad floods that inundated Mill Lane to a depth of 3 ft (1 m) above street level, no doubt causing extensive damage to the furnaces and halting operations for a time. Nearby residents were also badly affected, and to help dry their homes, Alfred Pass donated two sacks of coal per house (*BEP*, 17 July 1968, 32; BCC 2023, 17; Penny 2005, 69).

In 1895, Capper Pass & Son became a limited company with £120,000 of share capital. The following year, the company made £87,000 in profit and the shareholders (including Alfred Pass, who held most of the shares) were rewarded with a 25% yield. It was around this time that the company started importing tin concentrates from the Republic of Bolivia, which became available following the completion of a railway between Oruro and the Pacific coast in 1892 (Little 1963, 21–2, 24; Mitre 1981, 166–7). Between 1890 and 1910, Bolivia increased its output of tin concentrates from 1700 tons/year to 22,800 tons/year, which made it the world's second largest producer after British Malaya. However, the tin they produced was impure and was exported for refining, mainly in Europe. The concentrates were all exported, again mainly to Europe (R. Smith, pers. comm. 2024).

Figure 5.2 1885 OS Town Plan (surv. 1883). Reproduced with the permission of National Library of Scotland and British Library. https://maps.nls.uk

The Goad Fire Insurance Plan of 1896 (Fig. 5.4) depicts the smelting works in some detail but notes that admission to the works and all information about it was refused by the proprietors. It therefore seems likely that the plan was compiled using existing maps and/or observations from adjacent streets and properties. The 1896 plan shows how many storeys the buildings had, construction materials, and some details of their internal layout. The main works building comprised an agglomeration of various large sheds and extensions that had been constructed over the preceding 56 years. Many of the sheds were open sided for ventilation, and most were built of brick or timber. A few of the newer sheds were metal framed. The roofs were either pitched and tiled, or curved iron-tie roofs clad in corrugated iron. Some of the latter had large ridge vents for additional ventilation. The metal-framed buildings were all clad in corrugated iron. Four chimneys are shown on the plan, two of which were within the current development site. These are shown as being 120 feet (36.6 m) and 100 feet (30.5 m) high respectively. The Paul Street frontage was occupied by a two-storey brick office building. Apart from a small two-storey building in the north-east corner of the site (identified as a smithy on the 1885 OS plan), all the smelting works buildings were single storey, though 20th-century aerial photographs (Fig. 6.2) show that many were quite tall.

In the late 1890s, Alfred Pass purchased all the houses along Margaret Place and Margaret Gardens to the west of the smelting works. The houses were subsequently demolished, and a third blast furnace was constructed in their place, along with more open-sided sheds and a large brick chimney (Little 1963, 21–2). The new blast furnace was used to process Bolivian tin ores (R. Smith, pers. comm. 2024). The Goad Fire Insurance Plan of 1927 (Fig. 6.1) indicates that the new chimney was 150 ft (45.72 m) high. The extent of the works at the turn of the 20th century is shown on OS maps of 1904–5 (Fig. 5.5).

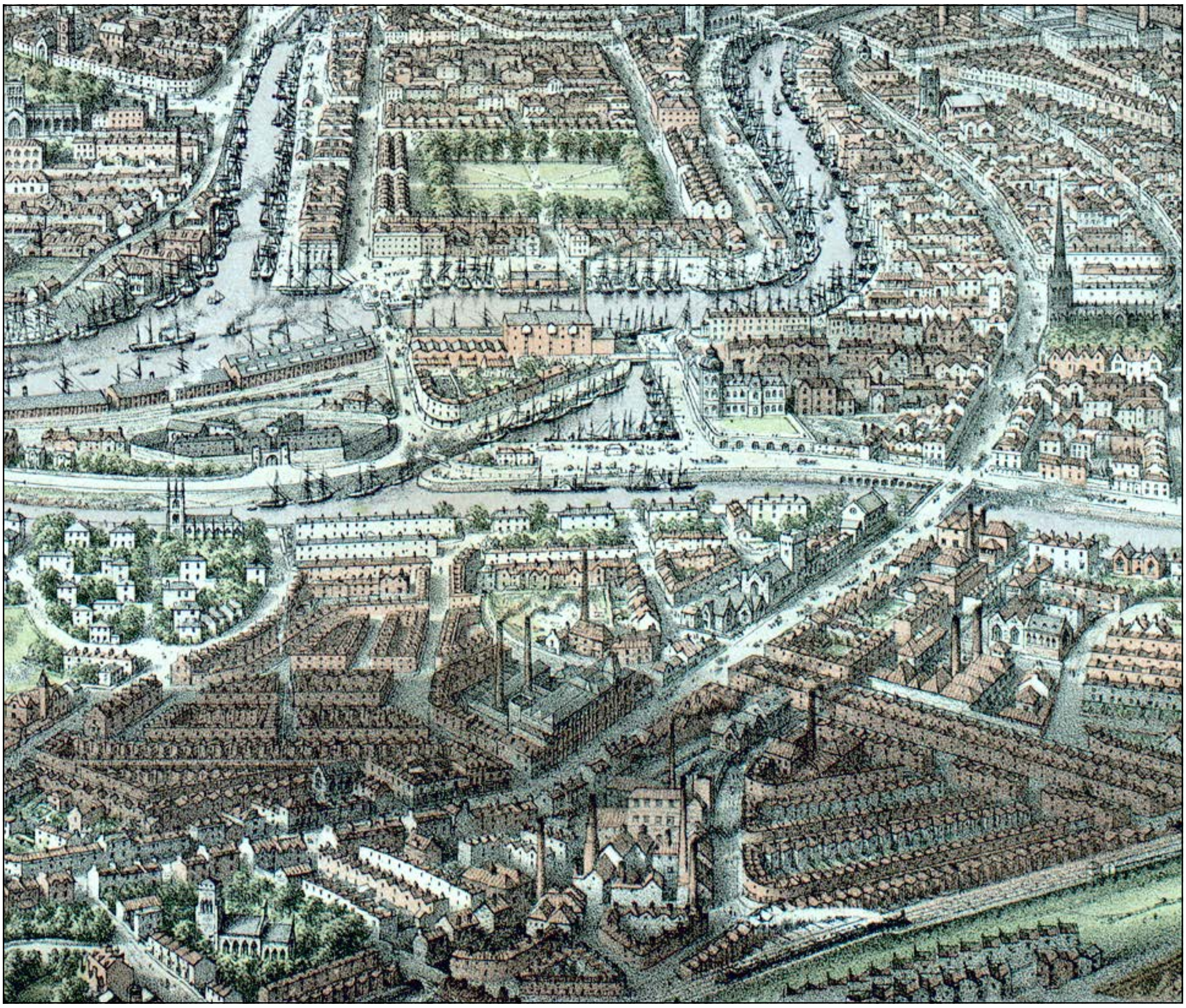


Figure 5.3 Extract from Edward Colston Lavar's Bird's Eye View of Bristol, 1887. Image courtesy of Bristol Museums

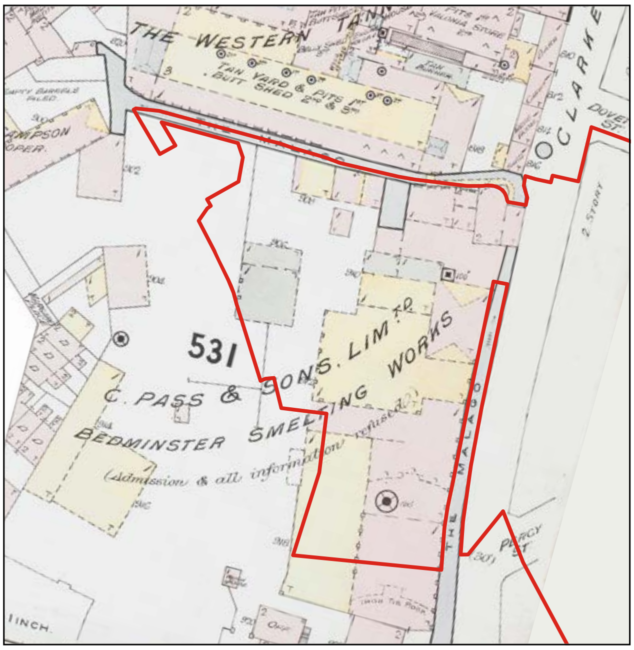


Figure 5.4 Goad Fire Insurance Plan, 1896. Reproduced with the permission of Bristol Archives

Alfred Capper Pass died at home in Wooton Fitzpaine Manor in 1905. His son, Alfred Douglas Pass, subsequently became Lord of the Manor and the majority shareholder of Capper Pass & Son Ltd. Although he maintained an active interest in the company, its day-to day management was overseen by Stanley Badock, who served as managing director from 1905 to 1936 (University of Bristol 2024).

In 1905–14, the company's main product was solder, though casting copper, soft lead and antimonial lead were also produced, along with copper sulphate derived from a coppery tin alloy known as metalline. Between 1907 and 1914, the company produced over 4000 tons of solder a year and profits remained high throughout the period (Little 1963, 24–5; Vincent 2022, 30). This facilitated further investment in the works, beginning in 1906 with the construction of a large two-storey store and tank room fronting onto Paul Street. This building had concrete stanchion bases that supported an iron-framed building, with brick walls, concrete floors, and a bowed iron-truss roof clad in corrugated iron

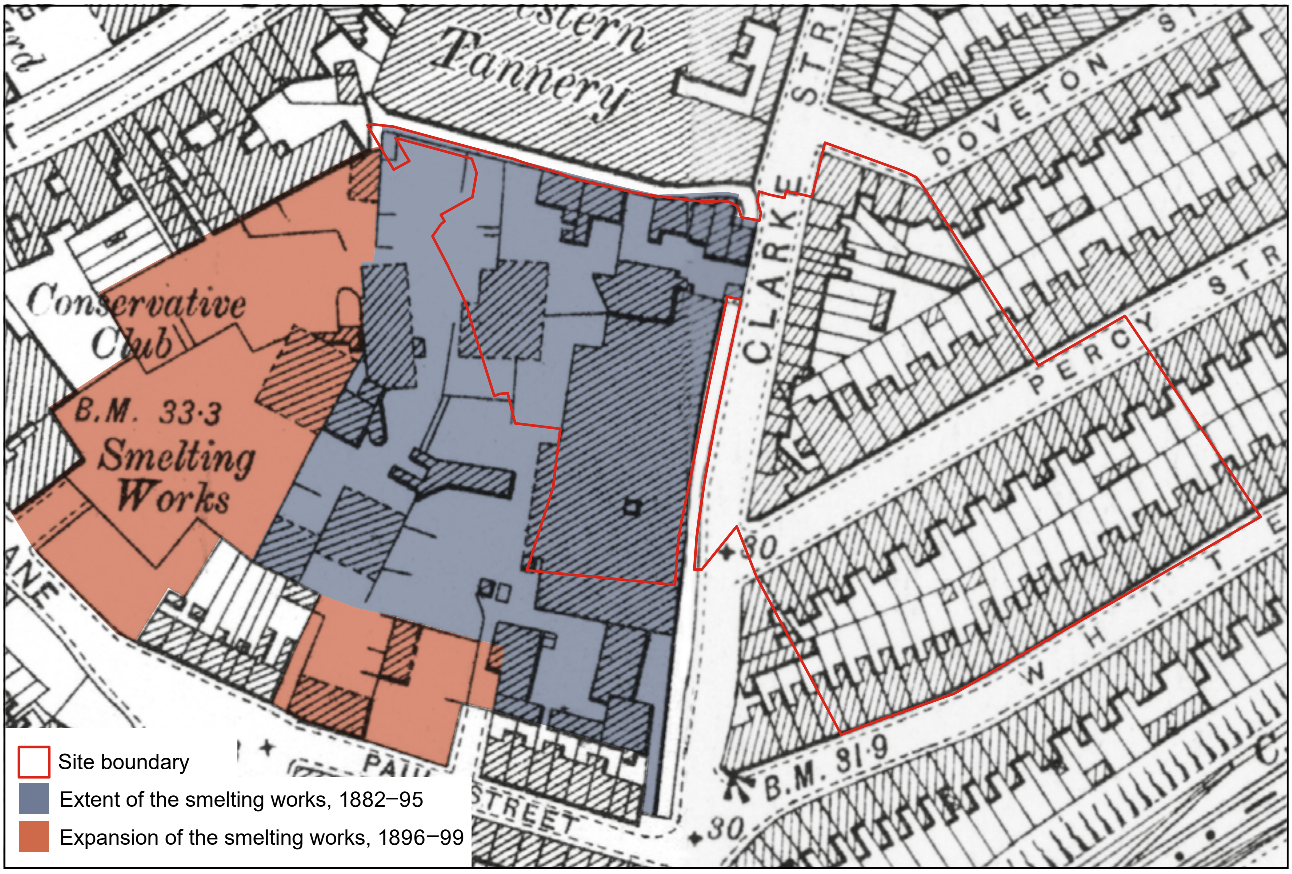


Figure 5.5 1904–5 OS plan (revised 1902). Reproduced with the permission of National Library of Scotland. https://maps.nls.uk

Figure 5.6 1918 OS plan (revised 1913). Reproduced with the permission of National Library of Scotland. https://maps.nls.uk

(BA Building_plan/Volume_51/50b). In 1908, electrical equipment and lighting was brought into the works, and a new office, designed by George Herbert Oatley, was built on the corner of Coronation Steet and Paul Street. The following year, Douglas Pass employed his university friend Paul Gottlieb Julius Gueterbock as head of research (Anon 1955, 35–6; Little 1963, 25; Vincent 2022, 30).

By 1908, it had become clear that the Bedminster site was too small for the needs of the expanding company, and the management began looking for new premises in and around Bristol. Sites were examined in Avonmouth, St Philip's Marsh, Keynsham and Brislington, but none were suitable. In 1909, the redundant Malago Brick & Tile Works came up for sale and Capper Pass & Son Ltd were able to acquire the eight-acre site, which was spread over two plots either side of nearby Shene Road. These, together with other smaller local purchases, more than doubled the company's landholdings in Bedminster. Initially, the main use of the Shene Road site, known within Capper Pass & Son Ltd as 'the Malago', was as a store for coal and metal residues awaiting treatment (Little 1963, 24; R. Smith, pers. comm. 2024).

The were further investments in 1912: a new blacksmith's shop and a two-storey mill shed were built, and all the timber buildings were replaced with iron-framed structures clad in corrugated iron to reduce the risk of fire (Little 1963, 24–5). The 1918 OS plan, which was surveyed in 1913, (Fig. 5.6) shows the extent of the smelting works on the eve of World War I.

The early 1910s were a period of major social unrest in Britain: the campaign for women's suffrage was becoming increasingly militant; millions of working-class men were still ineligible to vote due to property qualifications; and industrial disputes, collectively known as the Great Unrest, brought frequent strikes and sometimes violent confrontations between unionists and the authorities. The unrest was fuelled by anger at legal attempts to constrain the power of unions and a feeling that business owners were profiting at the expense of their workers. This resulted in a large uptake of union membership. There were no strikes at Capper Pass & Son Ltd in this period, but in 1913, between 60 and 70 of the 189 employees joined the National Union of Gas Workers and General Labourers. This union was subsequently, and probably reluctantly, recognised by the management (*ibid*., 25–6).

Figure 5.7 Workers at the Coronation Steet entrance to the Bedminster Smelting Works, photographed c. 1880s/90s. BMAG ref. P12546. Image courtesy of Bristol Museums and M Shed

Figure 5.8 Managerial and white-collar workers of the Bedminster Smelting Works, photographed c. 1880s/90s. BMAG ref. P10799. Image courtesy of Bristol Museums and M Shed

Archaeological Remains

1871–83

Smelting works building B6 was extended northwards in two phases (B9 and B10; Figs 5.9–5.12) between 1871 and 1883. Building B7 was also extended and adapted during this period. The new extensions were all constructed of red brick, bonded with black ash mortar, with yellow firebricks used in furnace linings and flues (see Chapter 9, 'Bricks').

Within building B6, there was a large (over 6.9 x 3.7 m) rectangular structure (S20; Figs 5.13 and 5.14), which is interpreted as the base of a reverberatory furnace that extended southwards beyond the limits of excavation: its total length is unknown. The structure comprised an area of heat-affected and extremely degraded firebricks, defined by an existing stone wall to the north, and a red brick wall to the east. The west side of the structure was defined by an area of brick flooring and a row of rectangular robber cuts, which had truncated pads of brickwork and embedded iron bars in their bases. These are interpreted as robbed-out mountings for iron ‘stay bars’: these would have bound the above-ground brickwork together as it expanded and contracted during heating/cooling (see Fig. 5.15). The firebricks lining the base of structure S20 had been subjected to such extreme heat that many had disintegrated into a yellow powdery material. Analysis of this substance (see Chapter 8, sample 3) showed that it contained no significant metal content. Instead, it was found to largely consist of calcium sulphate with vitrified ceramic and glassy slag inclusions. The absence of metal residues might be explained by the practice of digging out used furnace linings, in order to reprocess them in a blast furnace to recover any metal that had leached into them. It is possible that structure S20 was the base of a row of two or more east–west-aligned reverberatory furnaces with fireboxes on the west side (R. Smith, pers. comm. 2024).

Smoke and gas from the furnace S20 was channelled towards chimney S6 via underground brick flue S21. The latter truncated earlier flue S11 and abutted the pillars of building B9. The inner face of flue S21 was coated with dust, analysis of which (see Chapter 8, sample 8) showed that it comprised calcium sulphate, lead and tin sulphates, with small amounts of arsenic and mercury: these minerals are probably derived from ore roasting. The flue probably went out of use *c.* 1910 and was subsequently backfilled with greenish ash mixed with lumps of blast furnace slag (see Chapter 8, sample 1). Analysis of similar green ash from flue S5 (See Chapter 8, sample 5) showed that it had a very high copper content.

The room to the east of furnace S20 was surfaced with rough and heavily worn stone paving, overlain by a layer of concreted green and dark grey slag containing numerous small iron and copper alloy objects (mostly nuts and bolts). Analysis of the floor layer (see Chapter 8, sample 4) showed that it was a very mixed deposit, containing metal slag from various processes, and crushed crucible and/or firebrick fragments, set in an iron-rich compound.

The first phase extension to building B6 was a north–south-aligned open-sided shed that measured 14.5 x over 11 m (B9; Fig. 5.9 and 5.10). The Goad Fire Insurance plan of 1896 (Fig. 5.4) shows that this building had a timber-framed gable roof covered with tiles. The north and east sides of the building were defined by rows of rectangular brick pillars with bullnose bricks on the corners: these provided a degree of impact protection for the pillars and may have helped prevent injuries to workmen and/or carthorses. The floor of building B9 was paved with bricks bedded on red sand. To the east of building B9 there was an open yard (OA7), surfaced with rough stone paving (Figs 4.12 and 5.16). The paving was heavily fractured, and several areas were resurfaced with bricks or stones, indicating heavy use and repeated impacts by heavy objects. Building B9 was subsequently modified by the construction of a low retaining wall around its perimeter (between the existing pillars). The interior of the building was then infilled with rubble to a depth of 0.7 m and refloored in brick.

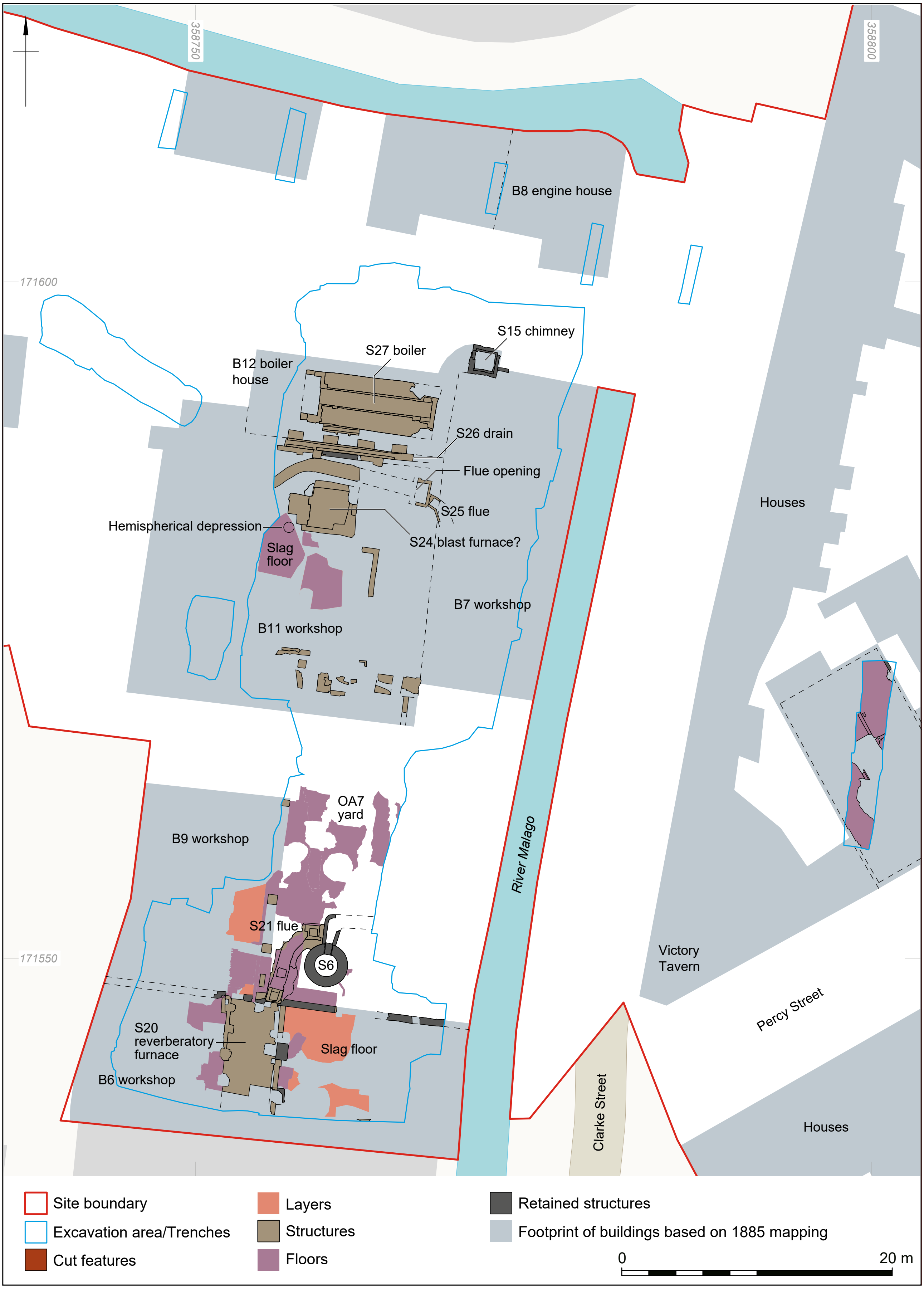


Figure 5.9 Archaeological features, 1871–83, phase 1

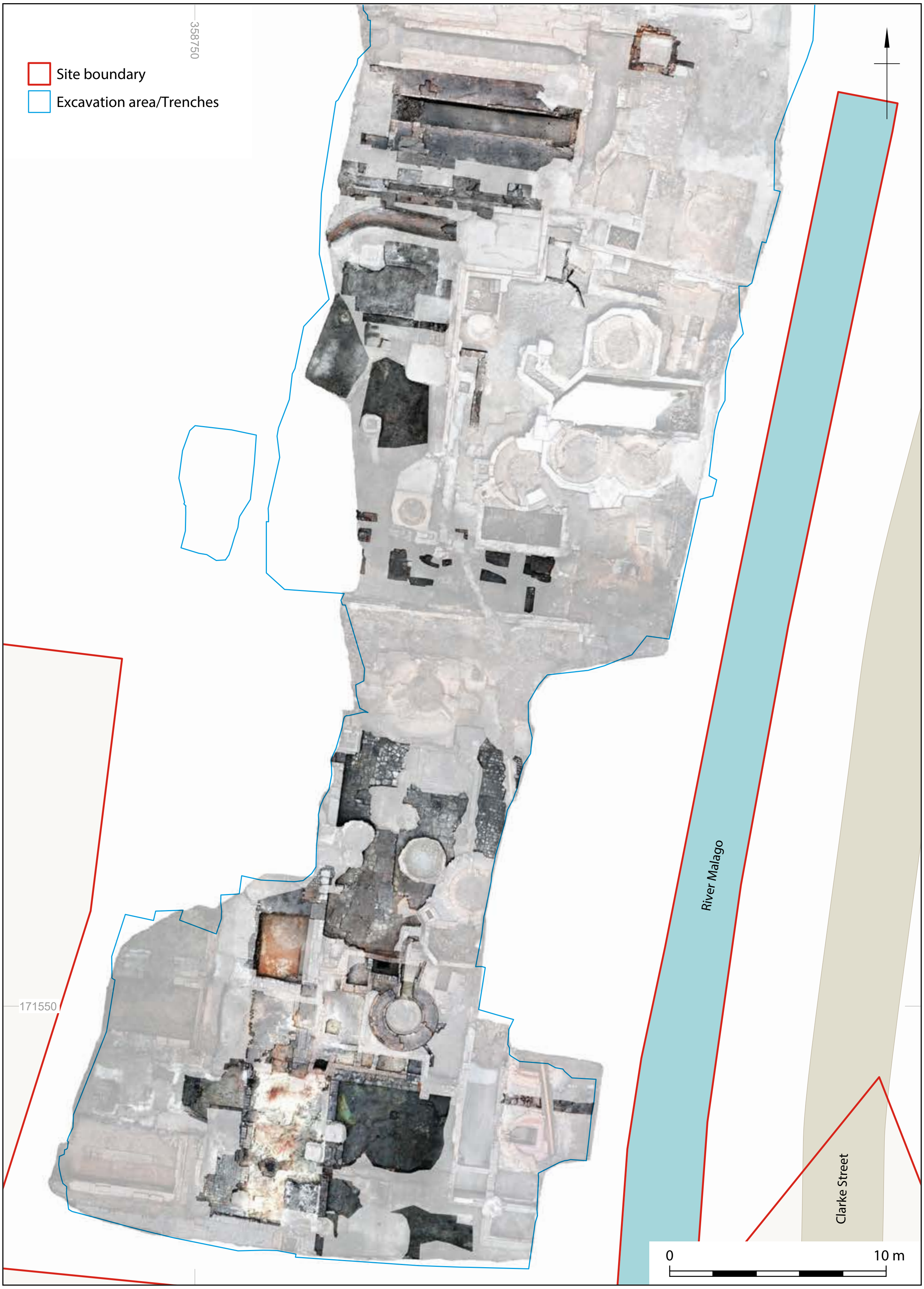


Figure 5.10 Orthographic plan from photogrammetric model, showing 1871–83 archaeological features, phase 1

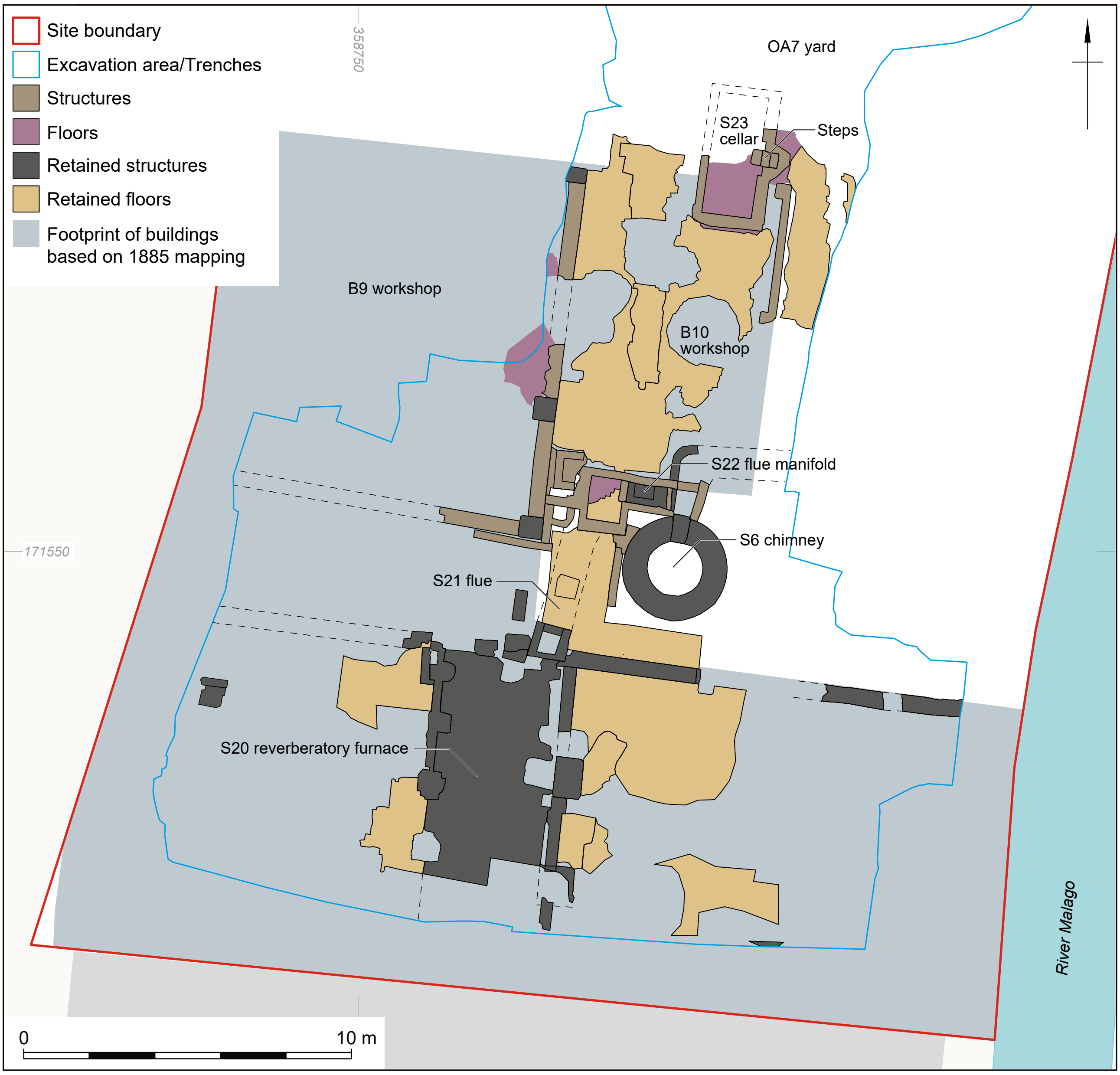


Figure 5.11 Archaeological features, 1871–83, phase 2

This may have done in response to a major flood that occurred on the 24 October 1882 (Anon 2017). The new floor was bedded on black ash mortar, with large limestone blocks used as coping. The corners of the limestone blocks were very worn, probably due to repeated impacts by heavy objects.

The second phase of expansion comprised the construction of a north–south-aligned, 9.4 x 6.2 m, brick shed (B10; Figs 4.12, 5.11, 5.12 and 5.16) and a manifold flue system (S22; Figs. 4.11 and 4.12). The east side of building B10 was defined by a brick wall, which had a series of internal bullnose-cornered buttresses that mirrored the pillars of building B9. Within building B10, there was a brick-built cellar (S23; Figs 5.11, 5.12 and 5.17), with a flight of steep steps on the east side. The cellar, which was 1.44 m deep, 1.5 m wide and over 2.7 m long, corresponds with a structure shown on the 1885 OS plan (Fig. 5.2). Cellar S23 was infilled with a deliberate dump of fine black granular slag; the function of the cellar is unknown. The purpose of manifold flue system S22 was to gather various flues together, so that they could be channelled into a single opening at the base of chimney S6. This was done to preserve the structural integrity of the chimney, which would have been compromised if it was pierced by multiple flue holes.

Figure 5.12 Orthographic plan from photogrammetric model, showing 1871–83 archaeological features, phase 2

Between 1874 and 1883, the western half of building B7 was replaced with a large (21 x 20 m) open-sided shed (B11; Figs 5.9 and 5.10) and a boiler house (B12; Figs 5.9, 5.10, 5.18 and 5.19) that measured 15.5 x 6.4 m. The Goad Fire Insurance Plan of 1896 (Fig. 5.4) shows that both buildings had timber-framed pitched roofs that were supported by brick pillars and covered with tiles. Within building B11, there was a massive stepped rectangular foundation pad (S24; Figs 5.9 and 5.10), which was aligned east–west and measured over 5.1 x 3.9 m at the base, 5.1 x 2.5 m at the top, and was over 1 m high. It had a lead pipe, probably for water, embedded in the north-west corner of the brickwork. This structure is interpreted as the base of a blast furnace. The area to the south was surfaced with a succession of slag floors and an area of rough stone paving.

Figure 5.13 Building B6, showing probable reverberatory furnace S20, looking south-east

Figure 5.14 Building B6, showing probable reverberatory furnace S20, looking north

Analysis of the slag (see Chapter 8, sample 15) showed that it is derived from a blast furnace. There was a 0.8 m wide hemispherical depression in the slag surface adjacent to the south-west corner of structure S24. This probably represents an accumulation of slag at the base of a round-bottomed iron fixture, possibly a vertical air receiver, which would have provided a smooth flow of blown air for the blast furnace (R. Smith, pers. comm. 2024). At Capper Pass & Son, primary smelting was done in rectangular water-jacketed blast furnaces with forehearths that allowed a continuous overflow for slag. The latter were needed due to the high slag/metal ratio (Wright 1966, 182). Figure 5.20 shows a typical rectangular water-jacketed blast furnace used for non-ferrous smelting; Figure 5.21 shows the layout of the contemporary Anaconda Copper Mining Company's smelting works in Montana, USA (Anaconda Copper Mining Company 1897). Although the layout of the Bedminster Smelting Works and precise form of its blast furnace is likely to have differed from the illustrated examples, the scale and general setup are likely to have been similar.

To the north of structure S24, there was a large brick flue (S25; Fig. 5.22) that was constructed of red press-moulded bricks bonded with black ash mortar. Flue S25 abutted and respected the north wall of the building B11. Analysis of the dust coating the interior of the flue (see Chapter 8, sample 7), showed that it comprised gypsum, brick dust, lead and calcium sulphates, and tin oxides derived from solder and lead smelting.

Building B11, and the brick pads that defined the south side of boiler house B12, were abutted by a brick-lined drain (S26) that would have channelled rainwater from the roofs of the two buildings (Fig. 5.9). Each of the rectangular brick pads on the south side of boiler house B12 had four iron bolts embedded in their upper surfaces.

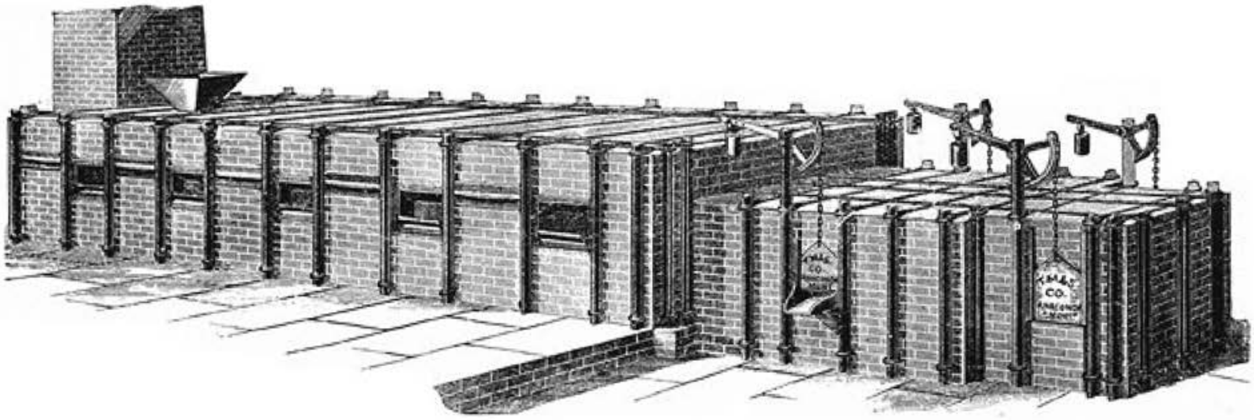


Figure 5.15 Late 19th-century reverberatory roasting furnace, Anaconda Copper Mining Company 1897, plate 50

Figure 5.16 Yard OA7, building B10, solder pot S30 and iron tank S43. Looking south-west

Figure 5.17 Cellar S23, looking east

Figure 5.18 Aerial photograph of boiler houses B12 and B14 and boiler bases S27 and S36 (photograph reproduced with the permission of Bristol & Bath Heritage Consultancy Ltd)

Figure 5.19 Aerial photograph of boiler houses B12 and B14 and boiler bases S27 and S36, looking west (photograph reproduced with the permission of Bristol & Bath Heritage Consultancy Ltd)

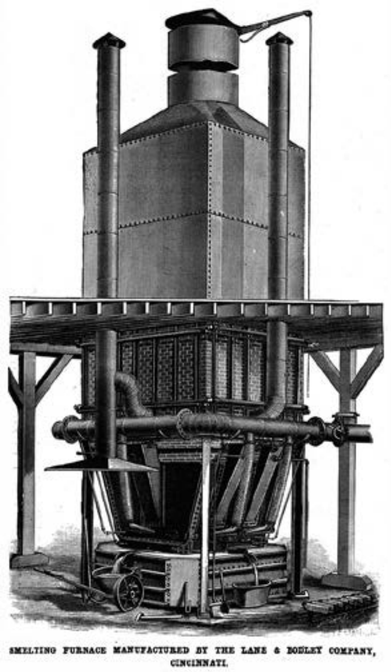


Figure 5.20 Late 19th-century water-jacketed non-ferrous blast furnace, Scientific American 47(19), 4 November 1882, 258

These are likely to have been mounts for a steel- or iron-framed building that housed a large Lancashire steam boiler (S27; Figs 5.9, 510, 5.18 and 5.19). The 1896 Goad Fire Insurance Plan (Fig. 5.4) depicts building B12 as a timber structure with a tiled roof. However, given that the plan states that the surveyors were denied access to the works, it is possible that there are inaccuracies in the plan. Steam boiler base S27 (Fig. 5.18) was aligned east–west and measured over 10.1 x 3.9 m. There was a blowdown pit for wastewater at the west end of the boiler base, and the mounts for a flue damper at the east end. A detailed examination of the western end of the boiler base was hindered by the presence of degraded asbestos fireclay. This substance, which was removed by specialist contractors, was probably used to seal up gaps between the boiler and the surrounding brick flues and may also have been used to seat the boilers (R. Smith, pers. comm. 2024). The boiler flues were lined with yellow firebricks from the Dykehead Fire Brick Works and the Glenboig Union Fireclay Co. The core of the structure was built using press-moulded red bricks from the Malago Brick & Tile Works. The latter company was marketing its ‘well-known pressed bricks’ by 1877 and continued to do so until the company closed in 1908 (Hammersley 1992, 19; *WDP*, 23 October 1877, 4). Cartographic evidence suggests that boiler S27 was built between 1874 and 1883.

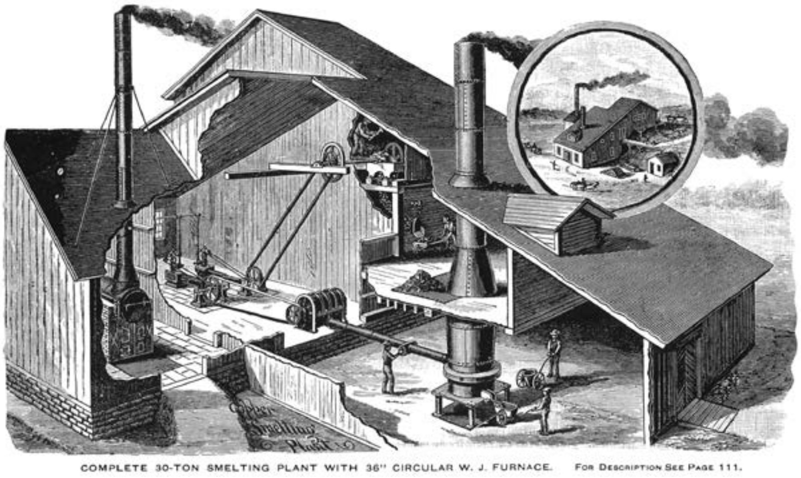


Figure 5.21 Late 19th-century smelting works, showing 30-ton water-jacketed non-ferrous blast furnace, steam boiler, engine and blower, Anaconda Copper Mining Company 1897, plate 83

Figure 5.22 Flue S25, with possible blast furnace base S24 to the left, and the north wall of building B11 to the right, looking west. Scale: 0.5 m

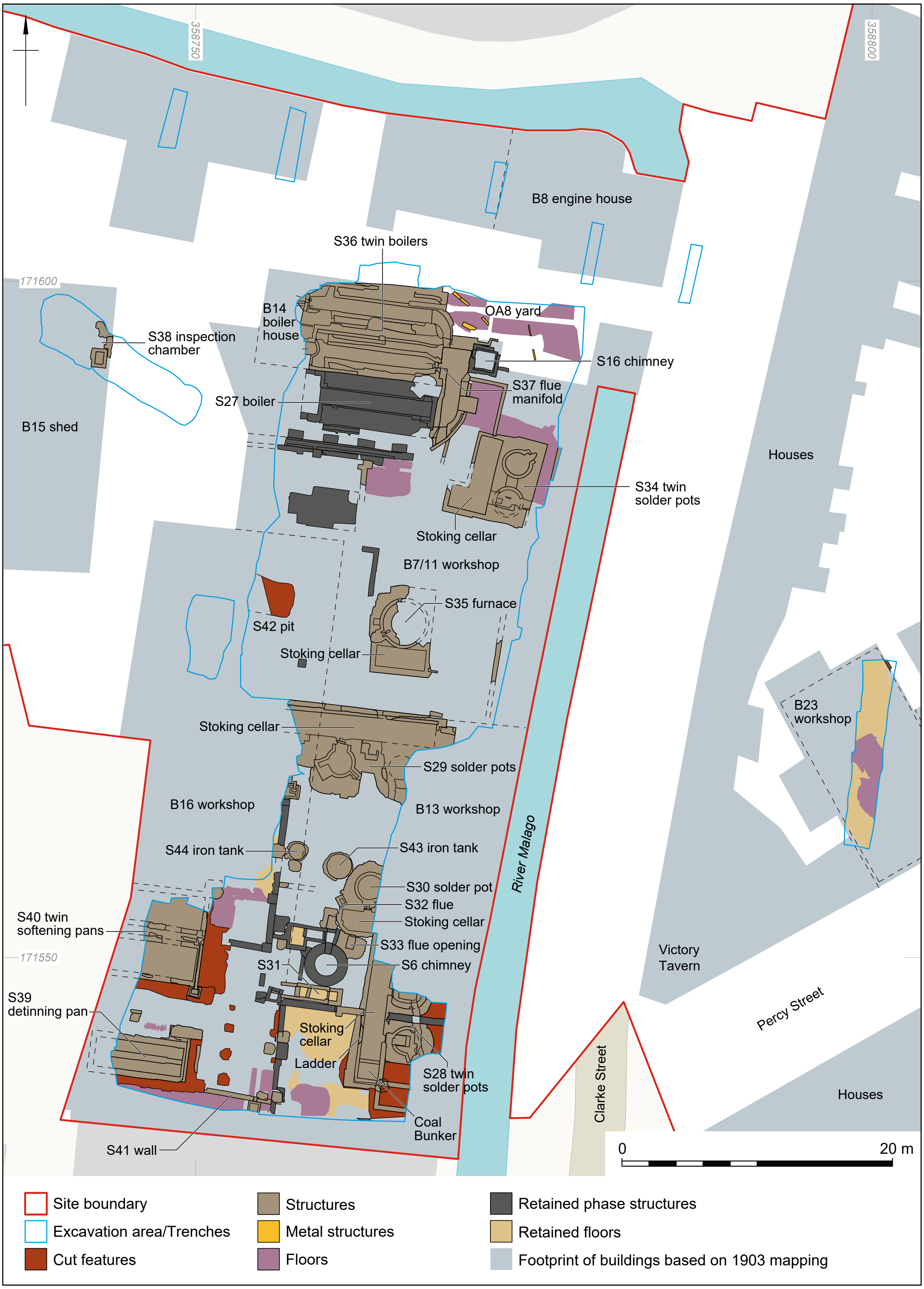


Figure 5.23 Archaeological features, 1884–1913

Figure 5.24 Orthographic plan from photogrammetric model, showing 1884–1913 archaeological features

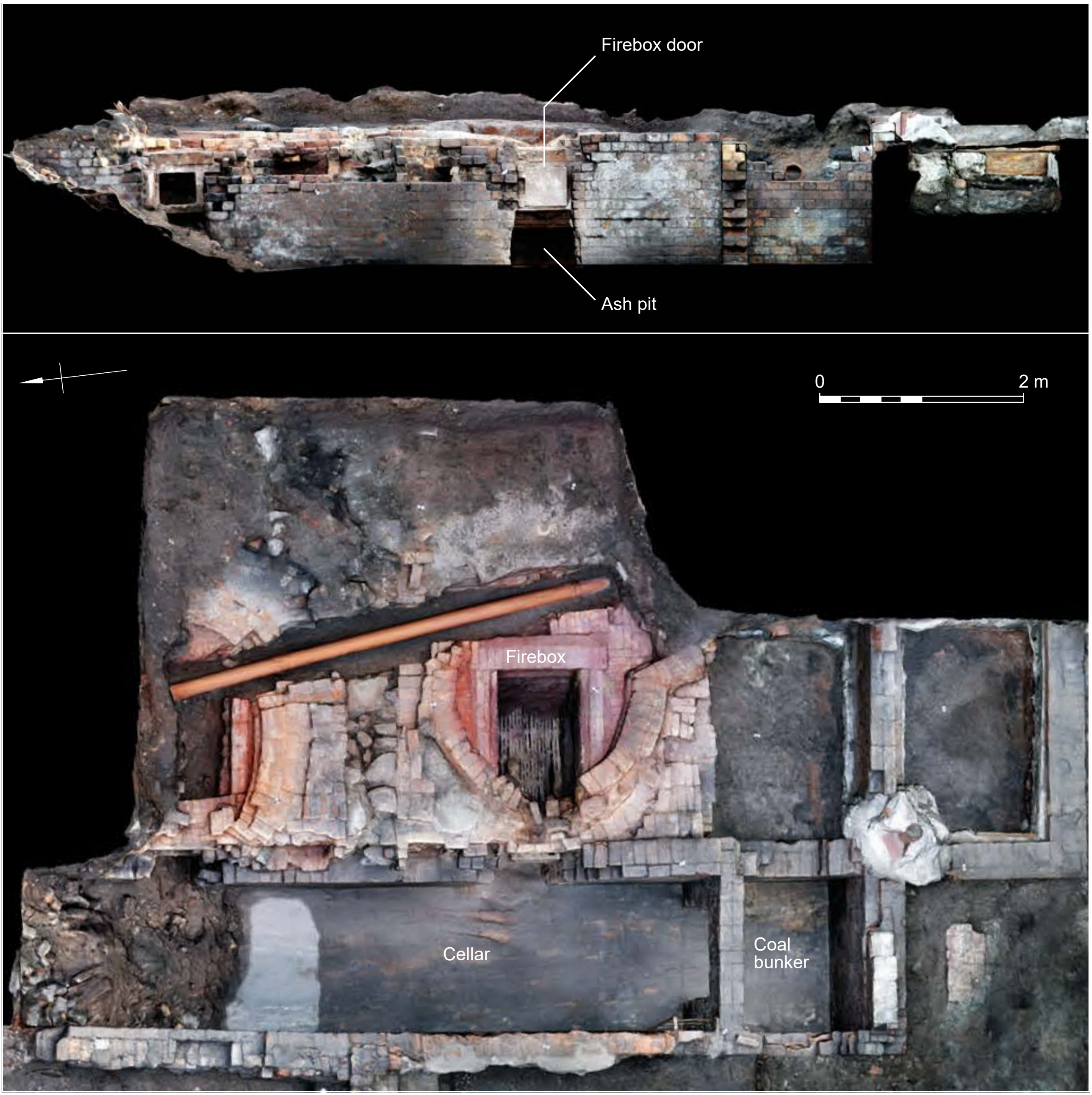


Figure 5.25 Photogrammetric plan and elevation of solder pots S28.

1884–1913

Historic mapping (Figs 5.2–5.6) shows that between 1887 and 1896, a new bowstring iron-tie roof sheathed in corrugated iron (B13) was built to cover the formerly open yard between buildings B9/B10 and B11. This roof, which was fitted with a large ridge vent, also extended southwards over the eastern half of building B6. Building B13 was probably built as a shelter for two new banks of coal-fired 'solder pots' (furnaces for mixing molten lead and tin to create solder). Each bank of solder pots (S28–S30; Figs 5.23–5.24) had an associated cellar that provided access to the doors and ash pits of one or more brick-lined furnaces. These were used to heat ground-level hemispherical cast-iron vessels (sometimes referred to as 'kettles') with capacities of between 20 and 50 tons of molten metal.

The cellar of solder pots S28 (Figs 5.23–5.28) was fully excavated. Its floor was paved with bricks bedded on concrete. The furnaces were built of red brick bonded with black ash mortar, with unmarked yellow firebricks lining the fireboxes: the latter were bonded with red sand. The upper parts of the furnaces were circular and had an internal diameter of 1.7 m. The furnaces had thick cast-iron doors and cast-iron grates

Figure 5.26 Solder pots S28, showing furnaces and stoking cellar, looking south. Scale: 1 m

Figure 5.27 South furnace of solder pots S28, looking east

with ash pits below. Oxygen was provided via air inlet holes to the sides of the doors: these were fitted with iron dampers that allowed the furnaceman to regulate the airflow, and therefore the heat, of the furnaces. The grates were overlain by concreted clinker and greyish purple ash from the final firing of the furnaces. Access to the stoking cellar was provided by a fixed iron ladder in the south-west corner of the structure. A chamber at the south end of the cellar was half-filled with coal dust, which suggests that this was the fuel store. The furnace flues vented upwards and would presumably have fed into overhead metal ducts. Although furnaces S28 are marked on a 1962 Goad Fire Insurance Plan (Fig. 6.4) as 'solder pots', their position within the smelting works would be more appropriate for lead melting pots, and they may have been used for this rather than solder mixing (R. Smith, pers. comm. 2024).

Figure 5.28 South furnace of solder pots S28, looking west. Scale: 0.5 m

Figure 5.29 Structure S31 and building B6, looking south-east. Scale: 0.5 m

To the west of solder pots S28, and immediately to the south of chimney S6, there was a row of box-like brick compartments (S31; Figs 4.11, 5.23, 5.24 and 5.29). The western end of structure S31 was abutted by a contemporary construction make-up layer composed of clinker and crushed Morgan Crucible Co. assaying crucibles (see Chapter 9, 'The Science of Smelting: Assaying and Analysing'). The compartments within structure S31 were partially filled with grey and bright green ash, identical in composition to the ash in flues S5 and S21. This suggests that structure S31 was probably associated with the flue system. The purpose of structure S31 is uncertain, but the compartments may have been settling chambers intended to collect flue dust, or the bases of primitive fume scrubbers. Alfred Pass experimented with 'steam boxes' for this purpose in the mid/late 19th century and S31 could be the base of these structures (R. Smith, pers. comm. 2024; Wright 1966, 182).

Figure 5.30 Furnace S35, looking north-west

The cellar of solder pots S29 (Figs 5.23 and 5.24) was not excavated because of asbestos contamination. The excavated remains comprised two solder pot furnaces. There is likely to have been a third solder pot in an unexcavated area to the west. The westernmost excavated furnace was well preserved and appears to have been of near-identical design to solder pots S28. The circular part of this furnace had an internal diameter of 1.77 m. The eastern furnace was heavily truncated. These solder pots, which are shown on the Goad Fire Insurance Plan of 1961 (Fig. 6.4), both had capacities of 50 tons. Solder pots S29 were associated with an episode of ground raising and the rebuilding (S32 and S33; Figs 4.12, 5.23 and 5.24) of the flue manifold (S22) to the north of chimney S6.

In building B7, there was another pair of circular furnaces and an associated stoking cellar (S34; Figs 5.23 and 5.24). The northern furnace is depicted on the 1961 Goad Fire Insurance Plan (Fig. 6.4) as a 20-ton solder pot. The circular part of the furnace had an internal diameter of 1.71 m. The associated stoking cellar, which was cleared by specialist contractors without archaeological supervision, was infilled with fragmented asbestos cement roofing sheets. A lime mortar surface to the north of solder pots S34 was contiguous with a brick floor that abutted boilers S36. This suggests that solder pots S34 are of a similar (i.e., 1883–96) date.

Within building B11, there was a much larger furnace (S35; Figs 5.23, 5.24 and 5.30), of similar design to the smaller solder pots. Furnace S35 measured 6.6 x 4.6 m externally and had a stoking cellar on the south side, with a circular furnace to the north. The circular part of the furnace had an internal diameter of 3.15 m. Excavation of the stoking cellar was halted due to the presence of asbestos. The exposed northern elevation of the stoking cellar revealed an arched furnace doorway constructed of red bullnose bricks. The north-eastern half of furnace S35 was truncated by later activity (see Chapter 6). The width of the furnace suggests that it may have been a casting pot, used to make ingots of solder for sale. The wide pot would have allowed moulds to be arranged around it without the need for water cooling (R. Smith, pers. comm. 2024).

Boiler house B12 was extended northwards between 1883 and 1896. The new building (B14; Figs 5.18, 5.19, 5.23 and 5.24) was constructed of iron or steel clad in corrugated iron. Building B14 was built to house a pair of Lancashire boilers (S36; Figs 5.18, 5.19, 5.23 and 5.24), which together measured 11.4 x 5.3 m. Parts of the boiler bases were contaminated with degraded asbestos fireclay, which was removed by specialist contractors. The boiler base was constructed using Glenboig Union Fireclay Co. and Cattybrook Brick Co. Ltd firebricks: the latter post-date 1877. There were brick settings for dampers at the eastern ends of the boiler flues. The flues were linked to a manifold (S37) that channelled smoke into an opening in the base of chimney S16. There were two sloping chutes on the south and east sides of flue manifold S37: these were probably used as access to rake out accumulations of flue dust. The yard (OA8) to the north-east of chimney S16 was surfaced with a hard limecrete floor, with a series of flat metal plates embedded in it (Figs 5.23 and 5.24); the purpose of these plates is uncertain.

Between 1883 and 1896, an iron- or steel-framed and corrugated iron shed (B15; Figs 5.23 and 5.24) was erected in the yard (OA6) to the west of buildings B11 and B14. The remains of this building comprised a rectangular stanchion base with embedded iron bolts, and a patch of brick flooring. An adjacent brick inspection chamber (S38) is likely to be of broadly similar date.

Historic records suggest that soon after the death of Alfred Pass in 1905, the company began a major programme of investment and rebuilding. The new buildings were predominantly built of steel, concrete and brick bonded with black ash mortar, with iron-truss roofs sheathed in corrugated iron. Within the excavation area, the first major alterations appear to have been undertaken in 1912. This comprised the demolition of building B9 and the western halves of buildings B6 and B11, and the construction of a large steel-framed shed (B16) in their place. Building B16 had a steel bowstring truss and corrugated iron roof, supported by rows of I-section steel stanchions bedded in concrete. The floor of the building was concrete.

Construction of building B16 probably coincided with the decommissioning and partial robbing out of reverberatory furnace S20 to the south. The structural ironwork of the furnace was removed and flue S21 was infilled and bricked up. The base of furnace S20 may also have been partially dug out to recover metal residues. Flue S21 was partially backfilled with green ash that contained large lumps of brownish-green slag. Analysis of the latter (see Chapter 8, sample 1) showed that it comprised litharge (lead oxide), lead silicate and a suite of other non-ferrous oxides: this is interpreted as a blast furnace shaft accretion that was cut out during maintenance and dumped in the disused flue. The robbed-out furnace was then buried beneath a 0.5 m thick dump of dark grey slag and white lime that covered most of the area to the south-west of chimney S6. The southern extent of slag and lime deposit was defined by wall S41, which appears to have been an internal partition. The area to the south of wall S41 was paved with bricks. An identical slag and lime deposit was also used to backfill the construction cuts of three lead detinning and softening pans (S39 and S40). Analysis of the slag (see Chapter 8, sample 2) showed that it contained a wide variety of non-ferrous metals and may be solder slag that had been cleaned of tin by smelting with lead in a blast furnace.

A row of five lead detinning and softening pans (a type of furnace) within building B16 may be contemporary with its construction *c.* 1912. These were used to remove tin and arsenic by oxidation at around 600°C and antimony around 800°C. The resultant Sn/As/Pb oxide dross (yellow scum) was then smelted on the solder charge and the Sb/PbO (heavy scum) was smelted in a pan to produce 45% Sb/Pb alloy with some liquated to 95% Sb metal. The latter was sold as 'star antimony' (R. Smith, pers. comm. 2024).

Three of the detinning and softening pans (S39 and S40; Figs 5.23, 5.24 and 5.31) were partially excavated. They each comprised a large east–west-aligned rectangular trough that measured over 5.5 x 3.2 m wide and up to 0.8 m deep. The pans were constructed using a mixture of red brick and yellow firebricks bonded with red sand. At the east end of the pans, there were pairs of horizontal iron girders attached to concrete pads. There were no fireboxes, ash, or other evidence of direct heating on the brickwork, which suggests that they were not coal-fired. The detinning and softening pans are

Figure 5.31 Detinning pan S39 , looking north-west. Scale: 1 m

depicted on the 1961 Goad Fire Insurance Plan (Fig. 6.4), which shows that they were linked to an overhead flue that directed fumes towards a building on the northern edge of the smelting works. The blast furnace and sinter plant to the west of the excavation area also discharged into this building, which was adjacent to a 'rectifier house' and 'wetter'. This suggest that the building into which the flues discharged contained an electrostatic precipitator (ESP), which was used to collect metal-bearing fume for reprocessing; the wetter was used to soak the fume to prevent it from blowing away. The ESP is likely to have been installed in the 1910s or 1920s as replacement for an 1890s baghouse. The latter used cloth bags to catch dust, which made them very liable to catch fire, particularly as the soot from the blast furnace was pyrophoric (R. Smith, pers. comm. 2024).

The 1961 plan also shows an 8000-gallon (36,269 l) fuel oil tank at the southern end of the building, which suggests that the detinning and softening pans are likely to have been oil-fired. There was a large spill of grey metal between the steel girders at the east end of pan S40. Analysis of this metal (see Chapter 8, sample 16) showed that it was predominantly lead, with 2–3%wt antimony, 0.5–1%wt tin, and some rare non-ferrous intermetallic compounds. This metal is likely to be partially detinned lead that was being prepared for fire purification (as opposed to electrolytic purification).

There was a sub-rectangular pit (S42; Figs 5.23 and 5.24) of unknown purpose to the north of the softening pans. The pit was backfilled with the same dark grey slag rubble and lime that infilled the construction cuts of the lead detinning and softening pans, which suggests that pit S42 was broadly contemporary with them. Possible interpretations of this feature include a construction cut for a structure to the west of the excavation area, or a metal-casting pit.

To the north of chimney S6 there was another solder pot and associated stoking cellar (S30; Figs 5.16, 5.23 and 5.24). The upper part of the furnace was circular, with an internal diameter of 1.73 m. It was built to the same design as the other solder

Figure 5.32 Iron tank S43, looking south

pots, using unmarked and Glenboig Union Fireclay Co. firebricks to line the firebox. The rest of the furnace was built using a variety of red and yellow bricks, including examples from the Cattybrook Brick Co., London Brick Co., Malago Brick & Tile Works, and Scourse & Kingston Ltd. The latter company was founded in 1908 and closed *c.* 1941, which provides a close date for the construction of this furnace. Given the general stagnation of the company in the inter-war period, it is probable that solder pot S30 was built shortly before the outbreak of World War I.

Immediately to the west of solder pot S30, there were two tanks of relatively thin mild steel set in concrete (S43 and S44; Figs 5.17, 5.24, 5.25 and 5.33). The tanks had diameters of 1.45 m and 1.2 m respectively and were infilled with demolition debris (probably derived from the demolition of the smelting works *c.* 1963). There were openings for pipes at floor level and the tanks may have been connected, but their function is uncertain. There were no obvious indications of hydrocarbons or other substances in the tanks, which suggests that they probably held water. Oral history recordings (BMAG OH69.1) indicate that molten solder was cast in water-cooled moulds to speed cooling. These moulds were hand filled using iron ladles to transfer the molten metal from the solder pots. It is possible that the tanks were reservoirs that held water used for this purpose, but this is far from certain, and there were other processes that required water. For example, the Chempur electrolytic tin process, undertaken on the Shene Road site from the 1920s onward, required anode casting facilities. The later P Process, also carried out at Shene Road, used granulated anodes held in steel baskets. These were made by pouring molten solder onto a vibrating perforated metal plate above a tank of water. This produced small (10–15 mm diameter) discs known as 'cockles' that were removed with a rake classifier. Either of these operations would have been best conducted when the solder or tin was already molten rather than casting ingots and remelting them at Shene Road (R. Smith, pers. comm. 2024).

Discussion

The Second Industrial Revolution, also known as the Technological Revolution, was a period of rapid scientific discovery and industrialisation, during which the processes of mass production and standardisation were refined and expanded. This period, which began *c.* 1870 and concluded with the outbreak of World War I, coincides with a phase of rapid development of the Bedminster Smelting Works. The workforce increased from 36 to 189 and the Works expanded westwards to accommodate new plant, workshops, sheds and storage space. The initial expansion entailed the demolition of houses along Coronation Street and Adelaide Place; this was completed before 1874. The next phase of expansion entailed the purchase of a tannery to the west of the Bedminster Mill tail race in 1882; this was demolished *c.* 1884–96. A further two streets of terraced houses, Margaret Place and Margaret Gardens, were purchased and demolished to create space for a new blast furnace *c.* 1896–9.

The primary output of the works during this period was lead and solder, produced from lead and tin ore and secondaries that were smelted on site. Primary smelting was undertaken in blast furnaces; the resultant metals were then refined in reverberatory furnaces. Blast furnaces are primarily above-ground structures, which makes identification of their remains from foundations difficult. These furnaces were extremely heavy, particularly when loaded with a charge, and would have required substantial foundations: a possible blast furnace base (S24) was identified in the northern part of the smelting works. An embedded lead pipe could indicate that this was a water-jacketed furnace (a type commonly used in lead smelting); the water might also have been used to cool slag from the blast furnace. The blast furnaces at Melton were similar to those at Bedminster: they were rectangular with water jackets up to about 2.4 m (8 ft), with firebrick shafts above, and forehearths to collect slag and metal (R. Smith, pers. comm. 2024). The floor adjacent to S24 was made up of successive layers of blast furnace slag. This material was also used extensively throughout the works as ground-raising and surfacing material, though its presence here may be the result of repeated spillages rather than deliberate surfacing.

Blast furnaces require a source of blown air, which was provided by a steam-powered blower. The engine for this blower was located in an unexcavated area in the north-east corner of the smelting works. Steam for the engine was produced by a boiler in the northern smelting works building. The original pre-1870 steam boiler was replaced with a larger Lancashire boiler sometime between 1874 and 1883, the new boiler was housed in an open-sided iron- or steel-framed shed with a tiled timber roof. It quickly became apparent that the new boiler was insufficient for the needs of the works, and by 1896, a pair of additional Lancashire boilers was added. They were housed in a new iron- or steel-framed boiler house with a corrugated iron roof.

A large rectangular furnace (S20) at the southern edge of the smelting works is interpreted as the base of a *c.* 1874–83 reverberatory furnace. This type of furnace comprised a long, iron-bound brick box with numerous iron doors along the sides to allow the charge to be manipulated and moved using long-handled metal hoes. Flames from the furnace would have passed over the ore or metal change, reverberating heat downwards from the roof of the chamber. The smoke and gases given off by this process were vented via underground flues at the northern end of the structure. Expansion of the southern works building between 1874 and 1883 necessitated a re-routing of the underground flues, but the reverberatory furnace probably remained in use until the early 1900s. Sampling of the heat-affected brickwork in the base of the furnace showed that it did not have a significant metal content, perhaps indicating that the base of the furnace was subsequently dug out to recover metal residues that had leaked into the brickwork. The furnace was probably demolished *c.* 1912. Ash from the furnace's associated flues had a high copper content, which suggests that the final materials processed in it were copper ore or copper-bearing secondaries. Although Capper Pass & Son did produce some copper in the 19th century, there are no records of them doing so in the early 20th century. They were, however, a significant producer of copper sulphate for agricultural use as Bordeaux Mixture. Large-scale production of copper sulphate can be achieved in a variety of ways depending on the chemical composition of the raw materials. Copper was isolated from tin, solder and lead refining as copper-rich drosses which were smelted with bought Cu/Sn/Pb materials to give an intermediate known as 'metalline'. This had a composition which permitted it to be crushed and ball-milled to a powder which was dead roasted to oxide and leached with dilute sulphuric acid to give copper sulphate solution and an insoluble mixed Sn/Pb residue which was re-smelted on the solder charge. Copper sulphate production would require a reasonable amount of space for crushers, ball mill, roaster, acid tanks, water tanks, leaching tanks, crystallisers, filters and possibly a dryer. These operations were probably undertaken elsewhere within the works (R. Smith, pers. comm. 2024).

At some point between 1887 and 1896, the yard between the north and south smelting works buildings was roofed over, probably to accommodate two banks of furnaces used for solder production. In contrast to the timber and tiled roofs of the earlier buildings, the new extension was covered with a bowstring iron-truss roof clad in corrugated iron. This reduced the risk of fire in the vicinity of the furnaces, and subsequently became the standard roof type within the smelting works. The new extension was open sided, with a large vent along the apex of the roof, both of which would have helped reduce the concentration of smoke and toxic fumes within the workshop.

Molten solder, tin and lead were held in large hemispherical cast-iron vessels known as 'pots', from which they were refined or cast into ingots. These were heated by subterranean coal-fired furnaces of similar design to lead smelting kettles. The solder pot fireboxes were stoked from associated cellars, which were accessed via fixed iron ladders. In contrast to the earlier furnaces, the solder pots appear to have had above-ground flues – probably metal ducts that channelled smoke into manifolds at the bases of the main chimneys. Marked bricks were recovered from many smelting works structures, but few are chronologically distinctive enough to allow close dating. The exception to this is solder pot S30, which contained local bricks dating from 1908–41. The earliest solder pots were probably constructed *c.* 1890, but it appears that they were still being built to a remarkably similar design in the late 1950s (see Chapter 7).

The death of Alfred Pass in 1905 ushered in a period of major organisational and technological change at Capper Pass & Son Ltd. While his son, Douglas Pass, maintained overall control of the company, the day-to-day operations were handled by a board of directors, led by Stanley Badock. The period prior to World War I was the most productive era of the Bedminster Smelting Works. The large profits generated by its principal product, solder, allowed investments in land, buildings and technology. This included the introduction of electrical equipment in 1908 and replacement of the last timber and tile-roofed buildings with fireproof steel-framed structures with corrugated iron roofs *c.* 1912. The impact of the technologies and processes of the Second Industrial Revolution is discussed in Chapter 10.

CHAPTER 6
THE FINAL YEARS OF THE BEDMINSTER SMELTING WORKS, 1914–63

Historical Background

World War I, 1914–18

The outbreak of World War I in August 1914 brought an abrupt end to the industrial unrest of the preceding years and radically altered the course of many people's lives. Millions of men were called up, and women began working in hitherto exclusively male occupations. Despite the upheavals of war, the conflict had little impact on the physical appearance of Bedminster, and the needs of the war economy were a boon to the local tobacco and smelting industries, both of which made goods that were consumed in vast quantities by the armed forces.

During World War I, 60 employees of the Bedminster Smelting Works were called up, along with the owner Douglas Pass, chemist Paul Gueterbock, and the company's accountant Humphry Prideaux, who were enlisted as officers. Although the loss of manpower led to a reduction in output (one of the three blast furnaces was mothballed), high prices and wartime demand for solder made it a profitable time for the company (Little 1963, 25–6).

In 1915, Captain Pass became a prisoner of war during the disastrous Gallipoli Campaign, and he remained incarcerated until 1918. Despite the imprisonment of the company's namesake and majority shareholder, business continued more-or-less as usual at the smelting works. In 1915, a new engineering shed, designed by Holbrow and Oaten, was constructed on the Shene Road site (BA Building_plan/Volume_64/43c). Despite the acquisition of additional land over the preceding decade, storage space was still a major problem and the search for a new smelting works site continued. In 1916, the company purchased 150 acres of land at St Anne's Farm, Brislington. The farm was too far from the docks and rail network to be suitable as a new works site, but it did prove useful as a slag dump. In 1917, the Ministry of Munitions recognised the importance of the company's products for the war effort, and the remaining men were exempted from military service (Little 1963, 26).

The end of the war in November 1918 led to a slump in demand for solder. This was still the company's main product, but high metal prices and a repayment of debts from German firms kept the company solvent in the first years after the war. The end of hostilities was marked by a resumption of industrial unrest, and in 1918, there was a short-lived walkout, when members of the National Union of General Workers tried to force the non-union men to join (*ibid*., 26).

The Inter-war Period, 1919–38

Wartime conscription revealed startling insights into the poor health of Britain's working-class population, something which many linked to the inadequate standard of their housing. To alleviate this problem, the government began planning for post-war improvements to the nation's housing stock. This was partially out of a feeling of fairness to the returning forces, but also out of a fear of social unrest: the latter being particularly acute after the Russian Revolution of 1917.

In 1918, the right to vote was extended to all men over 21 and women over 30 who fulfilled certain property qualifications. Prime Minster David Lloyd George also pledged that the returning forces would be provided with half a million state-funded 'homes for heroes'. The passing of the Housing and Town Planning Act 1919 provided the means to achieve this. Local authorities were given subsidies for housebuilding, with the aim of providing decent low-density housing designed along garden city principals (Baughton 2018, 33–4). Bristol Corporation purchased numerous farms on the edge of the city for the development of housing estates, the largest of which were in Bedminster parish. The first of the new estates were built in Knowle Park and St John's Lane (south of Windmill Hill) in the early 1920s. Over the following decades, these expanded southwards to form the vast Knowle and Bedminster Estate, which by 1939 had a population of some 28,000 (Boughton 2014). To accommodate this estate, more of Bedminster parish and parts of the adjoining parishes of Brislington and Whitchurch were subsumed within the administrative bounds of the City and County of Bristol in 1930 and 1933. The building of these estates moved the edge of the city some 2 km southwards, giving the historic core of Bedminster an increasingly urban character.

The end of the war brought several changes to the operation of the Bedminster Smelting Works. On Armistice Day, 11 November 1918, the company started preparing for the installation of electrolytic refining equipment at the former Malago Brick & Tile Works on Shene Road. In March 1919, Captain Paul Gueterbock rejoined Capper Pass & Son Ltd as a manager of the works (Anon, 1955, 35–6). The electrolytic refining equipment was used to refine Bolivian tin ore using a process developed in the USA. This produced tin of very high purity (Sn% 99.9918, Sb% 0.0031, As% 0.0001, Pb% 0.0025, Bi% 0.0004, Cu% 0.0004, Fe% 0.0016, S% 0.0002) that was marketed from 1921 onwards as 'Chempur' (chemically pure): this was said to be the purest tin in the world. A similarly pure tin (Sn% 99.9895, Sb% 0.0055, As% 0.001, Pb% 0.0008, Bi% 0.0001, Cu% 0.0005, Fe% 0.0025, S% 0.00025) was marketed as 'Pass No. 1 Tin' from 1933 onwards (Little 1963, 26–8; Mantell 1949, 56; *The Chemical News*, 24 February 1922, 16).

During the 1920s, there was a resumption of industrial unrest at the Bedminster Smelting Works, beginning with a strike by the company's carters in 1920, and a more serious dispute with the whole workforce over a proposed pay cut in 1921 (Little 1963, 28; *South Gloucestershire Times*, 30 April 1921, 5). This time the men went on strike for three months, leading to a significant slump in the company's output. The sale of solder recovered in 1922, but it never returned to its pre-war levels, partially due to competition from other foreign and domestic manufacturers (Little 1963, 28). This is reflected in the company's employment statistics (Fig. 10.1), which show a slight dip in post-war workforce. By 1937, the number of employees had returned to 190. The workers at Capper Pass & Son Ltd were never fully unionised, but the men did come out in support of the 1926 General Strike. There were no further industrial disputes after this date (*ibid*., 25–6, 28).

Apart from its use as a slag dump, the St Anne's Farm site (purchased in 1916) was of little use to the company, so in 1926 some of the land was sold to Bristol Corporation for the construction of the St Anne's Park housing estate (BA HOD/4627/81(A-F). The rest of the farm was sold privately and part of it was developed as an extension to the St Anne's Board Mill cardboard factory (Little 1963, 26, 29).

During the 1920s, production of antimonial solder and soft lead (much of which was sold to the lead sheet and shot manufacturers Sheldon Bush & Patent Shot Co. of Redcliffe Hill) and copper sulphate continued to be important parts of the firm's output. However, the demand for faster flowing solder for use in the automotive, electrical and canning industries forced the company to start producing softer antimony-free solders (BMAG OH33; Little 1963, 29). To find a market for the unwanted antimony, the company began producing type metal for use in hot-metal typesetting machines such as the Linotype, Intertype and Ludlow Typograph. Capper Pass & Son Ltd's type metal was marketed through a separate company, Pass Printing Metals, but because of the volume of used metal type already in circulation, this failed to be a major outlet for the company's surplus antimony. In 1934, Pass Printing Metals was sold to the London firm H. J. Enthoven & Sons (Little 1963, 29).

By 1930, it had become obvious that the market for solder and whitemetal alloys was saturated. The electrolytic Chempur process, which continued to be used at Bedminster until 1953, required an anode with less than 2% Pb and this limited the company to accepting medium-grade tin ores. Paul Gueterbock then developed the 'P Process', which was highly secret, even when the company closed in 1991. It enabled tin to be extracted from an anode with only 50–65% Sn, 3–6% Sb, 0.4% As, balance Pb (with As, Cu, Fe, etc. having been removed by dry refining). The product was Pass No.1 tin (see above) and Pass Electrolytic tin (Sn% 99.95, Sb% <0.03 and In% <0.04). A tin refinery, known as the 'P Shed', was erected on the Shene Road site, and the P Process later became the main production methodology used at Melton. The P Process enabled low-grade tin ores to be smelted with lead to give solder and a slag with a low tin content. This complex process was never patented, as it would have allowed competitors to run pirate operations. In addition to these grades of tin, the company produced a small amount of 'S Tin' which was 99.999% Sn and had less than 10 parts per million of impurities. It was made by re-refining Pass No. 1 tin using a much scaled-down Chempur process (R. Smith, pers. comm. 2024).

The Goad Fire Insurance Plan of 1927 (Fig. 6.1) notes that admission to the smelting works was again refused, but it does show the works in a considerable amount of detail. By this date, a formerly roofed area towards the northern end of the site had been opened up, but the buildings adjacent to the northern branch of the Malago appear largely unchanged. The footprint of the main smelting works buildings remained the same, though all but one of the timber and brick buildings had been replaced with metal-framed structures with corrugated iron roofs; this probably occurred *c.* 1912. These buildings are visible in a 1920s aerial photograph of the works (Fig. 6.2).

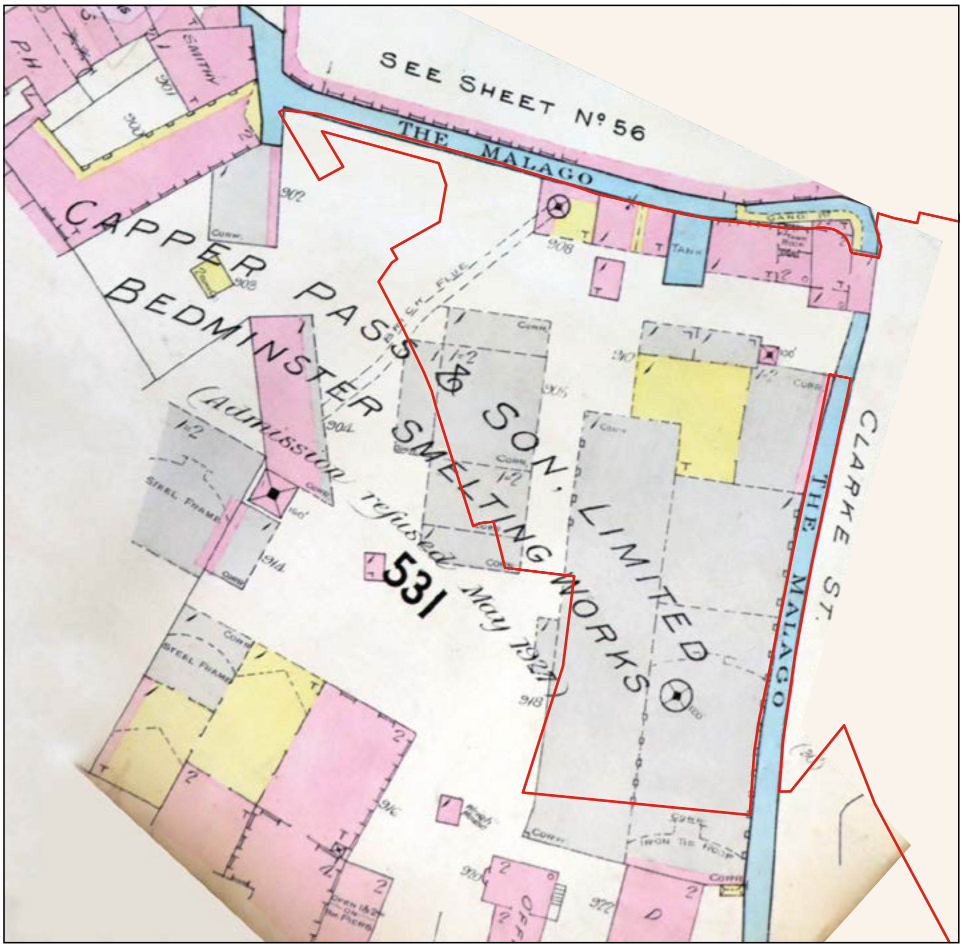


Figure 6.1 Goad Fire Insurance Plan, 1927. Reproduced with the permission of Bristol Archives

In 1927, the company purchased over 20 acres of land in Keynsham, but this was never used. The following year, the directors visited potential sites for a new smelting works in Newport, South Wales; Sharpness, Gloucestershire; Perivale, Middlesex; and Goole, Yorkshire. None were suitable. Eventually the company settled on a flat 120-acre (48.6 ha) greenfield site in Melton, Yorkshire. The land lay alongside the London and North Eastern Railway line, which provided a direct link to Humber Dock in Hull. It was also close to the Yorkshire coalfields, had ample local labour, a

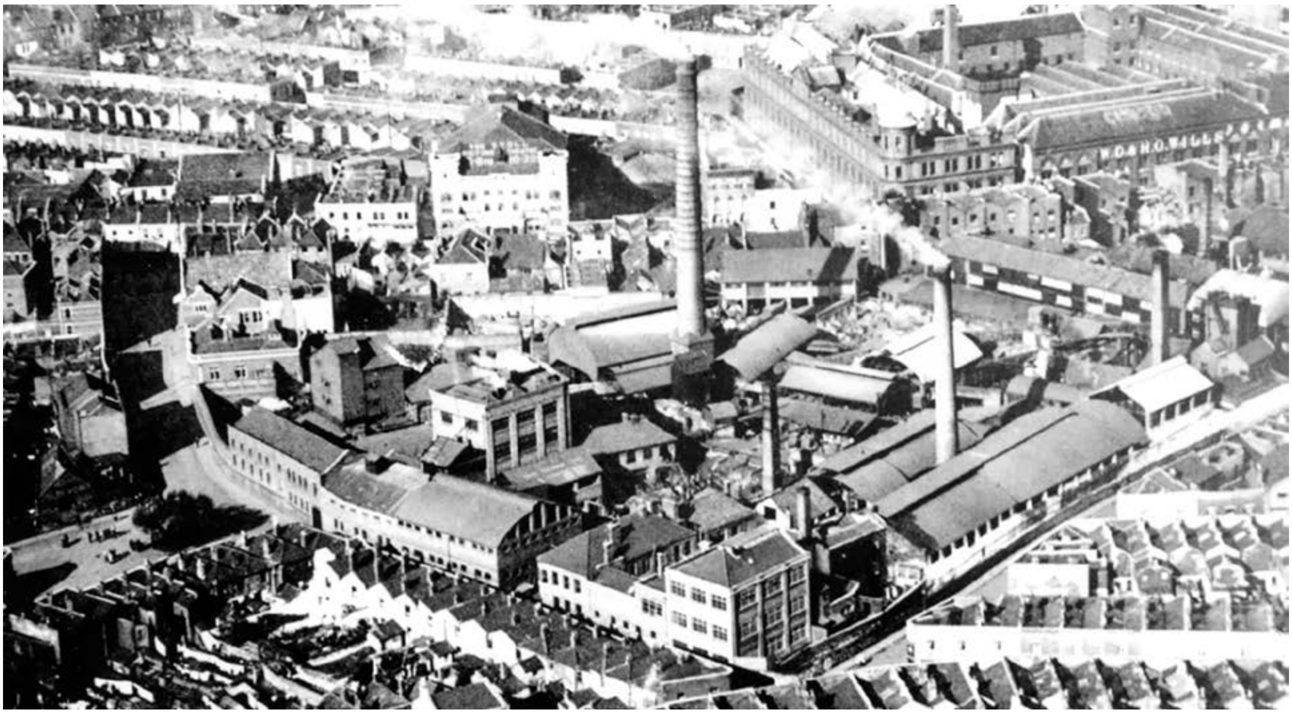


Figure 6.2 1920s aerial photograph of the Bedminster Smelting Works. BMAG ref. P12543. Image courtesy of Bristol Museums and M Shed

borehole for water, an adjacent chalk quarry for lime, and some disused claypits that could be used for dumping slag. The land was purchased for £12,000 in 1928, but the economic uncertainty of the Great Depression delayed construction until 1936 (Little 1963 , 26–30).

Despite its planned move to Melton, the company continued to invest in buildings in Bedminster: in 1931–2 two large steel sheds, a laboratory, and an electrical substation were built at Shene Road; a new building was built at Mill Lane in 1932; and the offices fronting Paul Street were extended in 1938 (BA Building_plan/Volume_110/23l; 115/13b; 115/57e; 116/41f-g; 165/7b).

In 1937, Paul Gueterbock was appointed as managing director of the company (Anon. 1955, 35–6). That year, 60 men were taken on at the Melton site and the first of its blast furnaces started operating. By 1940, there were three blast furnaces in operation in Melton, and 220 men were employed at the works (*Hull Daily Mail*, 21 May 1930, 6; Leeds Mercury, 27 February 1935, 3; Little 1963, 29–30). The site subsequently expanded to encompass 400 acres (161.9 ha), 55 acres (22.3 ha) of which was used for smelting activities; the remainder was a buffer zone containing agricultural land with some houses (R. Smith, pers. comm. 2024).

World War II, 1939–45

The outbreak of war in September 1939 had little immediate impact on the inhabitants of Bristol, but on the night of 19 June 1940, the Bristol Aeroplane Co. in Filton was bombed. This marked the beginning of the Bristol Blitz; an event that ultimately caused the deaths of 1243 Bristolians and reduced large areas of the city to rubble. There were much larger night-time raids between 24 November 1940 and 4 January 1941, which caused widespread destruction in the city centre. The final raid, which lasted 12 hours, caused serious damage in Bedminster. On the night of 11 April 1941, there was another five-hour attack known as the Good Friday Air Raid. During this attack, 193 tons of high explosive and 38,888 incendiary bombs were dropped on the city, many of which fell on Bedminster and Knowle (Penny 2001, 2, 8–9, 14, 22). The last, much smaller, raid happened on 15 May 1944 (Bristol Archives 2016, 1). The Bedminster Smelting Works escaped serious damage during the Blitz, but many of the houses in nearby Stafford

Street and Willway Street were destroyed by high explosive bombs, as were several houses on Clarke Street and the western end of Percy Street (BA 33779/7-8; Little 1963, 30; Wessex Archaeology 2022, 7–8). The Great Western Tannery, immediately to the north of the smelting works, was hit by a 1000 kg bomb that failed to detonate. The weight of the bomb caused it to burrow 30 ft (9 m) into the underlying alluvium, where it remained for nine years. It was eventually defused by the No. 5 Bomb Disposal Squad in 1950 (*WDP*, 25 March 1950, 1).

Tin was a vital wartime commodity. Battleships required several tons of tin each; every submarine needed three tons; and large quantities were also needed for components of tanks, trucks, aircraft, and ordnance (Rand 2023, 3). It was also an essential ingredient for various lead and copper alloys and was used to make ammunition boxes and morphine syringes (Collyns 2022). At the outbreak of war, the Republic of Bolivia was the most important source of Allied tin ore. Commencement of the Battle of the Atlantic in 1939 made the crossing extremely hazardous. To minimise losses, tin ore was shipped to the USA for processing in new government-owned smelting works in Texas (Little 1963, 30). Latin American countries were prohibited from trading with Axis powers and the price of tin was set by the Allies. This created an impression of exploitation by rich countries, something that the leftist Movimiento Nacionalista Revolucionario (MNR) used to delegitimise the conservative government of General Enrique Peñaranda del Castillo. In 1943, Peñaranda was deposed during a coup d'état led by Gualberto Villarroel, who established a pro-fascist military dictatorship in his place (Collyns 2022; Hillman 1990, 289; *The Canberra Times*, 22 December 1943, 1). The loss of Bolivian tin forced British smelters to look for alternative local sources. Cornwall was the country's traditional tin-mining area, and the large slag heaps left by previous generations proved to be a source that Capper Pass & Son Ltd were well suited to exploit (Little 1963, 30). Cornish tin was transported by rail (BMAG OH33), thus avoiding the perils of U-boat infested waters along the Atlantic coast. Despite the availability of Cornish slags and ores, tin remained in short supply, and the company was apparently sometimes forced to use silver in place of tin for solder making (*BEP*, 25 October 1960, 16).

Prior to World War II, Capper Pass & Son Ltd produced significant quantities of copper sulphate for use as a fungicide in vineyards and fruit farms. The occupation of Europe's winemaking regions dramatically reduced the demand for this chemical. To mitigate the loss of this market, the company switched to manufacturing electrorefined copper cathode (99.95% or more pure copper), which was used for electrical wiring. Electrorefining of lead was also undertaken to recover bismuth and silver (Little 1963, 30).

As well as providing for the needs of the war effort, Capper Pass & Son Ltd continued to operate as a commercial enterprise, and by the end of the war the company had acquired two other solder-making companies: Victor G. Stephens Ltd, trading as the Tyne Solder Co., of Felling-on-Tyne, County Durham; and Messrs George Pizey of London. The London company was subsequently closed, and its plant was moved to Felling-on-Tyne (Little 1963, 30–1).

Post-war Period, 1946–63

A 1946 plan of the smelting works (Fig. 6.3) shows its layout in some detail, though it does not show the furnaces or other equipment. The 19th-century boiler house was still extant at this time, and the boilers and steam engine may still have been operational. The accuracy of this plan is confirmed by contemporary vertical aerial photographs (not illustrated).

The end of World War II saw a resumption of Bolivian tin ore imports, most of which were processed in Melton (Matthews 1946, 1175). By 1948, Capper Pass & Son Ltd

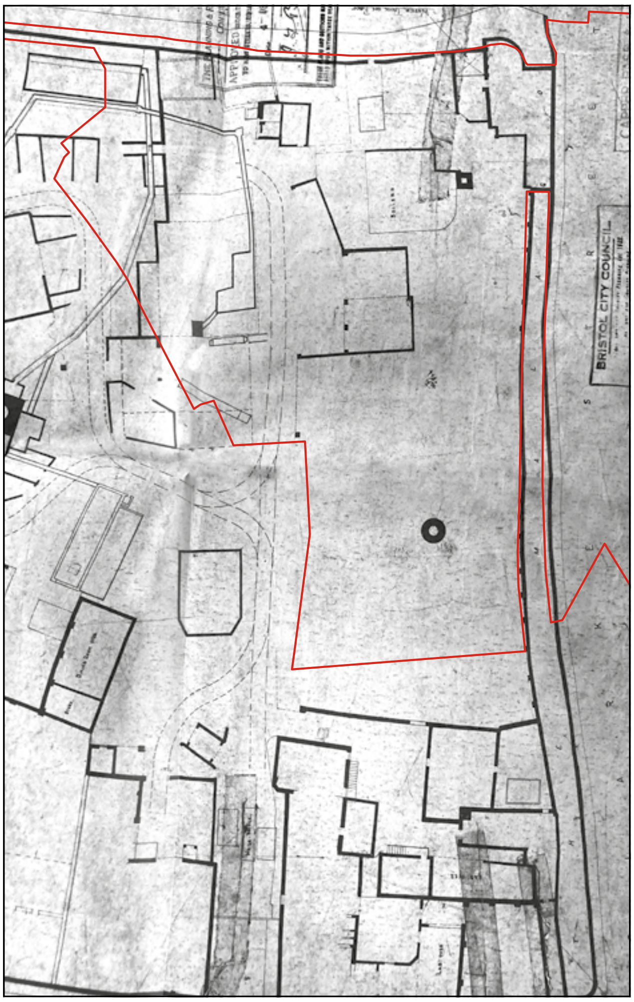


Figure 6.3 Plan of the Bedminster Smelting Works, 1946. Reproduced with the permission of Bristol Archives. Ref. Building_plan/Volume_197/6M

were producing 2500 tons of tin a year, which amounted to approximately 7% of British production (Central Intelligence Agency 1948).

Further political upheaval in Bolivia, particularly the Bolivian National Revolution of 1952 and the nationalisation of the mining industry by the reformist government of Victor Paz Estenssoro, brought further disruption to the tin trade. Fortunately for Capper Pass & Son Ltd, they were able to use their personal contacts to make agreements with the new state-owned *Corporación Minera de Bolivia* (COMIBOL) that ensured a continued supply of ore. The US wartime tin smelter in Texas was purchased by the Wah Chang Corporation in 1958, who adapted it to produce tungsten and tin alloys, leaving much of the Bolivian tin trade in the hands of Capper Pass & Son Ltd (Anon 2024; Little 1963, 31). To meet the increased demand, the workforce in Melton was increased from 228 in 1946 to 400 in 1952, some of whom were transferred from Bedminster (BMAG OH33). In 1955, the head office was moved from Bedminster to Melton (Vincent 2022, 32).

During the post-war period, the Bedminster works were primarily used to make solder, but electrorefining of tin did continue at the Shene Road site. In this period, the company's main customers for solder were local government, the Royal Air Force and large electrical companies (BMAG OH34.6). Solder from Bedminster was transported to Felling-on-Tyne for finishing; most of it was then transported south again to be sold. This was obviously inefficient, so in 1959, the company decided to close the Felling-on-Tyne works and transfer its equipment, along with 12 of its workers, to Bedminster (*ibid.*). The new equipment was installed in a purpose-built solder extrusion and casting workshop at the northern end of the works. The Goad Fire Insurance Plan of 1961 (Fig. 6.4) shows that the new building was steel framed with a corrugated asbestos cement roof. The older parts of the buildings, which comprised a mix of brick and metal-framed buildings with corrugated iron roofs, contained 20- and 50-ton solder pots and lead detinning and softening pans. The former engine house and smithy were converted for use as garages and workshops. The building containing the third blast furnace, which was located to the west of the excavation area, was also significantly expanded in the 1950s.

In 1960, Douglas Pass, who was 75 years old, retired as chairman of the board (Vincent 2022, 33). Two years later, it was announced that the Bedminster Smelting Works would be run down. This made 100 workers redundant, though 20 were kept on for solder and high-grade tin making at Shene Road (*BEP*, 25 October 1962, 2). The Bedminster Smelting Works closed in 1963.

Archaeological Remains

The transfer of solder-making equipment from the Tyne Solder Co. to Bedminster in 1959 necessitated a major reordering of the northern part of the smelting works. Specifically, boiler houses B12 and B14 and the northern end of B16 were demolished and replaced with a new steel-framed building (B17), built to house solder casting and extrusion workshops.

Figure 6.4 Goad Fire Insurance Plan, 1961. Reproduced with the permission of Bristol Archives

Building B17 was constructed of I-section steel stanchions founded on concrete pads. The spaces between the stanchions were infilled with brick bonded with Portland cement. The floors were concrete. The Goad Fire Insurance Plan of 1961 (Fig. 6.4) shows that the building had pitched steel-framed roofs covered with corrugated asbestos cement sheeting.

The only internal feature in the solder extrusion shop was an asbestos cement and concrete drain (S45). Within the solder casting shop, there were two small furnaces (S46 and S47; Fig. 6.5) and a large concrete foundation (S48) and associated drain. Furnaces S46 and S47 were constructed of brick and concrete (Fig. 6.6), with a layer of asbestos caulking sandwiched between the brickwork. Removal of the asbestos by specialist contractors entailed the partial demolition of the furnaces prior to recording. The furnaces were circular or semi-circular, with an internal diameter of approximately 1 m. There were no fireboxes. This, and the presence of an 8000-gallon (36,269 l) fuel oil tank at the southern end of works (Fig. 6.4), suggests that these were oil-fired furnaces. There was another furnace of similar design (S49; Figs 6.5 and 6.6) in the room to the east of the solder casting shop. A near-contemporary photograph of the Tyne Solder Co. (Fig. 6.7) shows identical furnaces prior to the dismantling and transfer of equipment to Bedminster. Furnaces S46, S47 and S49 were probably used to melt small quantities of solder for casting into strips or bars.

The function of structure S48 is uncertain, but it seems likely that it was a large machine base. Solder extrusion machines would have required foundations of this size, and this may have been its function. This interpretation is at odds with the function of the room stated on the 1961 plan (Fig. 6.4). It should, however, be noted the 1961 plan was based on an existing plan of the works rather than a new survey (the surveyors were refused access), so some details may be inaccurate.

Lead detinning and softening pans S39 and S40 probably remained in use until the closure of the smelting works. They were subsequently infilled with dumps of metallurgical laboratory equipment, including an assemblage of proprietary sample bottles dating from 1955–8 (see Chapter 9, ‘The Science of Smelting: Assaying and Analysing’).

As part of the 1959 reordering, solder pot S35 was demolished, along with the southern furnace of solder pots S34 (see Fig. 5.24). The stoking cellar serving the remaining furnace (labelled Z on the 1961 plan; Fig. 6.4) was rebuilt on a smaller scale.

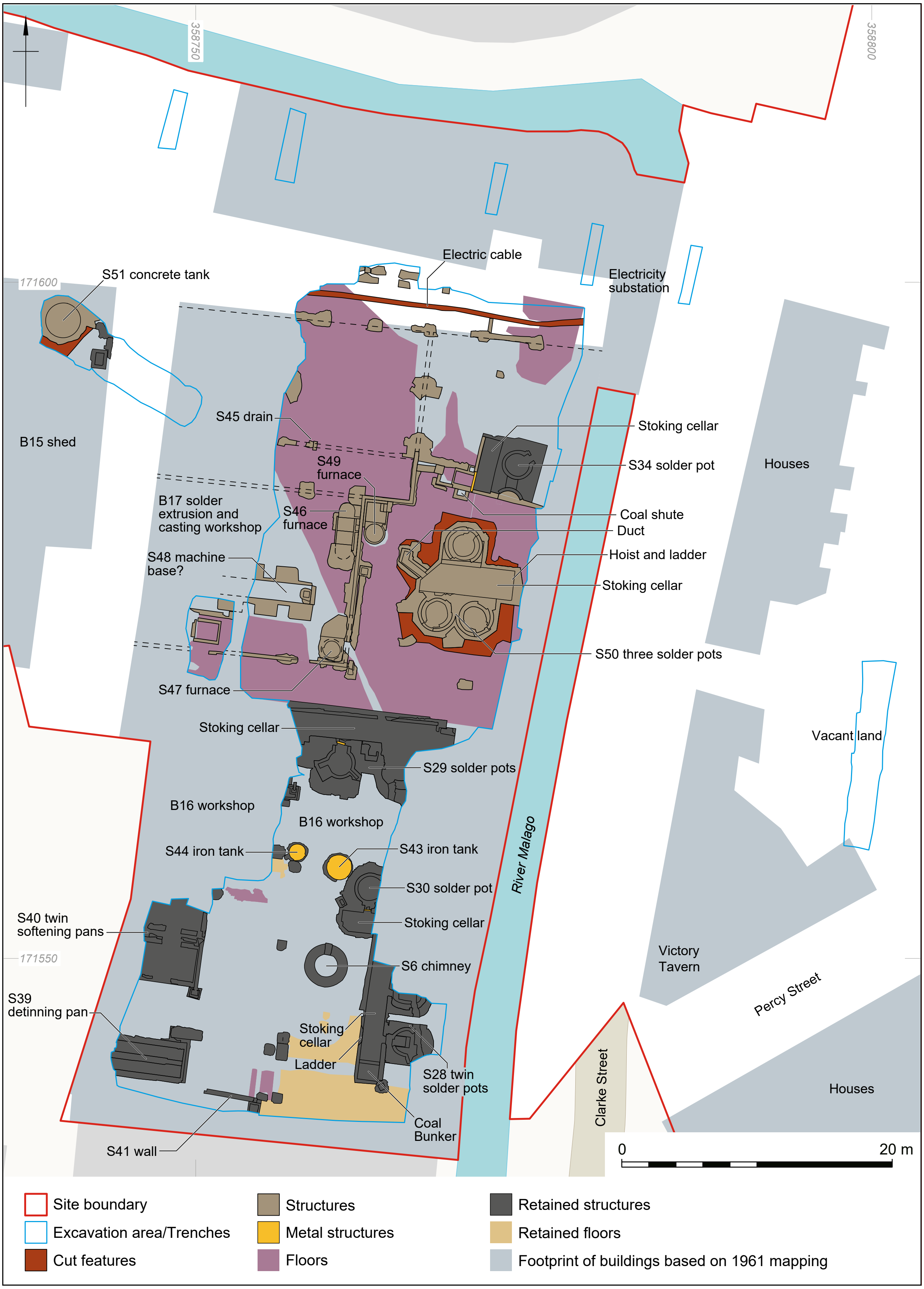


Figure 6.5 Archaeological features, 1914–63

Figure 6.6 Furnaces S46 and S49, looking south-west

The rebuilt cellar had a sloping concrete chute and a small compartment on its west side: this was probably a coal bunker. The demolished solder pots were replaced with a bank of three new coal-fired furnaces (S50; Figs 6.5 and 6.8). These furnaces, labelled K, L and M on the 1961 plan (Fig. 6.4), were all 20-ton solder pots. Solder pots S50 were built of brick and concrete, with corrugated iron used as shuttering. The stoking cellar could not be examined in detail because of flooding and contamination with asbestos and hydrocarbons. Solder pots S50 were built to the same design as the earlier solder pots, with arched firebox openings edged with bullnose bricks, and thick cast-iron doors to the furnaces (see Fig. 6.8). The flow of oxygen to the furnaces was regulated by air inlets to the sides of the fire doors. The stoking cellar was accessed via a fixed iron ladder. To the south of the ladder, there was a small square chamber that contained a coil of thick steel cable: this appears to have been the base of a hoist or lift. At the west end of the stoking cellar, there was a concrete duct capped with corrugated iron and concrete. The duct probably contained pipework, which was removed by asbestos removal contractors without archaeological supervision.

In building B15, there was a large circular concrete tank (S51; Fig. 6.5) with an internal diameter of 2.53 m. The tank was infilled with concrete rubble and fragmented corrugated asbestos roofing sheets. The infilled tank, which was capped with concrete, was probably decommissioned before the smelting works closed. Its purpose is unknown.

Figure 6.7 Interior of Tyne Solder Co., Newcastle, 1950s. BMAG ref. P10790. Image courtesy of Bristol Museums and M Shed

Figure 6.8 Solder pots S50, looking south-west

Discussion

The Bedminster Smelting Works was at its most productive in the years leading up to World War I. A large proportion of the workforce was enlisted during the war, but the demand for metal meant that this continued to be a profitable time for the company. This allowed further investments in buildings and equipment, though none of the excavated features can be attributed to this period. There were further changes in the inter-war period, notably the installation of electrolytic equipment for tin refining at the Shene Road site in 1919, and the gradual replacement of corrugated iron with asbestos cement roofs from the mid-1920s onwards.

The final phase of building at the smelting works was primarily related to the installation of the new solder finishing equipment that was relocated from the Tyne Solder Co. in 1959. The furnaces used to create the finished product were small and probably oil-fired, though a new bank of coal-fired solder pots also appears to have been installed at this time. Interestingly, the design of the solder pots was virtually identical to those of the late 19th and early 20th centuries, the only significant change being a more extensive use of concrete.

The fact that the company was willing to invest in a major rebuilding programme as late as 1959 is noteworthy, as it suggests that the decision to close the works was not taken until after this date. Similarly, Little's (1963) history of the company ends with an upbeat assessment of its prospects, with no hint that the Bedminster works would very soon be closed. The closure of the Bedminster Smelting Works in 1963 brought 123 years of metal production in Bedminster to an end, and within a few years all trace of the heavy industry that once dominated the district had been swept away.

CHAPTER 7
BRIGHT BOW BRICKYARD AND THE DEVELOPMENT OF CLARKE STREET, PERCY STREET AND WHITEHOUSE LANE

Historical Background

Bright Bow Brickyard

During the late 18th century, the land to the east of the River Malago (Plot B) was owned by Edward Elton Esq. of Greenaway House, Devon (Table 2.1; BA AC/PL/92), and like many of the fields to the north, it was used as a brickyard. By the mid-19th century this had become known as the Bright Bow Brickyard, named after nearby Bright Bow Bridge (*BM*, 4 October 1856, 1; census 1851).

Edward Elton was a wealthy landowner who served as Warden of the Society of Merchant Venturers in 1770 and High Sheriff of Somerset in 1780 (Beaven 1899, 127; Bristol Poll Book 1781, 80; Dunning 1983, 109–17). Like many prominent Bristolian merchant families, the Eltons derived much of their wealth from the Atlantic trade. This included substantial interests in slave trading, Jamaican sugar plantations, and sugar refineries in Bristol. Edward Elton's great grandfather, Abraham Elton, was also an important pioneer of the local glass and copper smelting industries. By the mid-18th century, the Elton family's business interests were increasingly focused on property ownership and estate management (Huxtable *et al.* 2020, 99). It is unknown how Edward Elton came to own the Bright Bow Brickyard: he may have inherited it, or he might have purchased it directly from the Smyth family. Elton died in 1811, and by 1826, the land had been acquired by Nehemiah Bartley Esq.

Nehemiah Bartley lived in Unity Street, Old Market, and ran a lead smelting business in nearby Great Ann Street (Bristol Poll Book 1830, 103; 1832, 105; Table 2.1). He leased the Bright Bow Brickyard to the brick and tile manufacturer William Coombs & Co., whose products included common bricks, roof tiles and malt kiln floor tiles (Crew 2021, 6, 7, 28). The brickyard is depicted on maps of 1827 and 1828 (Figs 2.3 and 2.4), which show large buildings, probably kilns and drying sheds, to the south of modern Philip Street, along with two large water-filled claypits.

In 1831–2, William Coombs placed a series of notices in local newspapers advertising the lease of his brickyard and the sale of stock. The latter included 20,000 pantiles, 1000 malt kiln tiles, and an unspecified quantity of bricks for 28s per 1000 (*BTM*, 9 July 1831, 3; *BM*, 21 January 1832). Coombs died in 1833, and control of the brickworks passed to his nephew William Martin (BA AC/M/11/35; P.St JBed/SD/1; *BM*, 24 August 1833, 3; census 1841; tithe apportionment 1841; Table 7.1). The landowner, Nehemiah Bartley, died the following year, but he is still listed as owner on the 1841 tithe apportionment, possibly due to an unresolved and long running legal dispute over his estate (BA PROB 11/1835/502; TNA C 14/191/B67).

Table 7.1 Land ownership, occupants and use in 1841

Plot	*Nos*	*Field name*	*Description*	*Owner*	*Occupant*
Bedminster Tithe Map, 1841					
A	553–6		Not listed		
B	557		House, garden, brick kilns, etc.	Nehemiah Bartley	William Martin

The Bedminster Tithe Map of 1841 (Fig. 4.1) shows a similar layout of brickyard buildings to the preceding maps. By this date, the northern claypit had been infilled and the southern claypit had been enlarged. The latter is depicted as filled with water. To the west of the brickyard there was a large tannery. Contemporary complaints about animal processing waste, including flesh and offcuts of hides, being dumped to the north of Whitehouse Lane suggests that the worked-out claypits were used as refuse dumps (Cotswold Archaeology 2018, 23).

The 1841 tithe apportionment identifies the brickyard's occupant as William Martin, though the census return for that year lists him as a brickmaker living in St Philip's Marsh. This is probably explained by the fact that the Martin family owned at least two brickyards: one in St Philip's Marsh and the Bright Bow Brickyard in Bedminster. The Bedminster yard appears to have been run by William's brother Henry, who is listed as the head of one of the four households (30 individuals) that lived at the brickyard (census 1841). All three of Henry Martin's sons (Henry II, William and Isaac) are listed as brickmakers. Two of the men that lived in the adjacent houses are also listed as brickmakers, one of whom, Abraham Coombs, was probably a relative.

William Martin died in 1847 (BA EP/V/4/42), and the 1851 census lists Henry Martin and family as sole residents of the Bright Bow Brickyard. Henry is listed as a 'brick and tile maker, employing six men'. Two of these were his adult sons, Henry and Thomas, who lived in the same house and are respectively listed as a tile maker and labourer. Henry Martin died in 1852 (England and Wales Civil Registration Indexes); the business was subsequently run by his widow, Jane Martin. By 1861, she and her sons were living in St Philip's Marsh. Jane is listed as the owner of a brick and tile works; her sons are recorded as a tilemaker and tile moulder. The Bright Bow Brickyard is depicted on Ashmead's plan of 1854 (Fig. 4.2), and was still extant in 1856 (*BM*, 4 October 1856), though it is uncertain if it was active at this date.

Clarke Street, Percy Street and Whitehouse Lane

The dispute over Nehemia Bartley's estate appears to have been resolved by 1850 (TNA C 14/191/B67; TNA C 14/1088/B78; TNA C 101/6344). The Martin family were still resident at the brickyard in 1851, but it is likely that the property was sold soon after. The land, also known as Whitehouse Mead and Rag Acre, was subsequently acquired by a bank manager and solicitor named William Clarke Esq. (BA 41478/5). By 1854, a street of terraced houses had been laid out immediately to the north of the brickyard kilns. The new road was named Philip Street, probably after William Clarke's son Philip Percy Doveton Clarke, who is also likely to be the namesake of the nearby streets that bear his middle names. The brickyard itself was cleared and redeveloped soon after, and by 1863 rows of terraced houses were being erected along Whitehouse Lane, Percy Street and Clarke Street. The development of Doveton Street started in 1864, and by 1874 all the streets within Plot B were lined with buildings (Fig. 5.2). As well as houses, there were a few commercial and industrial premises. The latter included a small foundry, known as the Bedminster Iron Tomb Railing and Iron Foundry, at 66–68 Percy Street, which was established by Richard A. Smith in 1863 (*WDP*, 6 July 1877, 4). Smith died in 1877, and the foundry sold to Messrs Gillett & Burns as a going concern (*WDP*, 18 July 1877, 4). One of the owners, James Gillett, was declared bankrupt in 1879, and the business, then known as the Bedminster Iron Foundry, was liquidated to pay his debts (*WDP*, 15 March 1879, 4).

Historic mapping and aerial photographs show that the basic layout of the streets within Plot B remained largely unchanged until World War II (Figs 5.3, 5.4, 5.6, 5.7, 6.2 and 7.5). Percy Street and Clarke Street suffered significant damage during the Good Friday Air Raid of 1941, including the complete destruction of several houses. The area never fully recovered from the War, and in 1958, a clearance order was issued for the whole of Percy Street, Clarke Street, Doveton Street and much of Whitehouse Lane.

By the following year, most of their inhabitants had departed, leaving a few elderly people awaiting rehoming (*BEP*, 21 August 1958, 22; 16 April 1959, 14–15). The land was subsequently cleared and used for light industrial and storage purposes.

Archaeological Remains

Claypits of the Bright Bow Brickyard

Cartographic evidence indicates that although the brickyard in Plot B was active in the late 18th century, the excavated clay extraction pits (S52; Fig. 7.1) date from the early to mid-19th century. In the areas unaffected by 19th-century clay extraction, the upper surface of the buried meadow was recorded at heights of between 7 m and 7.45 m OD. Previous geotechnical investigations recorded the base of the claypits at 5.3–6.3 m OD (Clarkebond 2020), indicating that the claypits were originally somewhere between 0.7 m and 2.15 m deep. The land surface and claypits were infilled and overlain by 1.5–3.5 m of dark grey silty clay, with lenses of rubble and occasional organic inclusions, including

Figure 7.1 Late 18th- to mid-19th-century claypits within Plot B

animal fur (tannery waste). The latter gave off a strong hydrocarbon odour, probably caused by anaerobic decay of plant and animal matter in water-filled pits. The infill deposits represent piecemeal dumping of tannery, construction and industrial waste, interleaved with natural silting. Very small quantities of 19th-century glass and pottery were noted in the infill deposits, including post-1830 improved stoneware. The dumped deposits were capped by a compact, 0.2–1.1 m thick layer of redeposited natural dark red silty clay, sand and Redcliffe Sandstone rubble, the upper surface of which was recorded at 6.6–8.38 m OD. The solid geology to the north-west of the Malago (see Fig. 2.1) is Redcliff Sandstone. In the mid-19th century, north-west Bedminster was an area of intensive housebuilding, and it is plausible that some of the debris infilling the claypits is spoil derived from construction activity in that area. In the trench adjacent to Whitehouse Lane, the capping deposit was overlain by a 1 m thick dump of brownish grey silty clay, which brought the ground level up to 7.72 m OD. The infilling and levelling of the claypits was probably undertaken in the late 1850s or early 1860s in preparation for the redevelopment of the land.

Clarke Street, Percy Street and Whitehouse Lane

The excavated remains of 1860s and later buildings along Clarke Street, Percy Street and Whitehouse Lane (Fig. 7.2) included the remains of six terraced houses (B18–B22), part of the Bedminster Iron Tomb Railing and Iron Foundry (B23) and an outbuilding (B24) to the rear of a house fronting Clarke Street.

The houses (B18–B22) were built to a common two-up two-down plan (Fig 7.3). The front door opened onto a corridor that provided access to a parlour, kitchen, scullery and a centrally located stair that provided access to the first-floor bedrooms. The rear gardens/yards, which were accessed via a door from the scullery, contained lean-to privies fitted with water-flushed toilets. The house foundations were constructed of limestone rubble bonded with pale brown lime mortar. The presence of brick sleeper walls and the absence of internal surfacing indicates that the ground-floor rooms had suspended wooden floors. Heating was provided by fireplaces: some were in the corners; others were centrally located against the party walls. Below the corridors, there were 9-inch (229 mm) diameter ceramic drains (S53 and S54), linked to a public sewer below Percy Street.

Building B24 was a 3.1 m wide by over 6.8 m long outbuilding, built of brick and limestone, with an internal limecrete floor. There were no indications as to the function of this building, which is probably best interpreted as a small workshop.

The remains of the Bedminster Iron Tomb Railing and Iron Foundry (B23; Fig. 7.4) comprised the external walls, which were one brick thick, and a brick floor that extended throughout the building. There were two parallel brick gullies running north-west to south-east down the centre line of the building. These might have been guides for the wheels of a travelling crane, or they may simply have been drainage gullies.

The basic layout of the houses along Clarke Street, Percy Street and Whitehouse Lane remained largely unchanged throughout their existence, but there were some small modifications to the rear of the properties, such as a post-1897 reconfiguration of the drains and the concreting of the yard to the rear of house B22. A small pit (S56), backfilled with pottery and glass dating from c. 1910–30, was probably a planting hole for a small tree or shrub.

Percy Street and Clarke Street suffered significant damage during the Bristol Blitz, evidenced by 1946 aerial photographs (Historic England 2024), which show a missing block of seven buildings towards the western end of Percy Street, and a further four missing buildings on the corner of Clarke Street and Doveton Street. Remains associated with World War II comprise the base of an Anderson shelter (B25), possibly

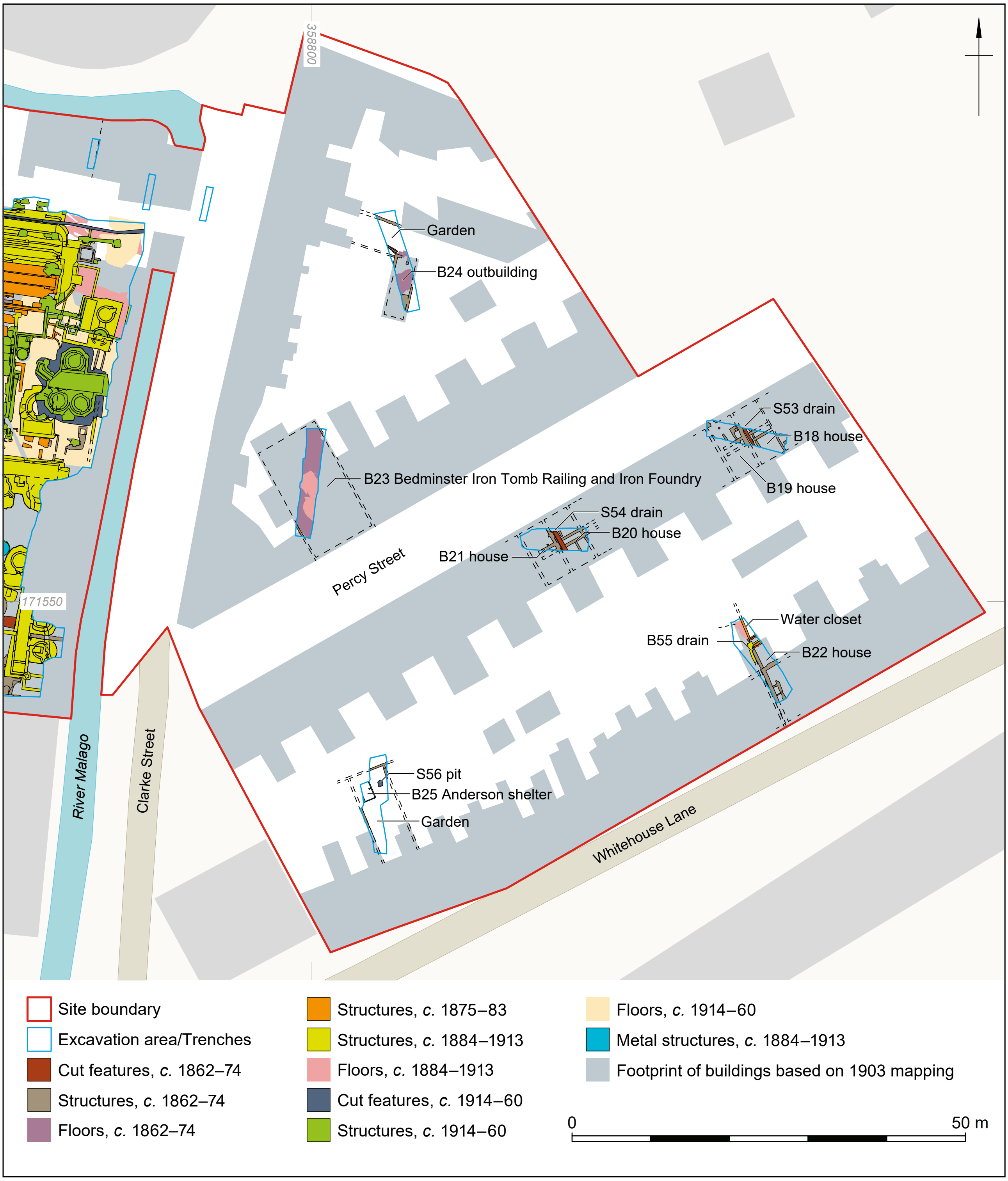


Figure 7.2 Terraced houses and other buildings within Plot B, c. 1862–1960

repurposed as a post-war garden shed, and a Vulcanite bottle stopper marked 'WAR GRADE', which was found in the adjacent garden soil. Vulcanite is a non-elastic hard rubber made from a mixture of natural rubber, sulphur and linseed oil. During World War II, rubber became a strategic resource, used to make gaskets, tyres, gas masks and other objects for military use. Civilian use was restricted, and Vulcanite manufacturers were forced to reduce the rubber content of their products; hence the phrase 'War Grade' (Hallett 2015).

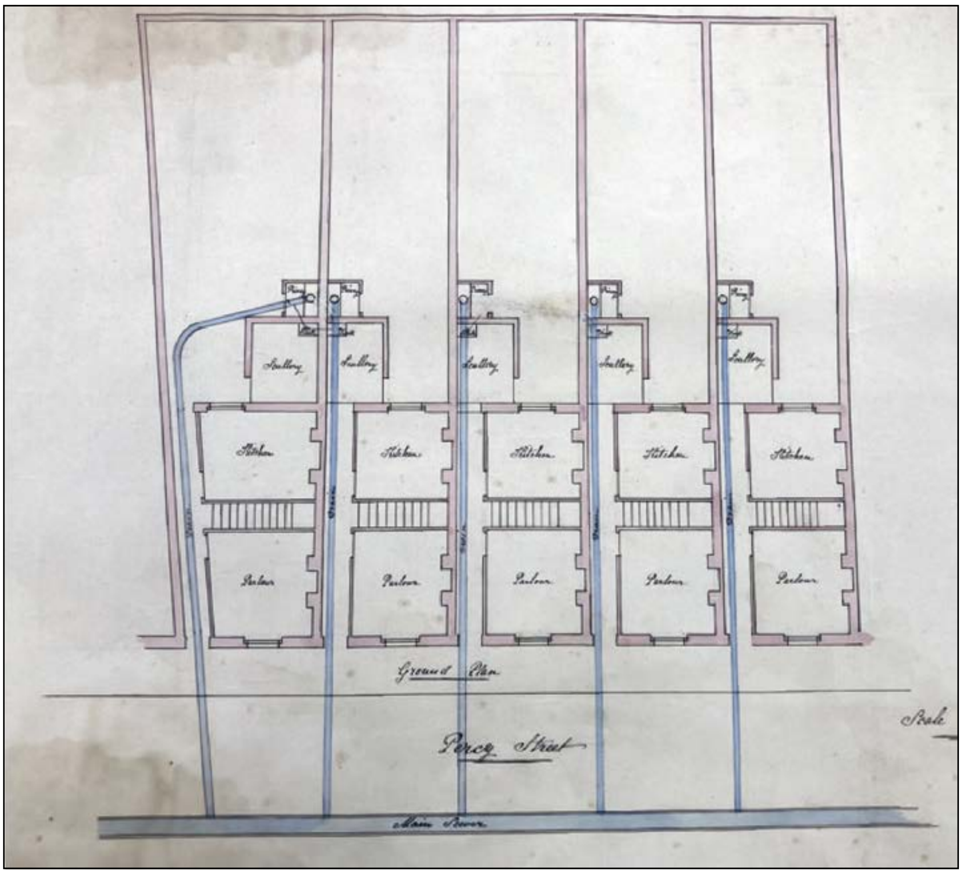


Figure 7.3 Plan of five houses on Percy Street, 1863. Reproduced with the permission of Bristol Archives. Ref. Building_plan/Volume_6/31a

By the early 1960s, the whole of Plot B had been cleared of buildings, leaving an expansive area of rubbly wasteland. The demolition debris was overlain by a compacted oily surface containing crushed brick, glass, metal, and rubber objects (including car parts). The nature of this deposit suggests that the area was used as a haulage and/or scrap metal yard prior to its development for light industrial use.

Discussion

There are extensive deposits of alluvial and intertidal clay throughout the northern part of the Malago Vale, parts of which were exploited for brickmaking from the early 18th century onwards. The Bright Bow Brickyard, which was active between the late 18th century and c. 1850, appears to have been a southward expansion of this activity. The brickyard was operated by the related Coombs and Martin families, who leased the land from a succession of wealthy landowners. They manufactured common bricks, roof tiles and malt kiln floor tiles, and ran a second brickyard in St Philip's Marsh. The kilns, storage sheds and associated workers' cottages were located to the north of the excavation area, in the area now occupied by Windmill Hill City Farm. By the mid-1820s, the land within the excavation area was being used for clay extraction. Quarrying in this location probably continued until the 1850s. This activity truncated the underlying ground by up to 2 m, thereby removing any trace of earlier remains. After the clay had been extracted, the claypits were used as dumps for industrial and construction waste.

The development of Bedminster as an industrial suburb required new homes for the area's growing population. The higher ground on Windmill Hill and Southville was developed with good quality houses for wealthier working- and middle-class residents, whereas the lower flood-prone ground alongside the Malago was used for industrial purposes and working-class homes. The former Bright Bow Brickyard was a far from ideal location for new housing: as well as the risk of flooding, the soft and poorly consolidated refuse infilling the claypits made it unsuitable for building. To remedy these shortcomings, thousands of tons of clean sand, clay and sandstone rubble were imported onto the site to cap the claypits, raise the ground levels and provide a firm base for construction. This material was probably sourced from construction sites on the west side of Bedminster, or other parts of the city where the digging of foundations generated large quantities of spoil.

By the early 1860s, rows of terraced houses had been built along Whitehouse Lane and the newly laid out Percy Street and Clarke Street. Most of the houses were two-up two-down terraces built in the late Georgian style that remained common in Bristol until well into the Victorian era. These houses had parapet frontages, butterfly roofs and front doors that opened directly onto the street: surviving examples of this style

Figure 7.4 Floor of the Bedminster Iron Tomb Railing and Iron Foundry (B23), looking south

of house can be seen at the south-eastern end of Philip Street. There were also a few shops, mostly along Clarke Street, and by 1871, the Victory Tavern public house had been established on the corner of Clarke Street and Percy Street.

In the aftermath of World War I, there was a concerted effort to improve the nation's housing stock (see Chapter 6). Many local authorities, including Bristol Corporation, began large-scale demolitions of 'slum districts' (a term vigorously disputed by many of their inhabitants) and the construction of new housing estates to rehome the displaced populations. In Bristol, the first areas to be cleared were the oldest and most dilapidated streets in the city centre. As the century progressed, the definition of a house 'unfit for human habitation' broadened, and by the 1950s, many of the city's older areas of working-class housing had been condemned to wholesale clearance. In 1958, the streets within Plot B were issued with a clearance order and they were demolished shortly afterwards.

Clearance of this area can be seen as part of a national and international trend, where governments and local authorities tended to view ill health and social problems of the poor as primarily a housing issue: the solution to which was invariably wholesale demolition of entire districts of working-class housing (Gaskell 1990, 7; Mason 2020b, 113; Massheder-Rigby 2018, 90; Murray and Mayne 2001, 90; Solari 2001, 22). But were there other local factors at play in the decision to demolish the houses in Plot B?

The houses along Clarke Street, Percy Street and Whitehall Lane (Fig. 7.5) were typical mid-19th-century Bristol houses, many examples of which survive as perfectly decent homes. So why were these condemned while other streets of similar houses were left intact? The location, on the site of a former brickworks close to a flood-prone river, certainly played a part. The houses were founded on a layer of imported soil and rubble overlying soft ground: this may have caused a degree of settlement, which could lead to cracked drains and walls. The Victorian developers tried to flood-proof the area by raising the ground level and building high retaining walls alongside the Malago. Unfortunately, this was insufficient, and the area remained vulnerable to periodic, and sometimes serious, flooding.

The area was seriously damaged during the Good Friday Air Raid of 1941. Some of the houses along Clarke Street and Percy Street were destroyed, and all the surviving buildings suffered some damage, though often limited to broken roof tiles and shattered windows. Many houses would have been quickly repaired, but some are likely to have

Figure 7.5 Aerial photograph of Bedminster Smelting Works and adjacent streets, pre-1927. Reproduced with the permission of Bristol Archives. Ref. 44819/3/89

been left uninhabitable and derelict. During the post-war period, Bristol Corporation built thousands of new council homes on the outskirts of the city, but there was little appetite for repairs to existing Victorian terraces. Streets in reasonably good repair might be spared the wrecking ball, but many of the Blitz-damaged areas were subject to wholesale clearance.

Heavy industry, a source of employment but also a blight on local houses, disappeared with the closure of Capper Pass & Son Ltd in 1963. Periodic flooding of the Malago, which occurred again in 1968, was solved by the construction of the Malago Storm Water Interceptor in 1971–4 (*BP*, 14 June 2022). Two years later, the unused land to the north of Plot B was repurposed as Windmill Hill City Farm: an institution that transformed the character of the local environment from a post-industrial wasteland to a green oasis in the heart of the city. By the late 1970s, the main issues that had blighted the area – flooding and industrial pollution – had gone, but so too had the inhabitants that might have enjoyed the change.

CHAPTER 8

TECHNOLOGICAL BACKGROUND AND ANALYSIS OF METALWORKING DEBRIS

by David Dungworth and Richard Smith

Introduction

Capper Pass & Son's Bedminster Smelting Works commenced operation as a non-ferrous smelting yard in 1840 and, after a period of experimentation, went on to become a leading manufacturer of tin, solder and related tin alloys (Wright 1966). The Bedminster works were subsequently largely surpassed by the company's new site at Melton, North Ferriby, on the River Humber, established in 1937. By the 1980s, the Melton site produced about 8% of the world's tin from low-grade and complex ores and secondaries. It also produced lead, copper, solder, antimony, bismuth, tellurium, zinc sulphate, silver, gold and precious metals, and was a leading producer of indium. The range of metals and slags produced by Capper Pass & Son at Bedminster was considerable, and the deposits that survived to be archaeologically sampled are unlikely to contain debris representative of all processes (known or inferred) that happened on this site. There are few comparable sites and almost no previous archaeological investigation of these. However, as noted above, the examination of 18 Bedminster samples is unlikely to encompass all historic smelting activity on this site.

Technological Background

Capper Pass & Son operated a non-ferrous smelting business in Bristol from 1815 until 1963. Initially they focused on scrap copper and lead from a backyard premises at Marsh Lane, St Philip's Marsh. They moved to Bedminster in 1840 under Capper Pass II and gradually changed from processing low-value metals to higher-value tin and tin alloy wastes which other smelters were unable to treat (Little 1963, 8–18). The area excavated and sampled covered a small part of the original purchase of 1840, and the subsequent purchase of 1852, but did not include the much larger area to the west bought after 1883 (see Figs 4.2, 5.1, 5.2 and 5.6). The first blast furnace was constructed after 1852, indicating that smelting before then was carried out in reverberatory or crucible furnaces, and that activities were mainly concerned with the melting of metal scrap.

The processes developed considerably and the most recent at Bedminster are known to be very similar to the earliest at Melton. The latter is known in detail by Richard Smith, who was employed by Capper Pass & Son Ltd at Melton, East Yorkshire, joining as Chief Analyst in 1973, followed by management roles in blast furnaces, dry refineries and electrorefineries, before taking over as Chief Metallurgist in charge of research, technical development and environmental affairs until 1989, when he joined 3M UK plc.

Raw materials consisted of complex and low-grade ores and secondaries, such as slags, flue dusts, metal drosses, scrap metal, etc. Fine materials were mixed, fluxed and agglomerated in a sinter plant located to the west of the excavated area, and which appears from plans to have been erected in the early 20th century. Before this, there is a record of 1874 referring to a single blast furnace, for which tannery slap (a mixture of slaked lime, hair and fat) was used for agglomerating dusty charges (Little 1963, 16). At closure, the Bedminster site was smelting with three blast furnaces on five charges: solder, lead, tin, DM (Pb/Sn/low Cu) and SM (Sn/Pb/high Cu). The initial meaning of DM and SM were unknown, even to those who had worked at Bedminster.

Blast furnace metal was cast into pigs and block and was then melted in the lead or solder dry refineries, which produced solder and fire-refined lead for sale. By 1919, Capper Pass & Son Ltd were producing electrolytic tin from Bolivian concentrates, and during the late 1920s they developed a unique electrolytic process that produced tin from solder. The electrolytic processes were operated at the nearby site of the old Malago Brick & Tile Works. Other products included solder, lead, whitemetal alloys, antimonial lead, and copper sulphate (sold to French vineyards as Bordeaux Mixture).

The interpretation of the analysed samples also benefits from a consideration of the wider development of non-ferrous smelting technologies and practices in the 19th and 20th centuries (e.g., Biswas and Davenport 1976; Bray 1947; Muspratt 1860; Percy 1861; 1870; Ure 1839; Wright 1966).

Early lead smelting had been carried out on a small scale and close to where the ore was mined (Willies and Cranstone 1991). The ore (galena, lead sulphide) was heated in simple open hearths and metallic lead produced under relatively oxidising conditions. Slightly more complex furnaces (ore-hearth and slag-hearth) were developed in which air was blown into the furnace by water-powered bellows (Willies 1991). These furnaces were highly successful in smelting relatively pure galena and using poor fuel (e.g., peat). By the 20th century, these had developed into large coke-fired blast furnaces up to 10 m high (Bray 1947, 52). From the early 18th century, the reverberatory furnace became more popular for most non-ferrous smelting. This furnace employed two separate chambers that kept the fuel and ore apart (this allowed effective use of coal as a fuel) and was usually operated in a batch mode that lasted around five hours (Ure 1839, 755). Reverberatory furnaces also allowed smelting without the need to provide a blast of air for the furnace, and so freed many smelters from the need to secure a suitable watercourse to power bellows (the tall chimney attached to the reverberatory furnace ensured sufficient draw of air through the furnace). It could be used to smelt ores, but smaller versions were often employed for roasting ores prior to smelting in more conventional ore-hearth furnaces. Lead smelting slags from these processes (e.g., Bray 1947, table 62; Tylecote 1992, table 74) do not all share the same chemical composition: some are rich in lead and sulphur and appear to be effectively mixed metal sulphates (incompletely smelted), while others are complex silicate slags. Many of the primary lead smelting slags still contained lead, and additional operations were introduced to re-smelt these slags (in a slag-hearth furnace) and recover the lead they contained.

The earliest tin smelting was also carried out on a small scale, at relatively modest temperatures. By the medieval period most tin smelting used small shaft furnaces with charcoal as fuel and air from bellows introduced through a single tuyere (Earl 1991, 57). Such simple furnaces continued in use in various parts of the world into the 20th century. In England, these 'blowing furnaces' were gradually superseded, from the start of the 18th century, by reverberatory furnaces, like those being introduced for lead and copper smelting. One of the major problems in tin smelting is that the ores are more difficult to reduce than those of lead or copper and only slightly less so than iron ores. This results in some iron being smelted along with the tin. Iron can be separated by cooling the tin but the dross which is removed contains roughly 90% tin (Smith 1996). The smelter is faced with a dilemma between producing clean tin under mild reducing conditions but leaving much tin behind in slag, or producing contaminated tin, which can only be cleaned at the expense of re-circulating a high amount of irony dross. The traditional tin smelting process worked well for very high-grade ores, but the issue became critical with medium and low-grade ores. Tin smelting slags are of varied character (Dungworth 2013; Farthing 2005; Malham *et al.* 2002; Tylecote *et al.* 1989), but it is not unusual to find 10–25 wt% tin in primary slags. The compromise was to smelt ores and refining drosses, under mildly reducing conditions (in either a blowing hearth or reverberatory furnace), to give a fairly clean metal and a tin-rich slag. The slag was then smelted in a smaller reverberatory furnace at a much higher temperature under extremely reducing conditions, and with more additions of lime, to produce irony tin, together with a roughly 1:1 tin–iron alloy called hardhead, and a clean slag. The irony tin was re-smelted in the first furnace, the slag was discarded and the hardhead was usually stockpiled or sent to a specialist metal refinery, of which Capper Pass was one of only a few in the world.

Tin could be removed from hardhead by smelting with lead to produce solder, from which iron could be more easily separated. However, this introduced further complications: other impurities such as antimony, bismuth, copper, arsenic and silver became more important and, in addition, it was difficult to ensure a consistent ratio of tin and lead. Capper Pass invested considerable research and analytical effort into overcoming these problems. The experience gained was used to treat low-grade and complex tin, copper and lead ores, as well as materials which other metal smelters produced but could not treat. In the 1980s, one series of company advertisements in metal trade journals simply said: 'Capper Pass & Son Ltd — the smelters' smelter'. The process of removing tin from silicate slags by smelting a wide variety of raw materials with lead (usually bought cheaply as complex secondaries or as waste slags from areas like Cornwall or the Mendips) eventually produced a glut of solder on the market. Therefore, during the early 20th century, the company turned its attention to smelting low-grade and complex tin ores and producing electrolytically refined tin, and then to separating tin from solder electrolytically.

Solder and lead were refined by gradually cooling the molten metals and skimming drosses containing iron and then copper. Iron drosses were returned to the blast furnaces as they contained over 90% solder or lead. Cooling progressed down to 300°C for solder or 330°C for lead. In later years, probably after 1930, sulphur was added with vigorous mechanical stirring to remove copper, producing a dross (sulphur ash) with about 30% copper. Efficiencies of separation were improved even later (probably during the 1950s) by using hot-metal centrifuges to remove liquid solder or lead from the drosses.

The copper-containing refinery drosses included much solder or lead (together with silver and other metals) and were smelted on two blast furnace charges, known as DM and SM (the meanings of these terms were unknown, even to the staff from Bedminster who worked at Melton). Drosses obtained by cooling, which contained 8–12% copper, were smelted on a DM charge, along with bought materials, to produce DM metal, which was cast into blocks. These were placed into reverberatory furnaces, which had removable roofs, and were heated to melting. After raking off any ashes, the metal was cooled slowly to about 350°C to give a solid crust 6–9 in (150–230 mm) thick and known as Pan 6 or Pan 7 SM, above a layer of molten solder. The latter contained about 35% tin (RP metal) which was de-coppered and then used for making solder. Pan 6/7 SM was broken into large pieces and smelted in a blast furnace on an SM charge, together with lead and solder sulphur ashes from the refineries. Bought materials, such as copper or gunmetal slags and skimmings, mixed gunmetal scrap and roasted complex copper/silver ores were added together with solder slags to produce SM metal (referred to by Wright (1966) as 'glanzmetall', which was tapped on to iron floor plates. This had about 43% copper and could be crushed, ball-milled, dead roasted to oxides and leached with sulphuric acid to leave a tin/lead residue and copper sulphate solution, from which copper sulphate crystals were obtained. Copper sulphate was not produced at Melton, where a copper electrowinning refinery was installed; it is not known if there was such a plant at Bedminster.

The blast furnaces at Bedminster and Melton were used for all the charges, and traces of all the smelted metals could be expected in the blast furnace residues found on site. Zinc was a common impurity, which was removed in slags, soot and accretions from blast furnaces, but which did not pass onward to the refineries.

Sample	*Context*	*Feature*	*Sample description/aim*
1	2085	S21	Large fragment of greenish brown copper waste material, taken from the backfill of flue S21. Sample taken to determine origin of this deposit (i.e., is it from copper alloy smelting, or something else?).
2	2071	S40	Greyish white lime ash and metal slag, taken from the backfill of construction cut for lead softening pan S40. Sample taken to determine origin of slag.
3	2044	S20	Yellowish orange burnt brick material taken from furnace base S20. Sample taken for chemical analysis of the degraded brick (i.e., does it contain metal residues from the smelting process?).
4	2026	B6	Greyish green copper and other metal slag material forming rough internal floor surface within building B6. Sample taken to determine origin of the material from which the surface is made.
5	2257	S5	Bright green deposit within flue S5. Sample taken to identify the nature and origin of the deposit (i.e., is it derived from copper alloy smelting, or something else?). Probably deposited in the very early 1900s.
6	3100	S14	Black ash in base of flue S14. Small sample taken for chemical analysis (i.e., what type of metal smelting is the ash derived from?).
7	3115	S25	Flue dust within flue S25. Contains noticeable crystals and may have a high lead content. Sampled for chemical analysis (i.e., what smelting process is the flue dust derived from?).
8	2203	S21	Soot on inner face of flue S21. Sample taken for chemical analysis of soot (i.e., what smelting process were the flue residues derived from?).
9	2235	S11	Soot on inner face of flue S10S11. Sample taken to determine what smelting process the flue dusts are derived from.
10	2178	S11	Deliberate backfill of flue S10S11. Sample taken to determine nature of deposits.
11	3026	S12	Soot inside flue S12. Sample taken to identify nature of flue dusts.
12	3073	S13	Soot inside flue S13. Sample taken to determine nature of flue dusts.
13	2208	S3	Charcoal layer in structure S3. Located on the south edge of excavated area. Sample taken to identify if there are any deposits related to metal smelting related deposits in this feature.
14	2154	S4	Vitrified yellow brick from relining of flue S4. Taken the whole brick as unable to get enough of the melted residue.
15	3052	B7	Dump of slag forming a surface adjacent to a possible blast furnace base S24. Sample taken to identify type of slag and origin (i.e., is it from the blast furnace, and what metal was being refined?).
16	2171	S40	Spill of (antimonial?) lead alloy from softening pan. Sample taken to determine stage of processing (i.e., is this an intermediate stage of processing, or is it a finished product such as solder or printing metal?).
17	3117	S13	Infill of redundant flue S13 with dump of slag boulders (some up to 0.6 m across). Sample taken to identify type of slag.
18	2006	B13	Assay crucible fragment found in late 19th-century made ground within building B13.

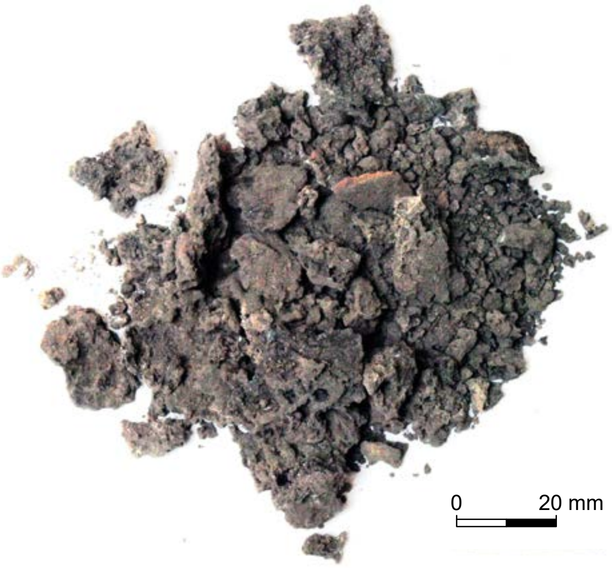
Table 8.1 Description of samples submitted for analysis

Description of Sampled Material

The samples varied greatly in their material and scope (Figs 8.1–8.31; Table 8.1). The largest (Sample 1) is solid and weighed approximately 7.5 kg (Figs 8.1–8.2), while the smaller samples comprised a few hundred grams of powder. The 'soot' and/or 'flue dust' deposits were usually collected while damp, but by the time they were analysed these had often dried out. Various attempts were made to analyse the dust deposits. In some cases (such as samples 7 and 8; see Fig. 8.3), fragments of apparent flue lining could be mounted in epoxy resin and ground and polished to reveal cross-sections. In most cases, however, these samples were too loose for effective preparation in epoxy resin. These intractable samples (such as sample 11; see Fig. 8.4) were sieved and the 0.2–0.5 mm fraction was strewn on aluminium SEM stubs (with a carbon sticky pad); the results from these samples were somewhat disappointing. The samples of slag, crucible and floor deposits were sufficiently robust to allow them to be mounted in epoxy resin; however, they responded to the grinding and polishing differently.

Figure 8.1 Sample 1 copper waste material

Figure 8.2 Close-up of sample 1 fracture surface



While the slag and crucible samples provided few unusual obstacles in preparing a polished surface, the floor deposits were friable (to varying degrees) and fragments of material were frequently plucked out during polishing (and scratching the surface of the sample). Sample 5 was particularly prone to such problems (Fig. 8.5) and the plan to obtain a 1-micron polished surface had to be abandoned; sample grinding was only carried to P600 (~0.04 mm scratches). Most of the friable samples also tended to be rather porous, and in several cases it was not possible to achieve the degree of vacuum necessary for conventional SEM imaging; these samples were analysed using a variable pressure mode SEM.

Figure 8.3 Sample 7 flue deposit (as received)

Figure 8.4 Sample 11 flue deposit (sieved into >2mm, 2–0.5mm, and 0.5–0.2mm fractions)

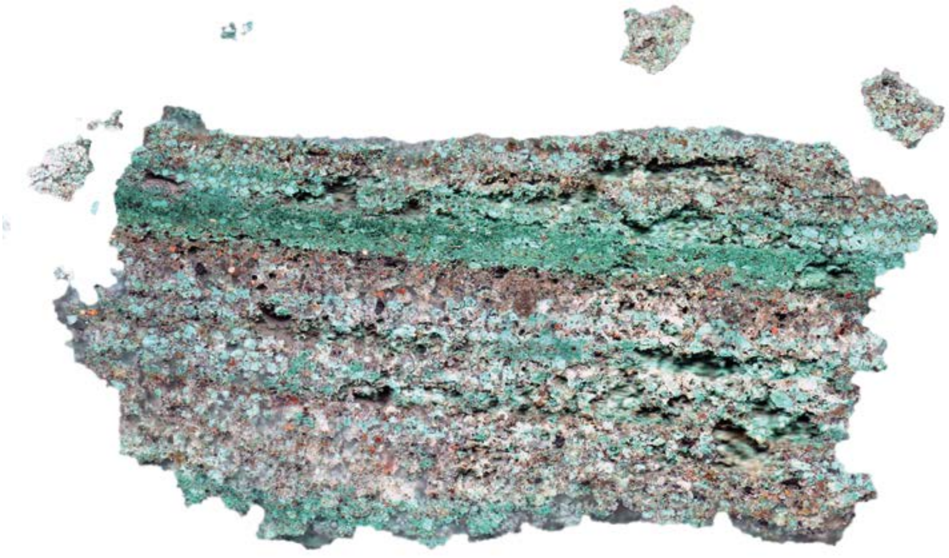


Figure 8.5 Sample 5 flue deposit mounted in epoxy resin and ground (P600). The sample is friable and the silicon carbide abrasive papers have plucked out some material (often from distinct layers in the sample)

Catalogue of Analysed Samples

The analysed samples are described in detail below, taking the metal, slag and slag-like materials first, the refractory materials second, and the powdery (floor and flue) samples last. All tables for this catalogue (Tables 8.2–8.15) are presented in Appendix 1.

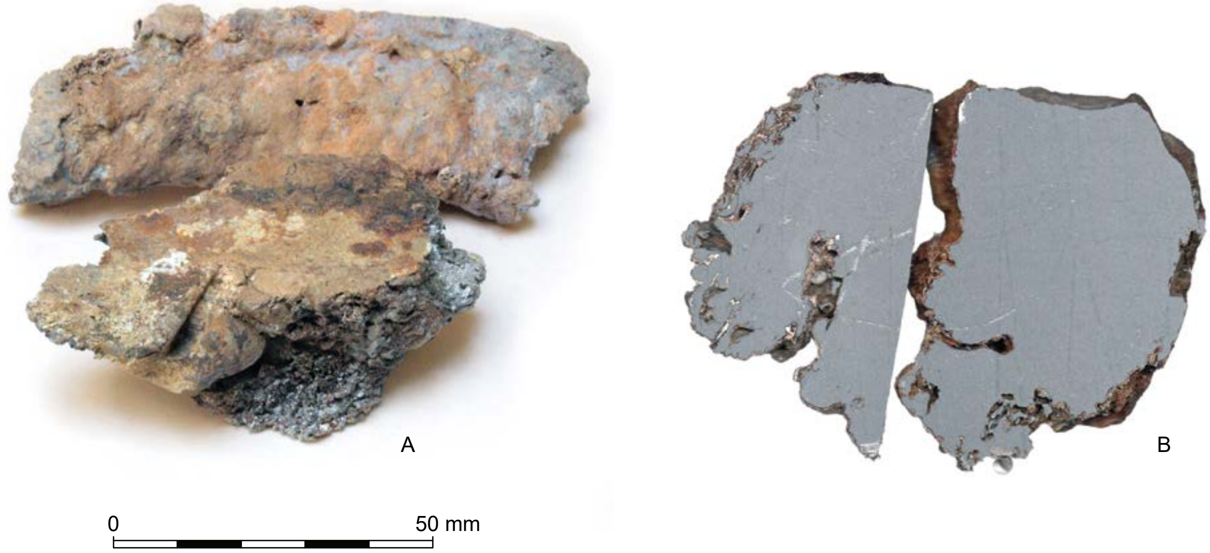


Figure 8.6 Two lumps of spilt antimonial lead (sample 16): A) before preparation; B) after preparation

Metal Sample

Sample 16

Sample 16 comprised two lumps of spilt metal, which were assumed to be antimonial lead alloy from a lead softening pan (Fig 8.6). The sample was taken to determine the stage of processing, i.e., is this an intermediate stage of processing, or is it a finished product such as solder or a printing metal? Sample 16 is a very soft metal, and this posed significant barriers in preparing a polished surface. During grinding and polishing, the abrasive media (SiC and later diamond) tended to become embedded in the surface of the soft metal (Fig. 8.7). It became clear that a perfectly polished surface could not be achieved.

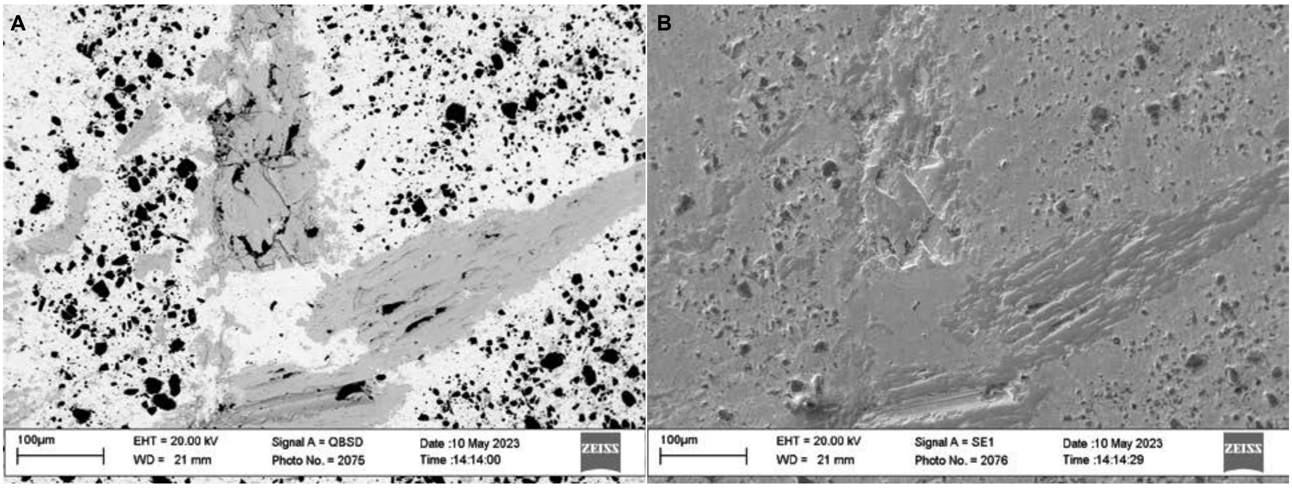


Figure 8.7 SEM images of sample 16: A) back-scattered electron detector showing metal (white), mixed metal oxides (grey) and abrasive particles (black); B) secondary electron detector

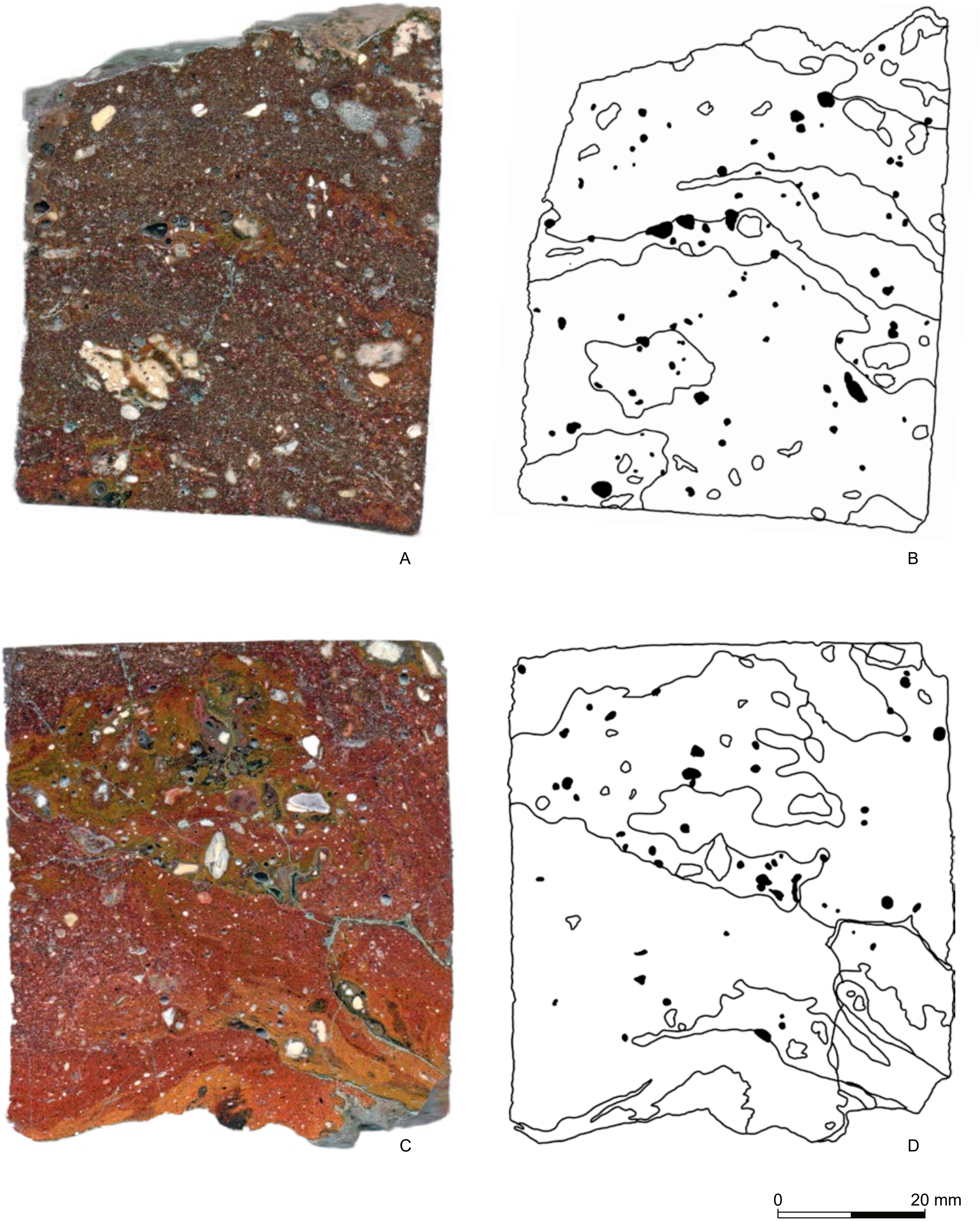


Figure 8.8 Scanned images and drawings of the mounted cross-sections of sample 1

The chemical analysis of both parts of sample 16 (Appendix 1, Table 8.2) showed that they share almost the same composition: typically, 0.5–1 wt% tin, and 2–3 wt% antimony, with the balance made of lead. There are rare intermetallic compounds also present (As-Sn-Sb-Pb). The metal composition seems too lead-rich to be a useful printing alloy or a solder. Both samples came from one of the lead softening pans. Lead pigs or blocks from the blast furnace were melted in refining pots and cooled in stages to remove Fe, Cu/Ni to give Clean Lead (CLD). This was then pumped (or otherwise transferred) to softening pans to remove Sn and As (together with any remaining traces of Fe/Cu/Ni, etc.). The pan was operated at 600°C and 'yellow scum' (35% Sn, 8% Sb, 3% As, balance Pb) was removed as a solid oxide crust every shift. At Melton this was operated as a continuous process and the last traces of Sn and As were removed as an oxychloride dross by treatment with chlorine in a hooded pot. However, it is probable that this process was never used at Bedminster and detinning was completed by raising the temperature to 700–750°C. The yellow scum was then smelted in a blast furnace on a solder charge, although the 'second scum' produced at the higher temperature would have been smelted on a lead charge. Antimony was then removed from detinned lead by oxidation in separate pans at up to 850°C to give 'fire-refined lead', which was cast into ingots for sale, and 'heavy scum' (45% Sb, 2% As, balance Pb), which was tapped on to the floor and then smelted separately to antimonial lead or further refined to produce 'star antimony' (95% Sb). Up until 1974, some of the Melton lead was fire refined alongside the more normal electrolytic lead (Melton Refined Lead). The absence of Bi and Ag indicates that the lead of sample 16 would not have been intended to be purified by electrolysis.

Slag Samples

Sample 1

Sample 1 (Figs 8.1 and 8.2) was collected from the backfill of flue S11 and was submitted for analysis to determine whether this was slag generated during copper smelting, or a different material produced by a different process. Given the scale of the original sample, a 30 mm wide section was taken through its entire depth, and to assist sample grinding and polishing this was divided into two sections (Fig. 8.8).

The polished sample is mostly a PbO red colour but displays layers (of slightly different shades of red) and inclusions. The significance of the varying shades of red is not immediately clear: they could reflect differences in the chemical composition of layers of material as it was tapped from a furnace, but they could also be a corrosion effect brought on by more than 100 years of burial. The inclusions tend to be a pale beige colour that is reminiscent of low-iron refractory bricks (cf. sample 14).

The SEM images (Figs 8.9A–D and 8.10A–B) show that most of the material is composed of litharge with relict refractory material. The refractory material comprises small (<50 microns) fragments of quartz (and some porosity) in a largely glassy groundmass which resembles many post-medieval refractory bricks and crucibles. Some of this relict refractory has dissolved into the surrounding litharge and this is often accompanied by some recrystallisation (Figs 8.9B and 8.10A).

Sample 1 comprises a $PbO-SiO_2$ groundmass (there are a range of other minor components (see Table 8.3, analysis 23) especially ZnO), in which there are a range of mineral phases that have crystallised from a melt (Figs 8.9C–D). The composition suggests a mixture of $PbO.SiO_2$ and $2PbO.SiO_2$ (with some substitution of lead by zinc and copper).

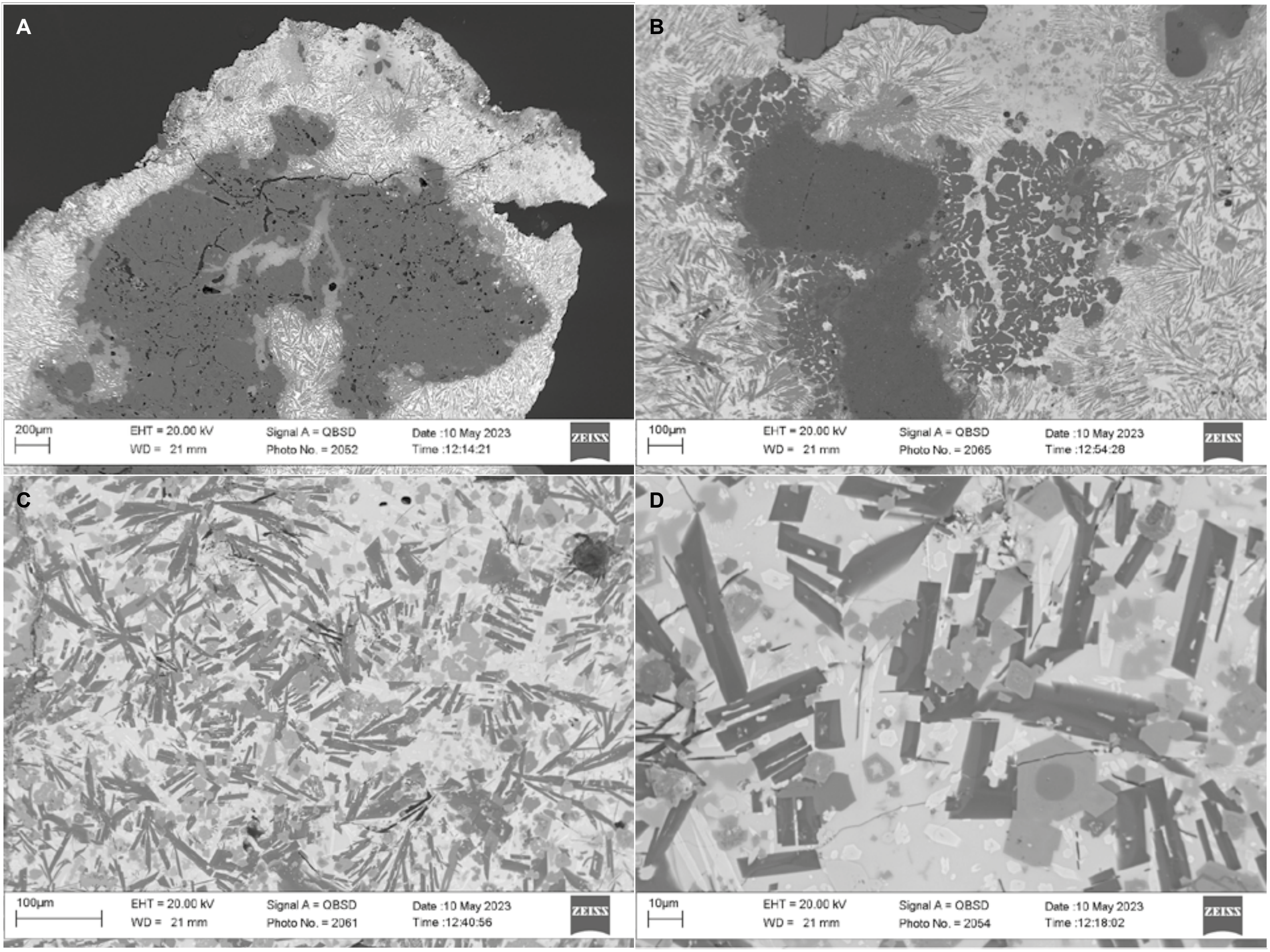


Figure 8.9 Upper half of sample 1 showing: A–B) relict refractory in a lead-rich matrix; C–D) lead-rich matrix, with crystals of spinels and complex silicates

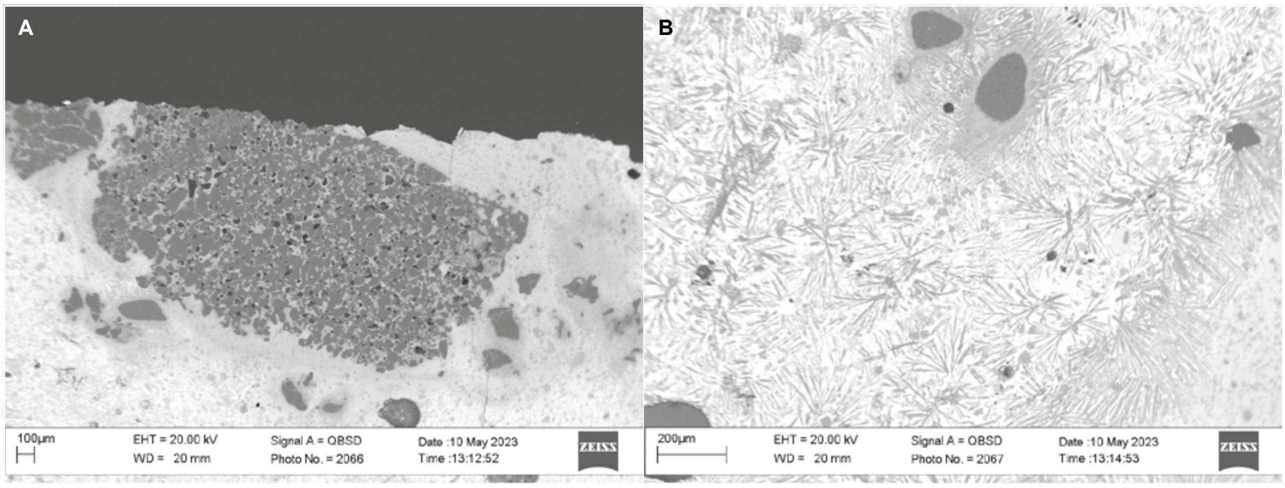


Figure 8.10 Lower half of sample 1 showing: A) relict refractory, partially dissolved in the litharge; B) lead silicate matrix, with relict refractory and crystals of complex silicate

The crystalline phases present (Appendix 1, Table 8.3) include some that are readily identifiable from their chemical composition, but also include some of uncertain nature. Phase 1 is present as small white hexagons (Fig. 8.9D) but has a composition that suggests an unusual calcium-lead arsenate. Phases 2a and 2b were taken on the larger hexagonal crystals (Fig. 8.9D), with 2a comprising the paler surrounding material and 2b the darker core. These both have complex chemical compositions, but it is suspected that they are spinels (with multiple substitutions). The most ubiquitous phase (3A–3D) appears to be an alkali aluminium silicate with some additional lead oxide. The form is similar to both leucite and feldspar, but this phase is too rich in silica to be either of these. The matrix also contains some copper oxide.

Sample 1 appears to be a mixture of litharge and lead silicate with a significant suite of non-ferrous metal oxides (Cu, Zn, As, Sn and Sb). The polymetallic nature of this slag could reflect the smelting of complex ores (or even mixtures of ores); however, it could also be the result of recycling of mixed non-ferrous scrap metal. The relatively high ZnO content of the sample is significant. Capper Pass processed zinc-containing materials (mainly fumes and flue dusts), but these were smelted in a blast furnace with the zinc either lost as fume or to the slag, with no progression through to the refineries.

Sample 1 probably represents litharge (PbO) attack on aluminosilicate firebrick. The matrix is composed principally of lead silicate, which would have melted at 745°C, with minor amounts of other metals. The lead silicate slag would dissolve available polymetallic elements, which subsequently precipitated as calcium-lead arsenate, spinels, and other phases. The origin of the sample is possibly a blast furnace shaft well above the tuyere zone, where there would be a neutral or oxidising atmosphere, together with a high temperature, and an opportunity for lead silicate to react with incoming raw materials, fume and shaft accretions. This material appears to have been a blast furnace shaft accretion, which was removed when the furnace was stopped for maintenance and the accretions ‘cut out’. It should not be assumed that the deposit came from the smelting of a single charge: Capper Pass normally used the same blast furnace successively with different charges (lead, tin, solder, DM and SM), and the suite of metals could represent a composite of these.

Sample 2

The slag from the construction cut for softening pan S40 was sampled to determine the origin of the slag. The slag comprises relatively small flows of a black (or dark grey) slag (Fig. 8.11A–B). The fracture surfaces are smooth, which suggests that few large crystals are present in the slag. The polished cross-section shows some apparent layers (variations in the black-grey colour), but these rarely extend across the entire section; in most cases the apparent boundaries fade away (Fig. 8.11C–D). Subsequent SEM examination suggests that these layers are produced by localised but rather subtle variations in the proportions of some of the principal phases present (Fig. 8.11E–H). The most abundant phase present in this sample is what appears to be an olivine, although the composition is complex and approximates to $(Ca,Fe)_2SiO_4$, with some additional substitution by magnesium and zinc. In many areas, this olivine is so abundant as to form a near continuous matrix (Fig. 8.11E). The second most abundant phase is a spinel (Al_2FeO_4), although this contains low levels of aluminium (some of the iron must be present as Fe^{3+} and occupying positions that would otherwise be occupied by Al^{3+}) and some zinc.

Overall, the chemical composition of sample 2 (Appendix 1, Table 8.4) is comparable with the blast furnace slags produced at Melton. A wide range of non-ferrous metals are present (Cu, Zn, As, Sn, Sb, and Pb) and the identity of the associated smelted metal is not immediately obvious. The low Pb, Sn, Zn contents suggest that this is a solder slag which has been cleaned in some way to remove Sn, perhaps by smelting with lead. The occurrence of spinels is not surprising as there was XRD evidence that these were present in the Melton solder slags, particularly when furnaces were in difficulty. The relatively high proportion of sulphur present in this slag is notable; however, its full significance is not clear.

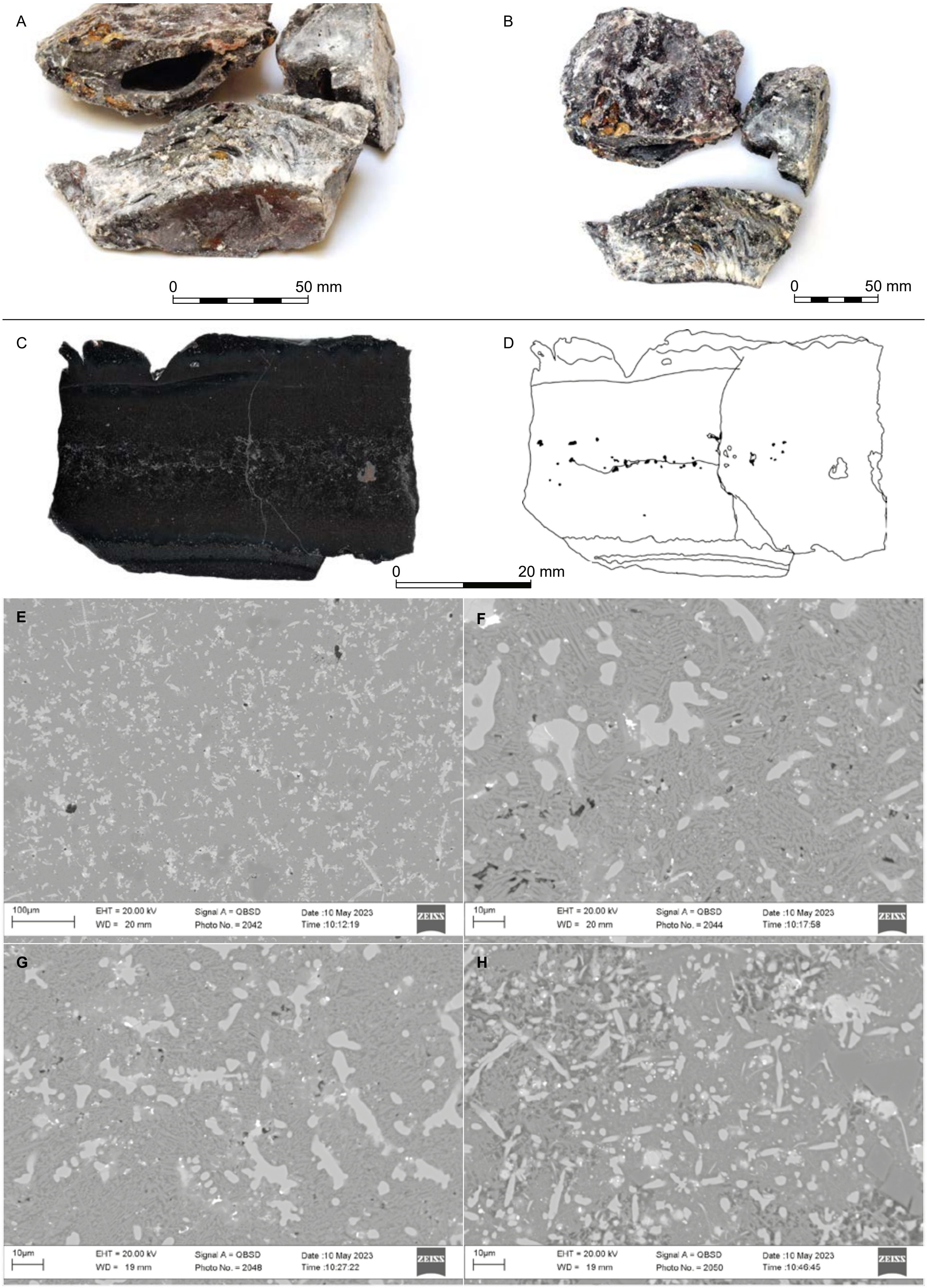


Figure 8.11 Sample 2: A–B) before sample preparation; C) mounted cross-section; D) drawn cross-section; E–H) SEM images

Figure 8.12 Sample 15 before preparation

Sample 15

Sample 15 was taken from a dump of slag forming a surface within building B7 and adjacent to a possible blast furnace base S24. The sample was taken to identify the type of slag and its origin, i.e., is it from the blast furnace, and what metal was being refined? The slag is black in colour and all the surfaces appear to be fracture surfaces (Fig. 8.12).

The polished cross-section shows that this sample is composed of a black slag with numerous small golden-coloured inclusions. These inclusions are mixed copper-iron

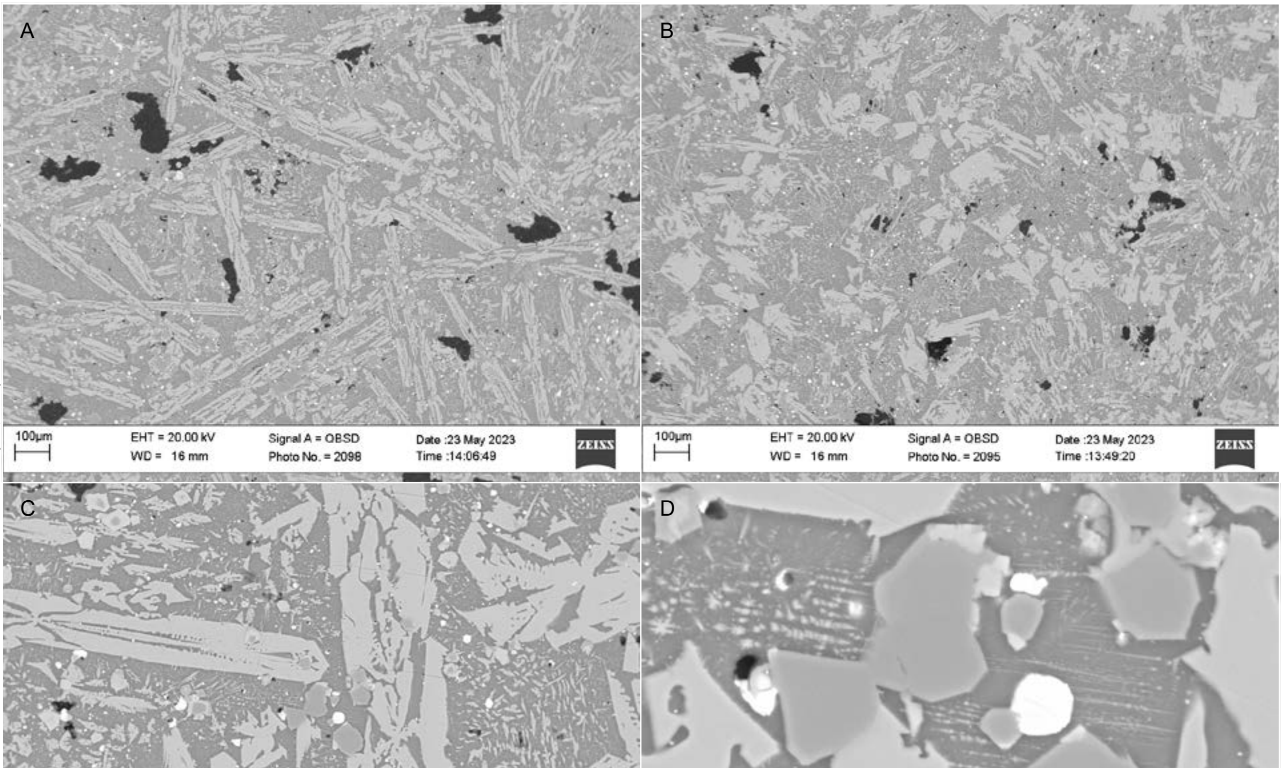


Figure 8.13 SEM images of sample 15 showing: A) fayalite laths; B) fayalite laths and equiaxed fayalite; C) fayalite laths and equiaxed spinels (darker grey); D) fayalite, spinels, and metal sulphide inclusions

sulphides (often with a small amount of additional lead). The slag is largely composed of fayalite (Fe_2SiO_4) in a glassy matrix (Fig. 8.13A–D). The fayalite is mostly present as laths, often with an open, 'ladder' or H-structure, but it is also evident as equiaxed grains. A small amount of spinel (Al_2FeO_4) is also present (Fig. 8.13D), as well as rare copper-iron sulphide inclusions.

The composition of this slag sample is remarkably uniform throughout (Appendix 1, Table 8.5). It is very similar to sample 2 and looks like a clean waste slag. The presence of Fe/Cu matte globules is puzzling but could be expected if it came from DM or SM smelts from the blast furnace.

Sample 17

Sample 17 was taken from the infill of redundant flue S13 to identify the type of slag. The slag comprises a fragment from a larger mass (Fig. 8.14A–B). This has several fracture surfaces (often rather hackly), but the upper surface (and a side surface) suggest that this slag was tapped into a trough or similar container. The cross-section shows that this is a black slag with few observable features. There appears to be a distinct thin layer towards the top of the sample (Fig. 8.14C–D), but SEM examination shows that this is only marked by a slight change in the size and form of the crystalline phases present and a decrease in the proportion of metallic sulphide inclusions.

Sample 17 (Appendix 1, Table 8.7) is remarkably uniform, and almost throughout it is composed of very long and very thin laths of fayalite (Fig. 8.15A). The sample also

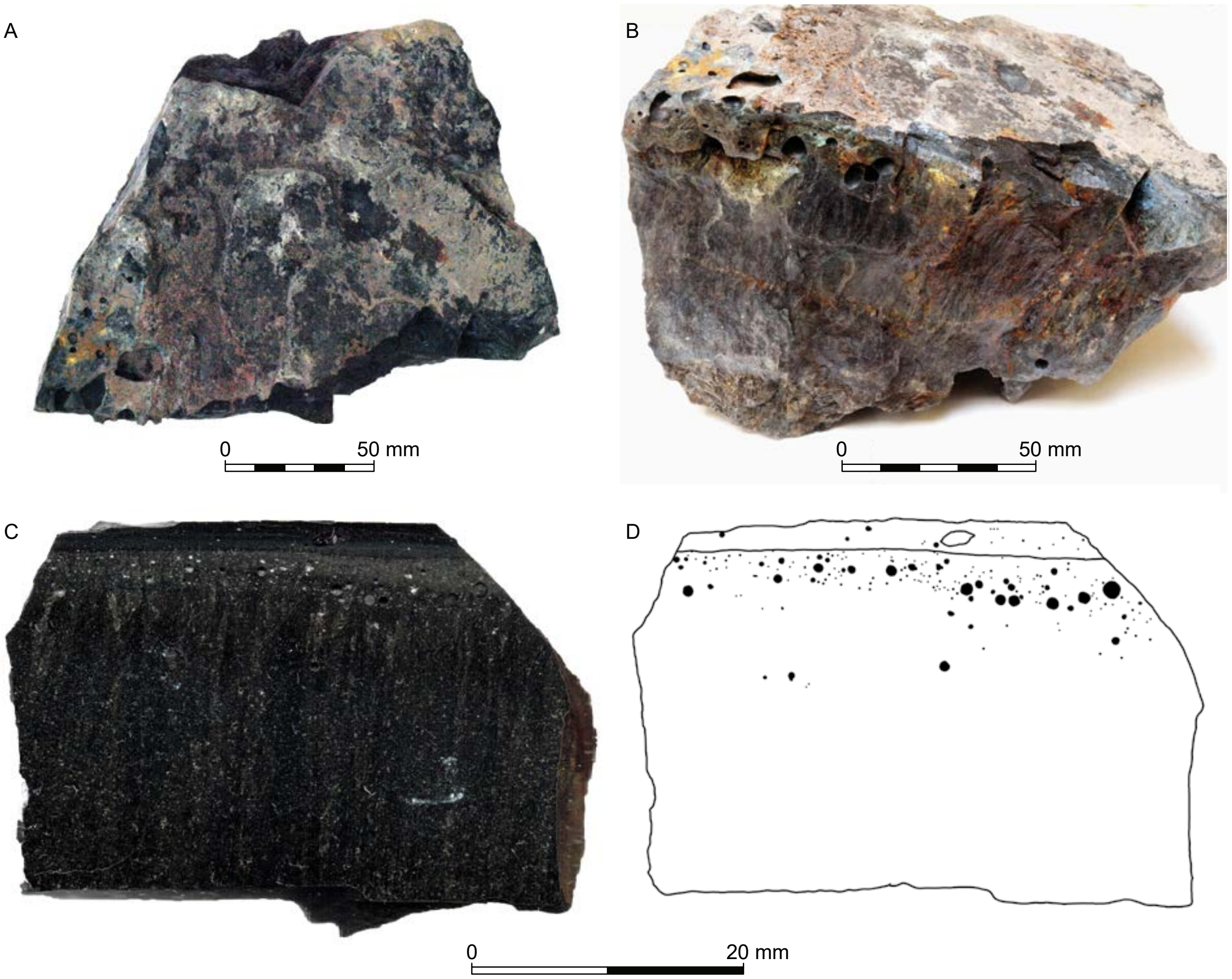


Figure 8.14 Sample 17: A–B) before preparation; C) mounted and polished; D) drawn cross-section

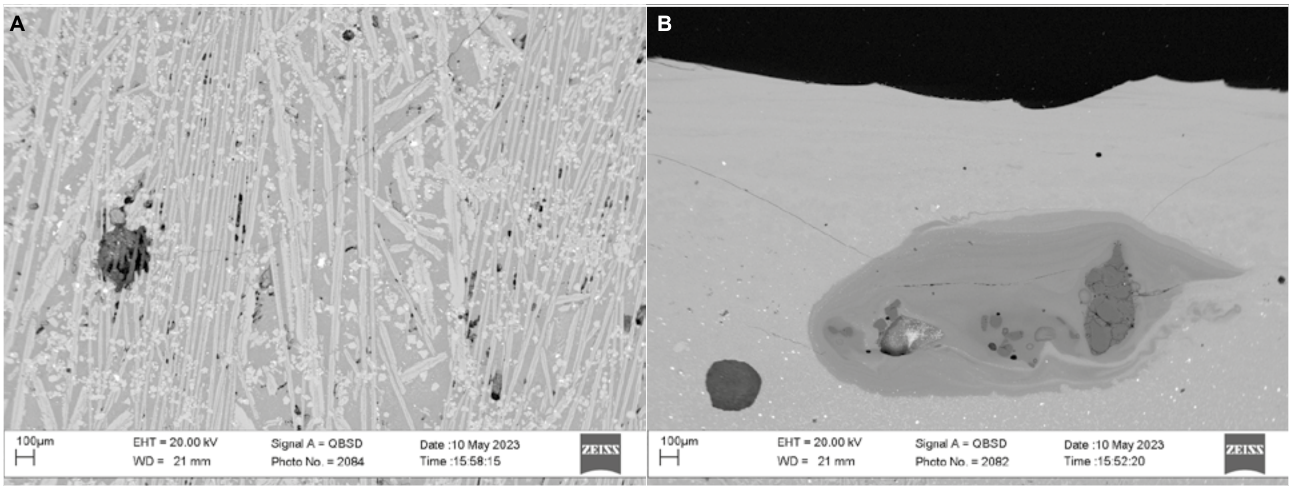


Figure 8.15 SEM images of sample 17 showing: A) long and thin fayalite laths and small, metallic sulphide inclusions in a glassy matrix; B) relict refractory in a glassy inclusion near the upper surface of the slag sample

contains a small amount of spinel (Al_2FeO_4, although some of the Al^{3+} has been substituted by Fe^{3+}), and rare copper-iron sulphide droplets. The sample contains a small fragment of refractory material (Fig. 8.15B) that is surrounded by a glass mass that probably represents reactions between the slag and the refractory.

This is very similar to samples 2 and 15 and looks like lead blast furnace slag, similar to solder blast furnace slag but with lower CaO. The high aluminosilicate content may have come from smelting waste furnace bricks to recover tin and silver; this was normal practice.

Refractory Materials

Sample 3

Sample 3 was described as a yellowish orange burnt brick material taken from furnace base S20. This sample (Figs 8.16 and 8.17) was selected to determine whether it contained any metal residues from the smelting process. The sample is soft and friable, and this impacted the preparation of the sample. The polished cross-section showed relatively few distinct features and much of the sample appeared to be formed of corrosion products. SEM examination showed that the sample comprises numerous inclusions of slag (Fig. 8.18A–B) and partially vitrified ceramic (Fig. 8.18C) in a matrix that is composed of a calcium sulphate (Fig. 8.18D).

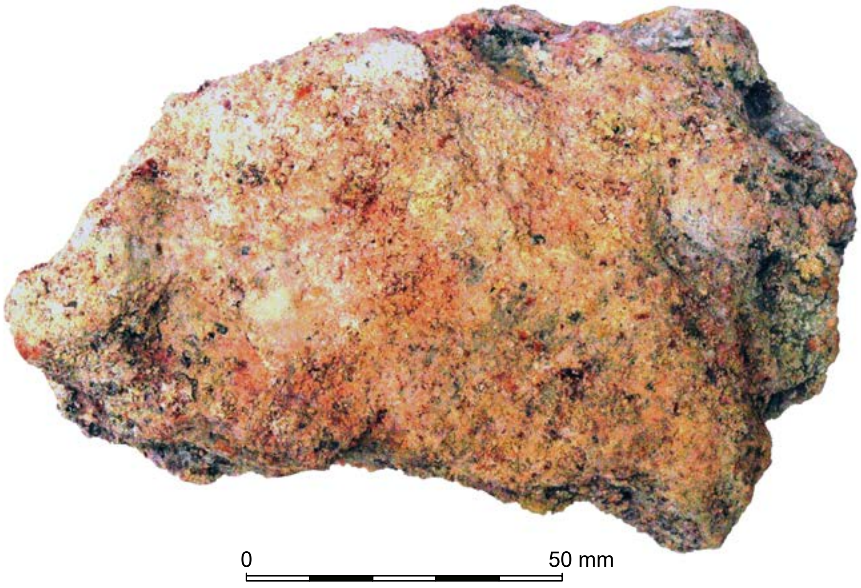


Figure 8.16 Sample 3 before preparation

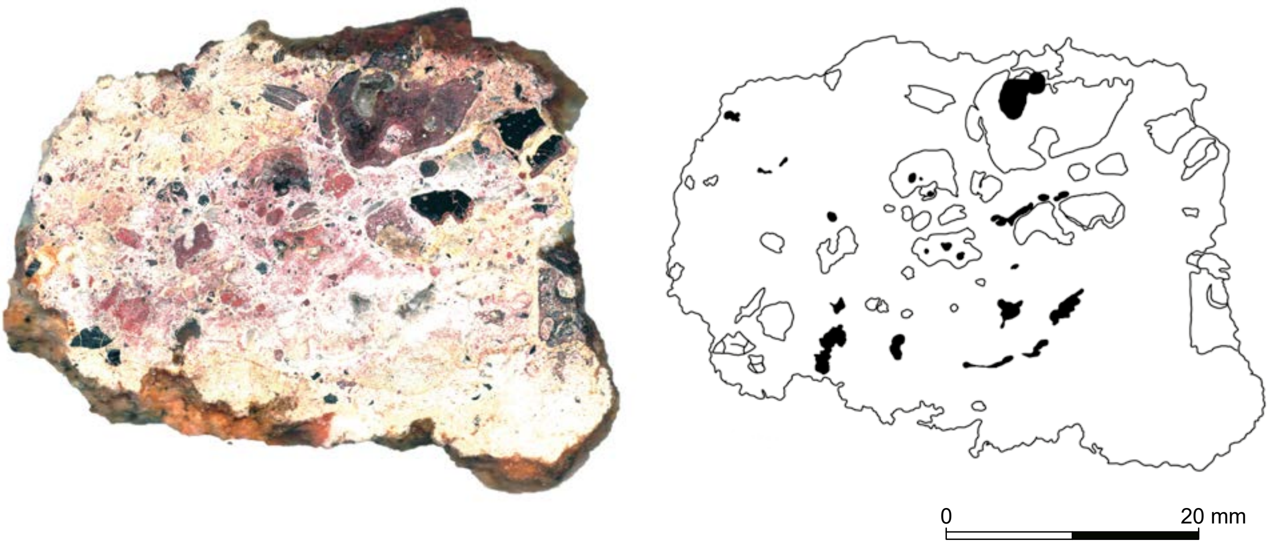


Figure 8.17 Sample 3: B) mounted and polished cross-section; B) drawn cross-section

Sample 3 contains fragments of slag, but these are of varied character and probably do not all derive from the same process (or stage). The analysed fragments of slag are generally poor in non-ferrous metals and the nature of the associated smelted metal(s) it is not immediately obvious (Appendix 1, Table 8.8). The presence of large amounts of calcium sulphate suggests post-depositional alteration.

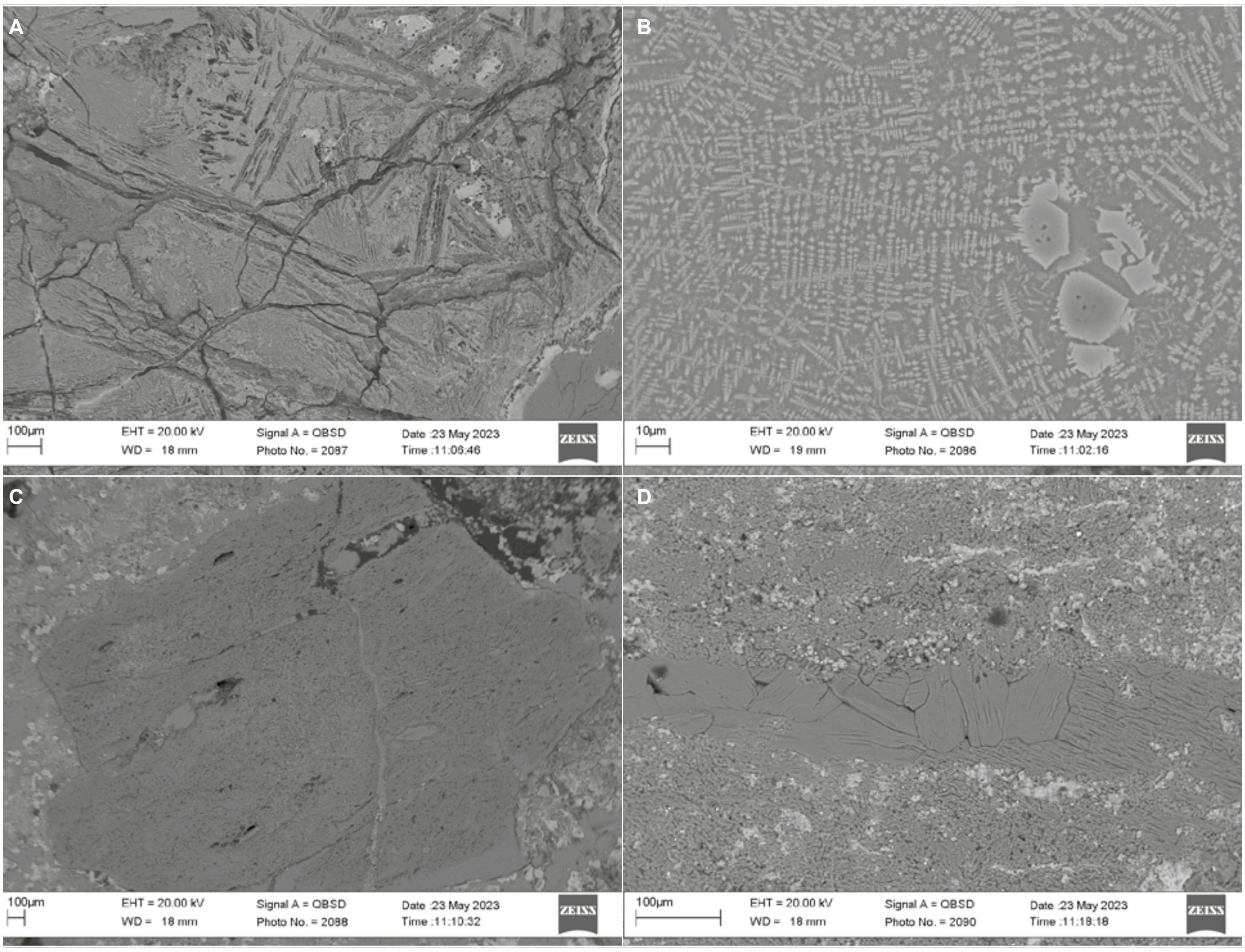


Figure 8.18 SEM images of sample 3 showing; A) a highly corroded slag inclusion; B) details of an uncorroded slag inclusion; C) a relict refractory inclusion; D) a band of calcium sulphate

The absence of metal residues suggests that this is a piece of slag-coated firebrick which has been subject to possible mechanical damage and percolation by groundwater and deposition of gypsum. The glassy slag composition is consistent with attack of an aluminosilicate refractory by a blast furnace solder slag. It is possible that this could be refractory re-used as hardcore.

Sample 14

Sample 14 comprises a small, slightly tapering brick with one vitrified surface (Fig. 8.19A–B), found in flue S4. The cross-section (Fig. 8.19C–D) shows that the ceramic is a pale yellow-beige colour with numerous grog particles (i.e., previously fired ceramic). Grog-tempering was a favoured method in the production of refractory ceramics from the late medieval period into the 20th century.

The SEM examination confirmed that the brick was composed of a fine-grained ceramic (Fig. 8.20A) with numerous grog inclusions (Fig. 8.20B). In general, the grog particles exhibit more vitrification and less porosity than the 'fresh' ceramic matrix. The vitrified surface of the brick has undergone significant corrosion but enough survives to show that this was largely glassy with two types of sparse inclusions (Figs 8.20C–D). The first (the brightest), comprises tin oxide (probably cassiterite), but possibly with some antimony and zinc (Appendix 1, Table 8.9, phase 2). The second inclusion comprises complex crystals (darker, diamond-shaped) that display significant zoning (the chemical composition changed as the crystal grew, giving a darker centre and brighter outer layers). The cores of the crystals (Appendix 1, Table 8.9, phase 1a) tend to be relatively aluminium-rich and often approximate to the spinel gahnite (Al_2ZnO_4), although some iron is present. The outer margins (Appendix 1, Table 8.9, phase 1b) are assumed to be spinels; however, their chemical composition is even more complex (e.g., presence of antimony) and the aluminium levels are very low (it is not clear which elements present are providing the necessary 3+ ions for a spinel).

The refractory brick has a chemical composition typical for 19th-century refractories (Appendix 1, Table 8.9). This has twice as much SiO_2 as Al_2O_3, and their combined contribution is more than 90% (*cf*. Dungworth 2008). The vitrified surface (glaze) shows an increase in a range of non-ferrous metals (especially Pb, Zn, Sn and As) as well as alkalis, calcium and phosphorus. This could be due to volatile material/ash derived from coal fuel and from non-ferrous alloy melting or smelting.

This sample is a fragment of aluminosilicate firebrick of similar composition to other samples. The SnO_2, As_2O_3, Sb_2O_3 and PbO in the glaze are typical Capper Pass elements; however, the presence of significant levels of ZnO and minor FeO suggests that this came from a blast furnace shaft rather than a hearth or forehearth. It was possibly formed by the reactions described for sample 1 and cannot be associated with any specific Capper Pass blast furnace charge. This is supported by the presence of spinel analogues in Phases 1a and 1b and of SnO_2 with minor Sb_2O_3 in Phase 2.

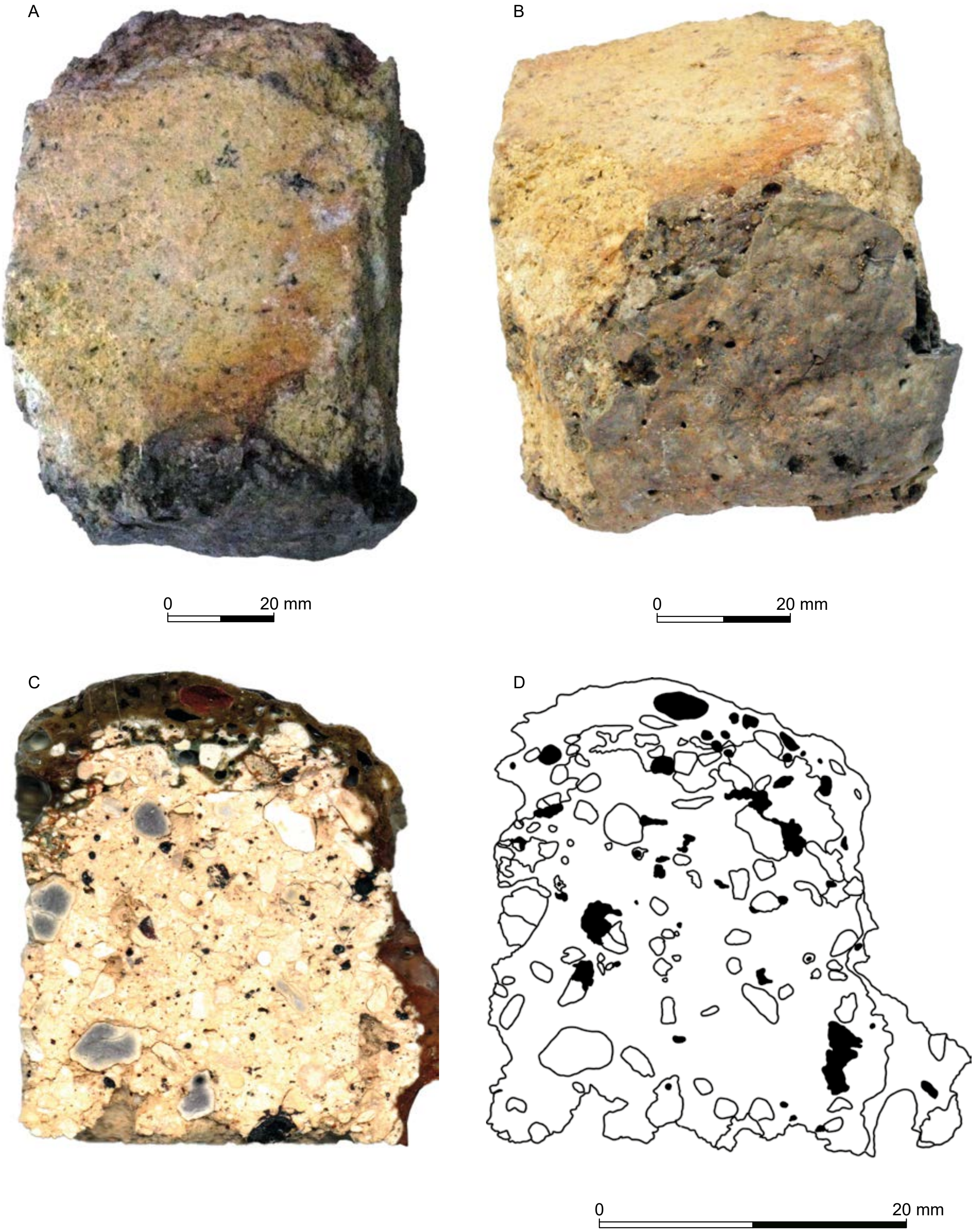


Figure 8.19 Sample 14: A–B) prior to sampling; C) mounted and polished cross-section; D) drawn cross section

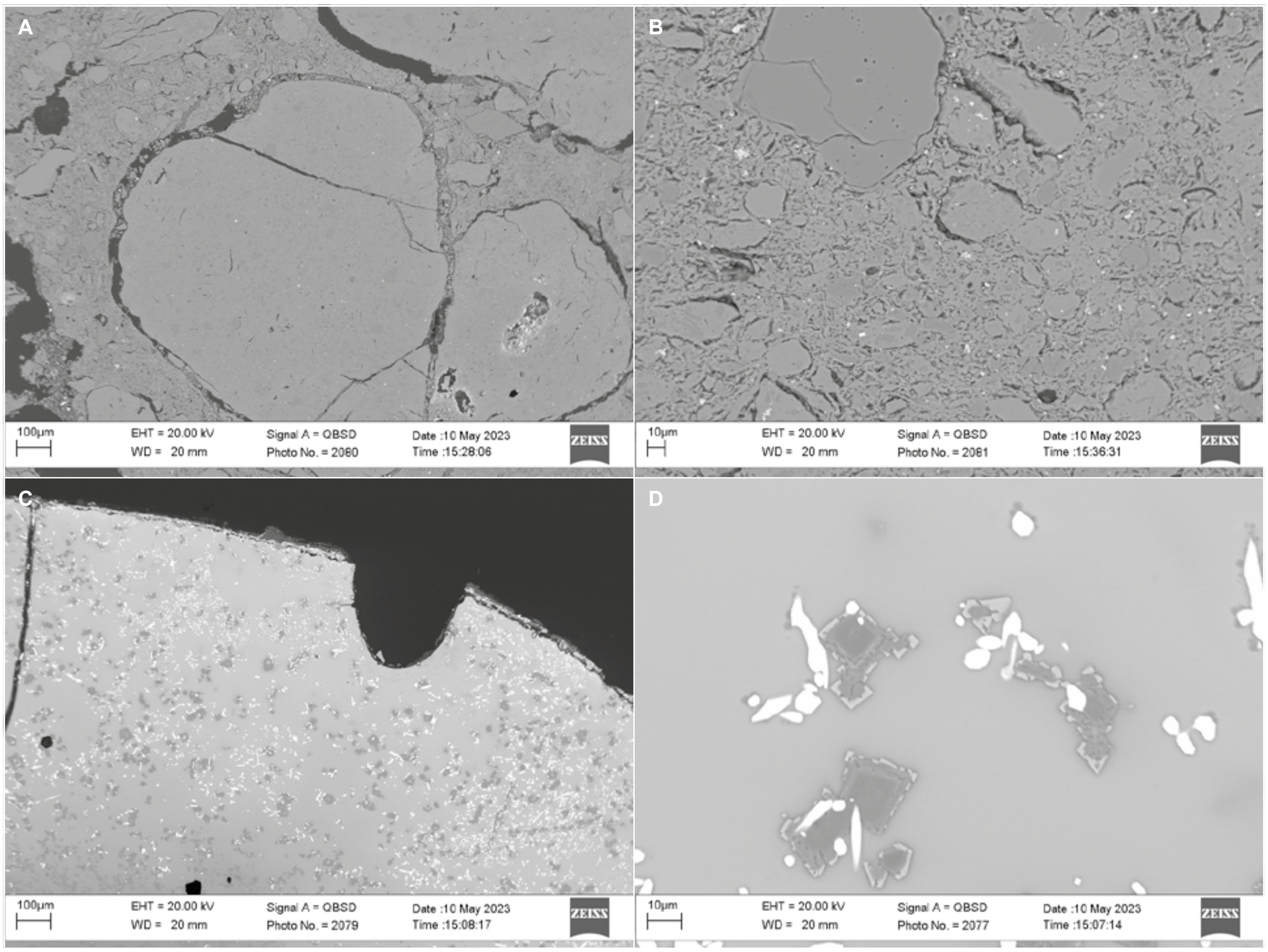


Figure 8.20 SEM images of sample 14 showing: A) grog particles in a ceramic matrix; B) the ceramic matrix; C) the vitrified surface; D) tin oxide (bright) and spinel inclusions (dark)

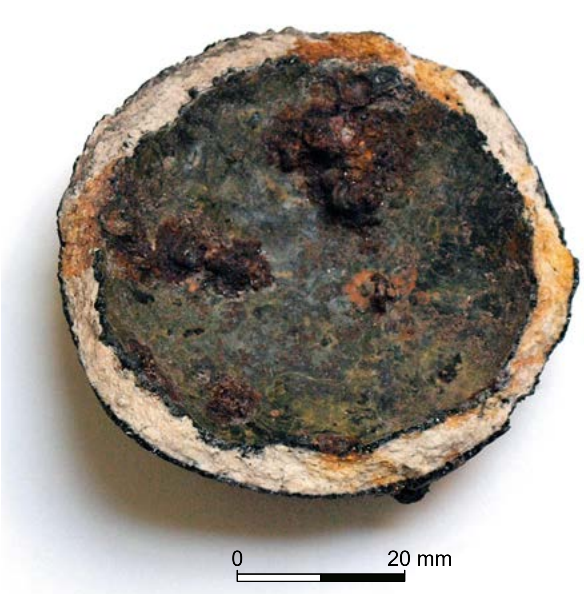


Figure 8.21 Sample 18 prior to sampling

Sample 18

Sample 18 comprises the base of a small crucible with black vitrified surfaces (interior and exterior). The interior surface also contains a large white metal inclusion (Fig. 8.21). The mounted cross-section (Fig. 8.22A–B) shows that the ceramic fabric is almost white (indicating a low iron content) with numerous quartz inclusions. The SEM examination confirmed the presence of fire-cracked quartz (or high-temperature polymorphs of quartz) in a vitrified matrix which contains numerous irregular cracks (Fig. 8.23A–B). The vitrified ceramic matrix also contains recrystallised mullite.

The vitrified surfaces display some corrosion and analysis areas were carefully selected to avoid such corrosion (Fig. 8.22C). The vitrified surfaces (Appendix 1, Table 8.10) contain high levels of aluminium and silicon that must derive from the ceramic, with extremely high levels of sodium. The origin of the sodium is uncertain, but it probably represents the use of flux during metal melting (and assaying?). Most analyses of the vitrified surfaces failed to detect any non-ferrous metals. Despite this, the interior vitrified surface contains a metal inclusion (Fig. 8.23D) that is lead-rich with a small amount (~4 wt%) of tin.

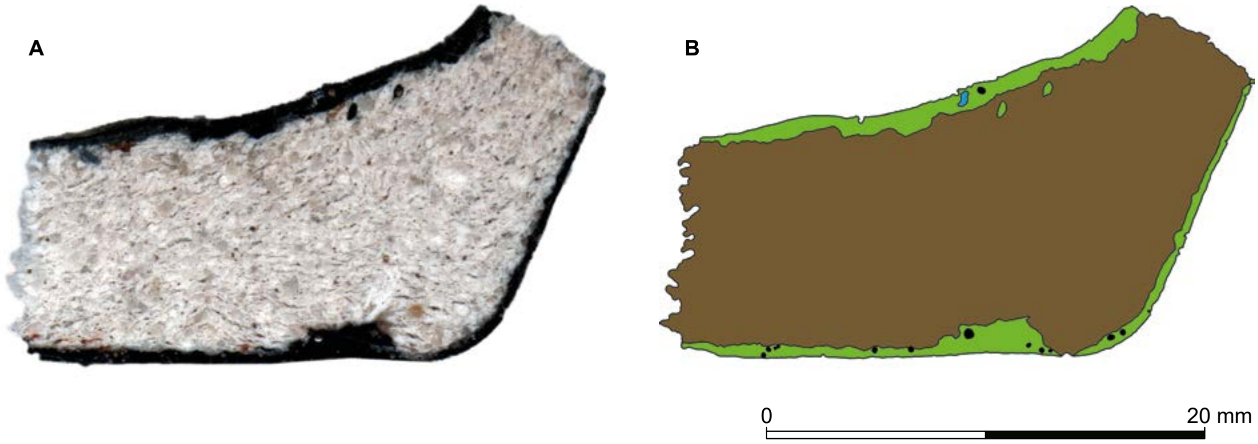


Figure 8.22 Sample 18: A) mounted and polished; B) drawn cross-section

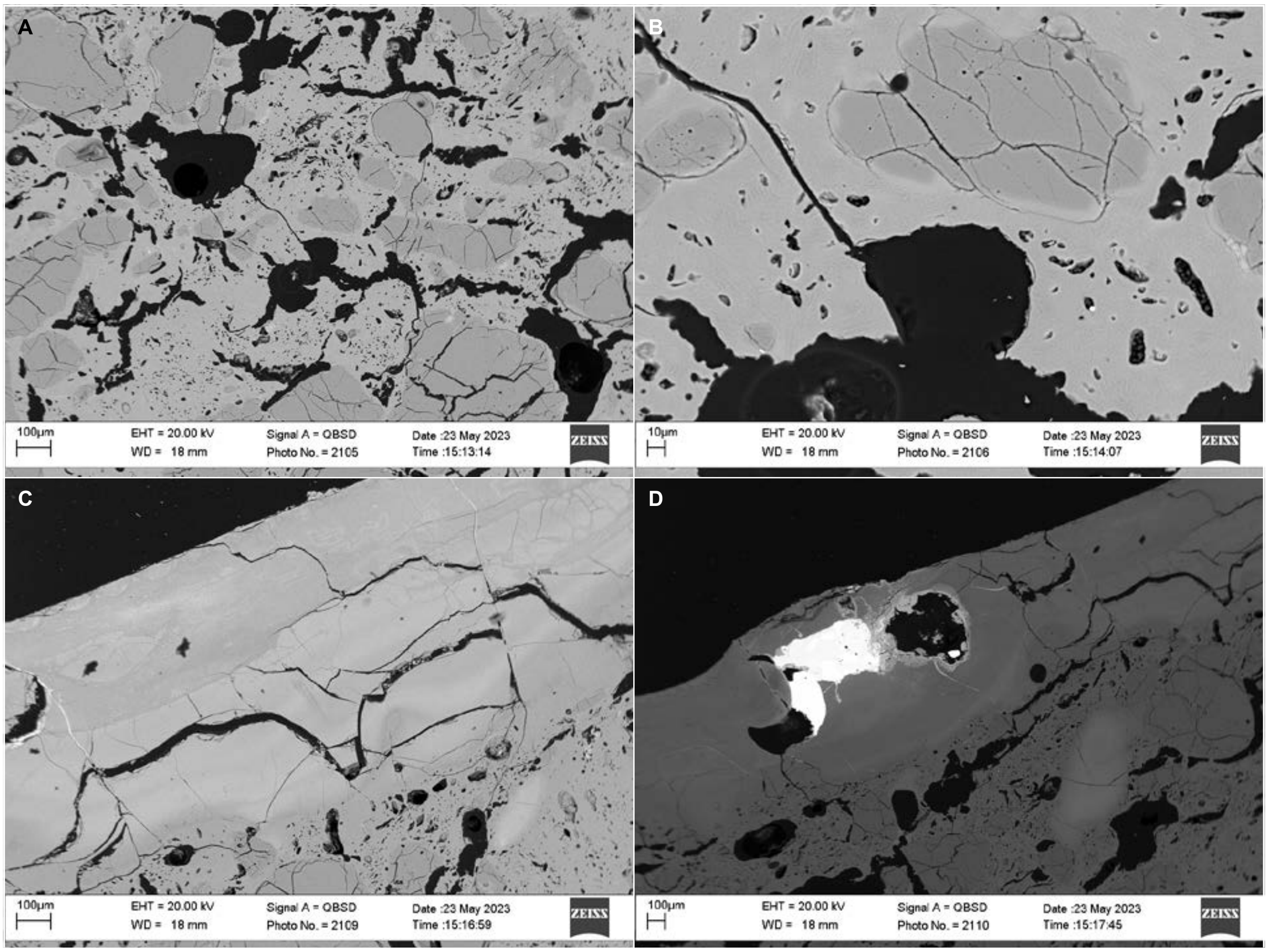


Figure 8.23 SEM images of sample 18 showing: A–B) quartz inclusions and porosity in a ceramic matrix; C) the (partially corroded) interior vitrified surface; D) a metallic inclusion trapped in the interior vitrified surface

Figure 8.24 Sample 4 before preparation

Floor and Flue Deposits

Sample 4
Sample 4 comprises greyish green copper and other metal slag material forming a rough internal floor within building B6. This sample (Fig. 8.24) was taken to determine the origin of the material from which the surface was made. The cross-section shows a wide range of slag fragments within a matrix concreted by iron compounds (Fig. 8.25A–B).

The various slag inclusions do not share the same microstructure (Figs 8.26A–F and 8.27A–F) or chemistry (Appendix 1, Table 8.11). The red slag inclusions tend to be glassy with copper oxide (Figs 8.26D and 8.27B), while the black slag inclusions contain a variety of complex minerals (Figs 8.26B, 8.26F and 8.27D; Appendix 1, Table 8.11). The finite analytical resources for this project only allowed the analysis of crystalline phases in slag inclusion 1. Phase 1 (the mid-grey hexagonal crystals in Fig. 8.26B) is rich in iron with some zinc and aluminium. The shape and chemistry of this phase suggest that it is a spinel, and close to magnetite. The darker crystalline phase (Fig. 8.26B) has a complex composition which hampers its identification. The relatively high silica content indicates that this is not an olivine (M_2SiO_4) but a pyroxene ($MSiO_3$). The glassy matrix of this sample is brighter than the crystalline phases (Fig. 8.26B) as this contains most of the lead in this sample. A similar microstructure can be seen in slag inclusion 4 (Fig. 8.26F). Sample 4 also contains at least one discrete metal droplet (Fig. 8.27E) of antimonial lead (Appendix 1, Table 8.12). The refractory inclusion contains silt-sized quartz inclusions (~20 microns) in a partially vitrified matrix that contains little porosity, no sand-sized quartz and no grog particles.

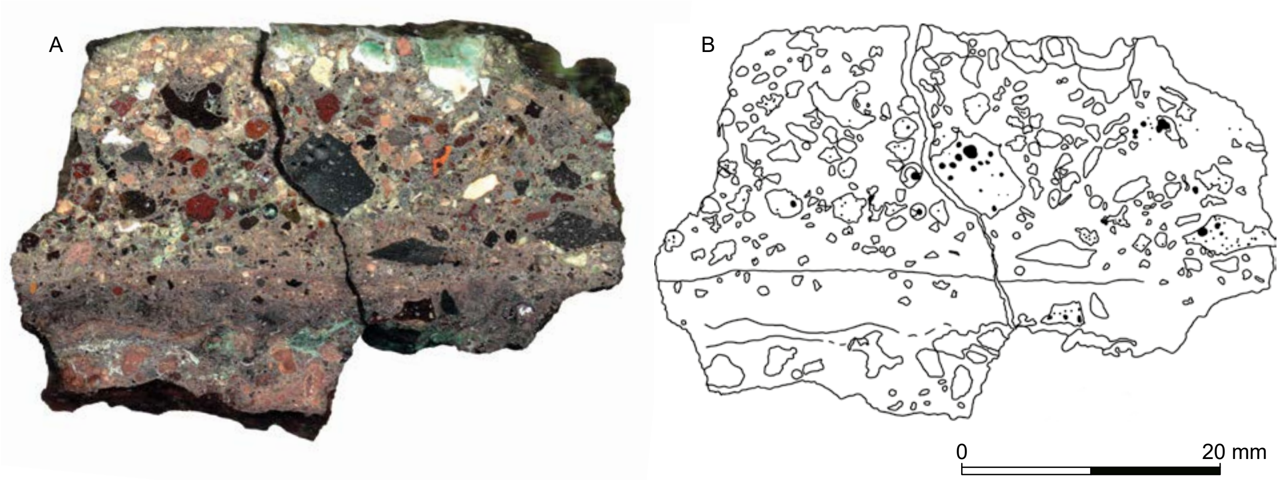


Figure 8.25 Sample 4: A) mounted and polished; B) drawn cross-section

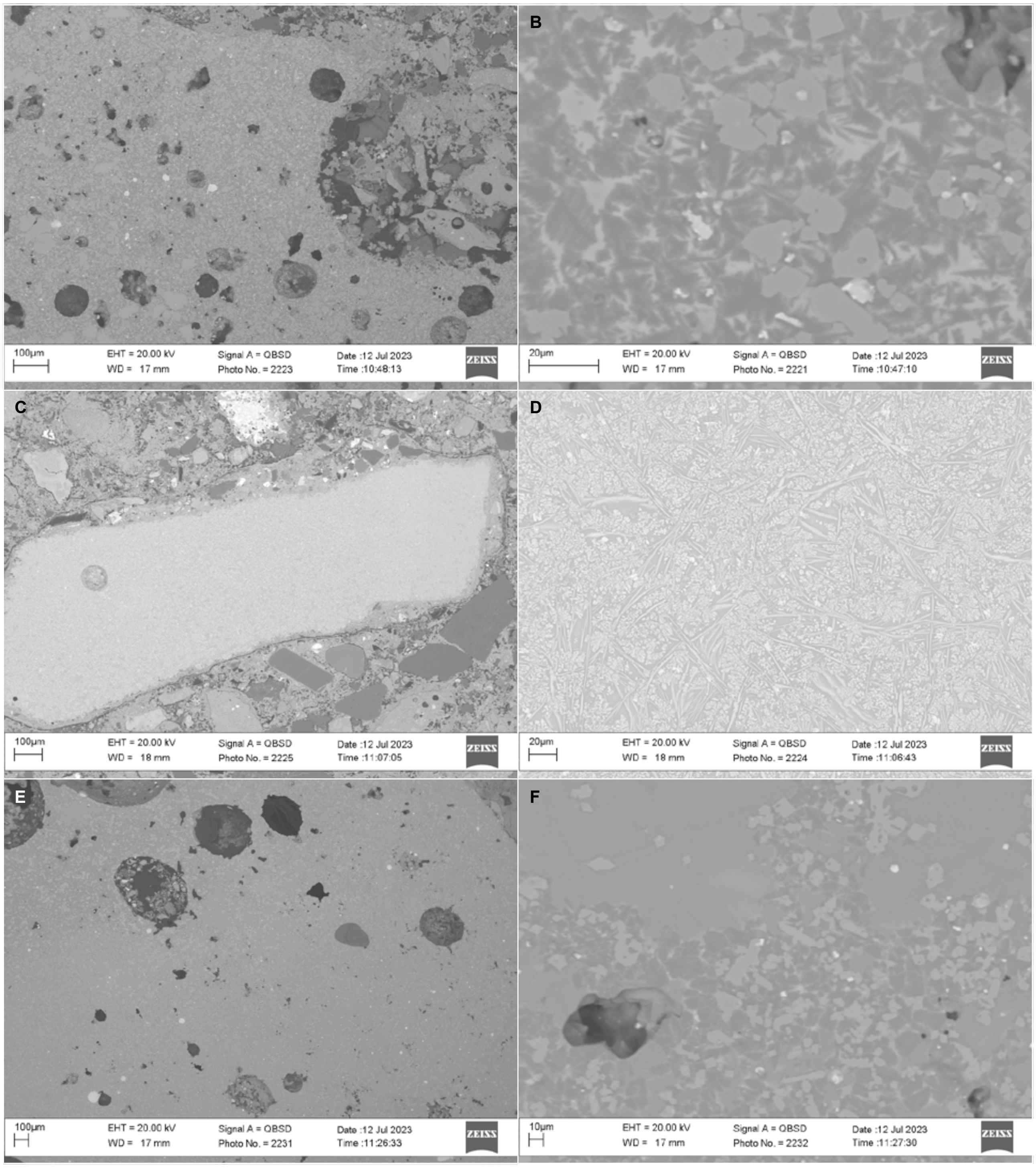


Figure 8.26 SEM images of sample 4 showing inclusions: A–B) slag 1; C) slag 2; D) slag 2 showing copper oxide in a glassy matrix; E–F) slag 4

The copper-rich droplets in two of the slag inclusions (Appendix 1, Table 8.12) fall into two types: an impure copper (or possibly a deliberate alloy) with small amounts of arsenic, tin, antimony, iron, zinc and lead, and copper sulphides.

The fragments of slag in this floor deposit are of varied nature. It is likely that they derive from several different processes (or stages of a process). The analysed slag fragments include high FeO/low CuO (slags 1, 4) and low FeO/high CuO (slags 2, 6), with slags 3 and 5 being intermediate in FeO/CuO but having high PbO. The high FeO slags appear to be solder slags and the intermediate slags (3, 5) may be DM or SM slags. Slags 2 and 6 are unusually high in CuO and may be from early 19th-century operations when copper and copper alloys were treated or bought material. The presence of Fe, Sn and Sb suggests bought copper scrap – iron comes from fittings such as nuts

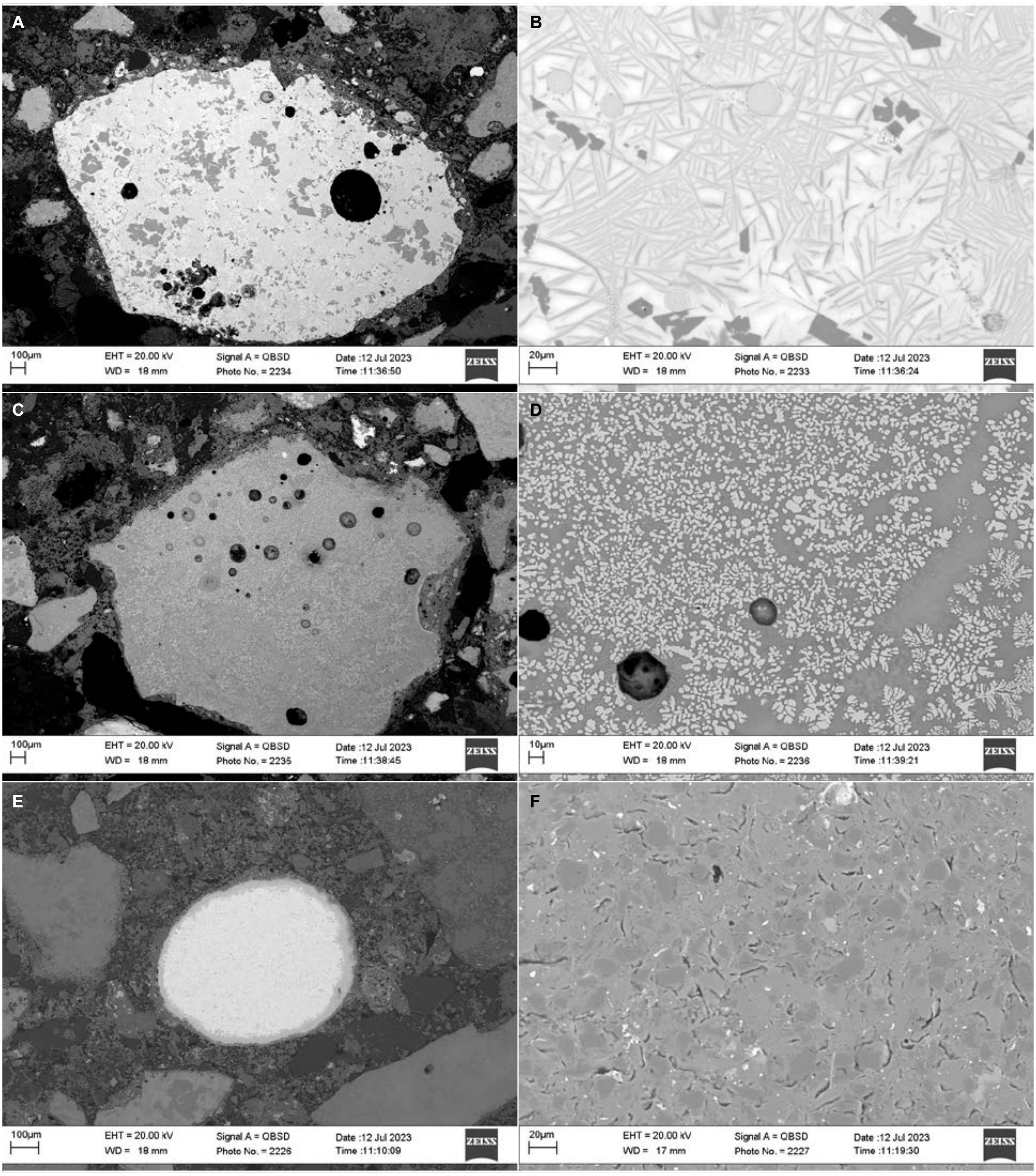


Figure 8.27 SEM images of sample 4 showing inclusions: A–B) slag 5;C) slag 6; D) slag 6 showing copper oxide in a largely glassy matrix; E) slag 2; F) refractory inclusion in sample 4 showing silt-sized quartz in a partially vitrified matrix

and bolts which were not sorted but separated as unmelted iron (in a crucible or reverberatory furnace). The presence of Sn/Sb may arise from whitemetal bearings in the scrap. The presence of Hg is not completely surprising as metallic Hg was once found in copper ore roaster flues at Melton, but vanished once a procedure was put in place to recover this. It was thought to come from low-grade Cu/Sn/Ag ores.

The presence of antimonial lead and refractory material further suggests that this floor deposit acquired debris from several sources. Some of this slag may have been deliberately stockpiled prior to further treatment to recover the non-ferrous metals that it still contained.

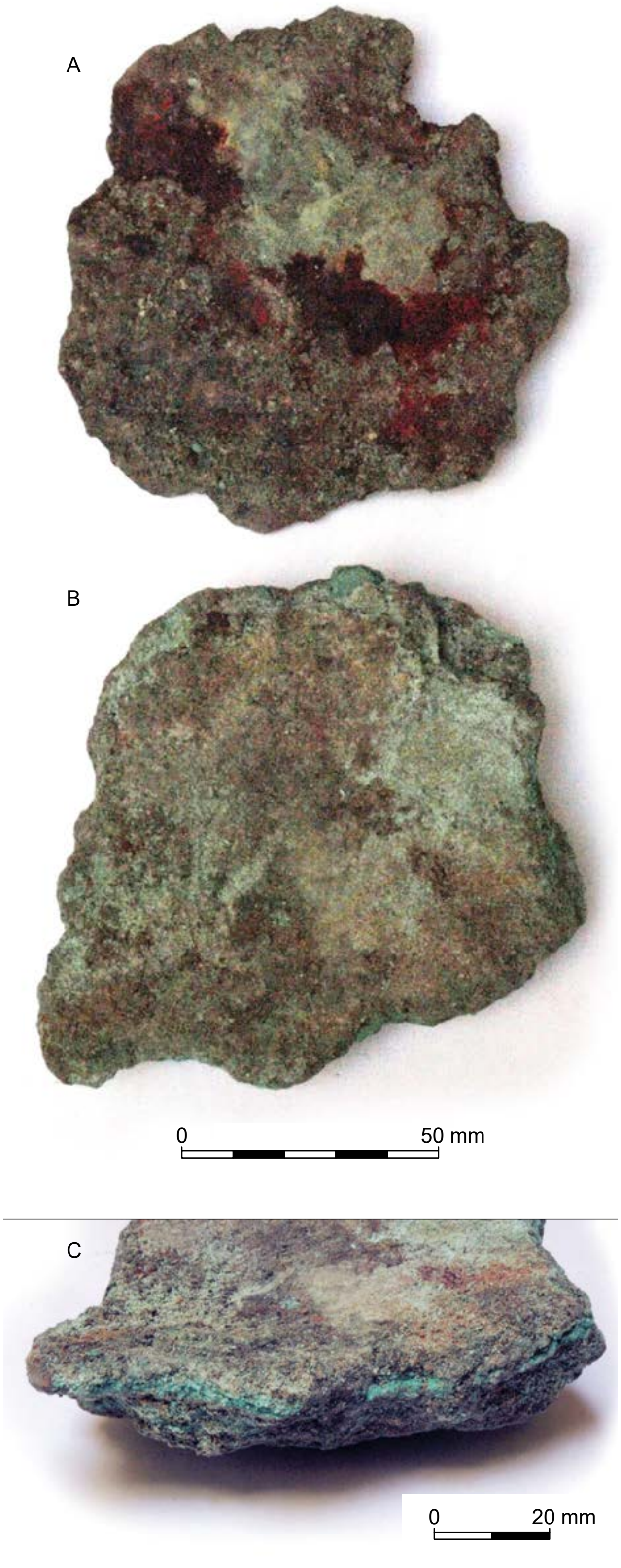


Figure 8.28 Sample 5 before preparation

The copper-rich inclusions in the black slag are puzzling. The slags are typical Capper Pass SM or DM slags (similar to solder slags but with Cu and lower CaO); however, the inclusions are too high in copper to be Capper Pass intermediates, although they could have arisen from Cu-based scrap which was added to the SM charge and which did not make it into the metal product. It is interesting that some of the black slags (see Appendix 1, Table 8.12, analyses 164, 166 and 179) have high S contents and very low Sn, As and Sb. It is known that when sampling copper secondaries, the presence of S with Sn, As and Sb can lead to volatilisation of these metals as sulphides (Smith 1978, 199; Smith and James 1981, 126).

Sample 4 is without doubt the most complex and puzzling of the samples. It seems to have been a floor surface made from crushed slags and refractory (or broken crucibles). This would have provided a disposal route for a small amount of waste material, and slag was commonly used as a floor material by some smelters. It is fairly certain that throughout the life of the works, slag and crushed refractory would have been used for flooring or hardcore at Bedminster.

Sample 5

Sample 5 is a bright green deposit (Figs 8.5 and 8.28) from within flue S5 and was probably deposited in the early 1900s. This sample was taken to identify the nature and origin of the deposit, i.e., is it derived from copper alloy smelting, or something else? The distinct green colour suggests the presence of malachite. This could represent a malachite ore employed in smelting, but the context suggests a copper-rich material which has subsequently corroded.

Sample 5 appeared to be fairly robust, but once cut and mounted in epoxy resin (Fig. 8.5) it became clear that the sample was weak and friable. Attempts to obtain a polished surface for analysis were abandoned (at P600) as material tended to be 'plucked' out and scratch the surface. Despite the poor sample preparation, every effort was made to image and analyse the sample; however, this was further hampered by the extreme porosity, which made it impossible to obtain a high vacuum necessary for SEM analysis. After several attempts, some imaging and analysis was obtained by employing the SEM in Variable Pressure mode. The increased air pressure within the SEM chamber is accompanied by a slight deterioration of the quality of images and analysis. The SEM images (Fig. 8.29A–B) show a somewhat porous material, although some of the apparent porosity may be an artefact of sample preparation as some material was 'plucked' out during grinding. Some of the material appears to be in form of rough spheres (Fig. 8.29B).

A series of chemical analysis were conducted through the thickness of the sample (Appendix 1, Table 8.13), starting

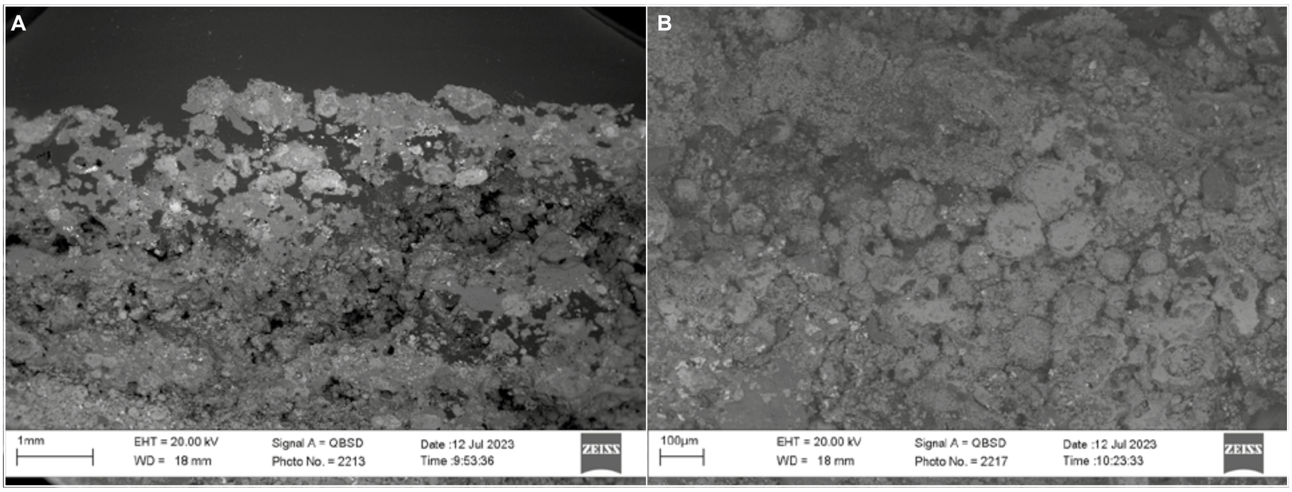


Figure 8.29 SEM images of sample 5: A) Table 8.13, area 1; B) Table 8.13, area 4

at the top and moving progressively to the base. The chemical composition is complex with a wide variety of elements detected. There is a strong positive correlation between calcium and sulphur, and it is likely that gypsum (or other calcium sulphates) is a major component of this sample. The presence of calcium sulphates in other samples (e.g., nos 3, 7 and 8) suggests that the calcium sulphate was deposited in the flues *after* use. Sample 5 also contains high levels of copper and chlorine that explain its green colour (i.e., the presence of malachite). Given the context, it is likely that the malachite is a post-depositional corrosion product.

The high copper content (with some Zn, Pb, Sb and the absence of Sn) suggests that this is fume/dust from copper smelting/melting and therefore dates from the early/mid-19th century operations. The presence of chlorine is significant in that CuCl is volatile when the metal is melted. This would collect as a dust on the walls of the flue and would be extremely friable. As the flue was subterranean, it is likely that the deposits were cemented by percolation of groundwater and subsequent precipitation of gypsum ($CaSO_4$) and calcite ($CaCO_3$). The Al_2O_3 and SiO_2 may be refractory dust or slag. The occasional presence of mercury (Hg) is not completely surprising as metallic Hg was once found in copper ore roaster flues at Melton, but vanished once a procedure was put in place to recover this.

Samples 7 and 8

Samples 7 (Figs 8.3 and 8.30) and 8 are near identical in form and chemistry and are described here together. Both samples are composed mostly of a calcium sulphate with brighter inclusions of metal sulphates. Sample 8 additionally has an adhering area of refractory ceramic: it is assumed that the calcium sulphate (and metal sulphates) condensed onto this brick surface inside the flue. The metal sulphate inclusions appear to include both $PbSO_4$ and $SnSO_4$ (and these can also contain small proportions of As and Hg). The metal sulphates can be found as distinct euhedral crystals entirely embedded in the calcium sulphate matrix, but are also found as less distinct (corroded?) crystals close to original surfaces. The presence of metal sulphates in these flue deposits suggests that they derive from an ore roasting stage. Sample 7 (Appendix 1, Table 8.14, analyses 95 and 96) appears to be smelting flue dusts from solder and lead charges respectively. They have been cemented as lead and calcium sulphates through percolation of groundwater or condensation of moisture. As $SnSO_4$ is soluble in water it is likely that Sn is present as the oxide. Most of the sample is gypsum with some refractory.

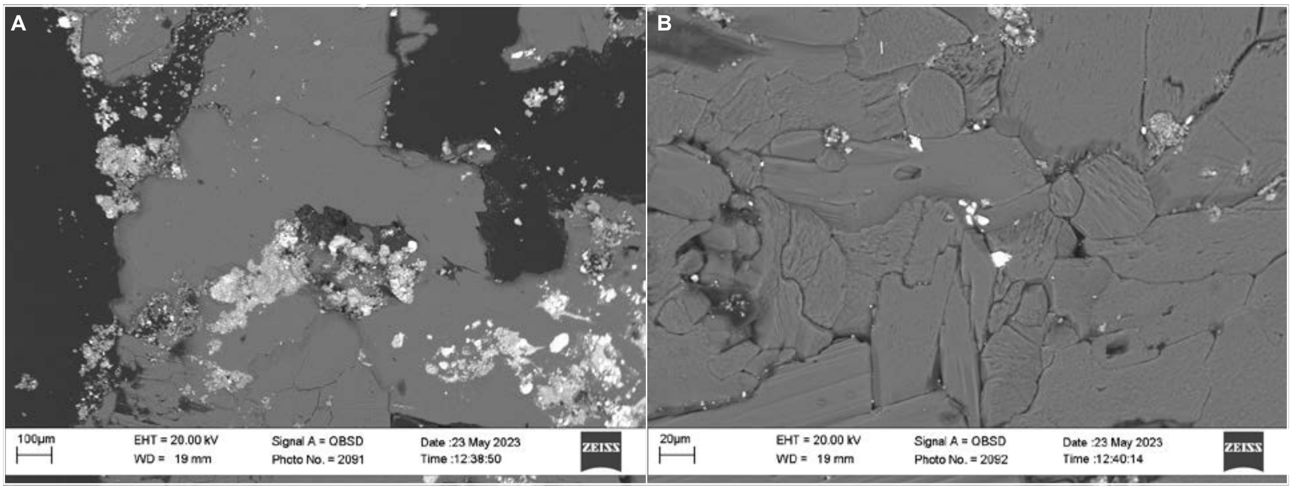


Figure 8.30 SEM images of sample 7

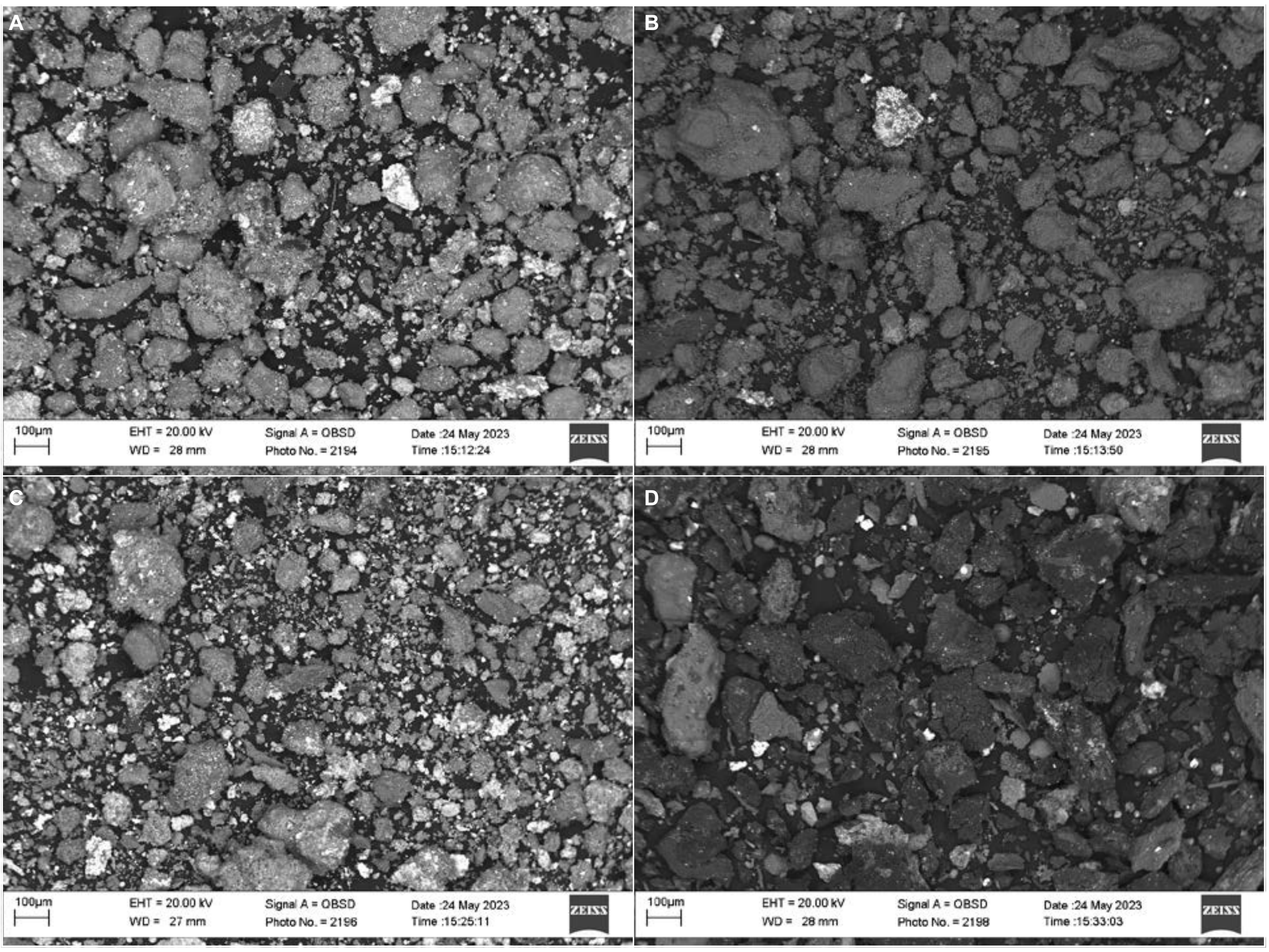


Figure 8.31 SEM images of: A) sample 6; B) sample 9; C) sample 10; D) sample 11

Samples 6 and 9–13

The remaining six samples (nos 6 and 9–13) were supplied as dust/sediment mostly collected from flues (Figs 8.4 and 8.31A–B; Appendix 1, Table 8.15). The state of these samples poses considerable difficulties in attempting to determine their detailed nature. These samples could not be embedded in epoxy resin (as the other analysed samples were) so it was not possible to examine cross-sections through any of the individual particles. Reliable chemical analysis of individual particles would be almost impossible (EDS geometry requirements, corrosion, etc). Ultimately, the decision was made to concentrate on the more promising samples discussed above.

These samples are of varied nature but most appear to contain some soil material. Two of the samples (nos 11 and 13) are dominated by fragments of clinker (i.e., vitrified coal ash), as well as coal dust and fragments of partially burnt coal. Samples 10 and 12 also contain fragments of (red) brick dust and fragments of brick. Most of the samples also contain particles that are rich in metals (the light grey and white spots in Fig. 8.31A–B).

As sample 6 came from a flue and was a friable particulate, the high zinc and arsenic content suggests a smelting dust, possibly from one of the blast furnaces, together with degraded refractory or slag, or both. The usual Capper Pass metals are all there and the fume could be from all of the different smelting charges.

Discussion

The examination and analysis of 18 samples from the Bedminster Smelting Works provide some illustration of the metal production processes that took place. Nevertheless, the results should be framed by a consideration of the range and scale of the metallurgical processes that are known from historical sources. The smelting of lead, tin and copper are all known to have been carried out, although the metallurgical balance of importance shifted over the time that the Bedminster works operated.

The only material evidence for alloy production comprises the two lumps of lead alloy (sample 16) which contain 0.5–1wt% tin and 2–3wt% antimony (with the balance made of lead). The tin and antimony additions would have enhanced the strength/hardness of the lead. However, the alloy additions (Sn and Sb) fall well short of most specified alloys (e.g., type metal or solder) and the sample probably represents an intermediate stage of processing. This is lead from a blast furnace which had been cleaned by melting and cooling to remove Fe, Cu and Ni as drosses, and which was in the process of being detinned in a reverberatory furnace (lead pan).

Whatever the specific nature of the smelting regime at any one time, smelting would have generated many tonnes of waste slag each year. At least some of the slag would have been retained and used later as feedstock in another smelting operation (and this is perhaps illustrated by sample 4), but ultimately a strategy was required to dispose of the material off-site. The quantities of slag recovered amount to less than 30 kg and it would be foolhardy to assume that what has been recovered is representative of the full range of Capper Pass processes. After 1890, the company built a large blast furnace on land to the west of the excavation area, bought in stages between 1883 and 1890. This would have provided much more space for depositing waste. In 1916, they bought a large plot in St Annes for dumping slag; the plot was then sold for housing in 1926. The excavation area was occupied by the lead and solder refineries according to the Goad Fire Insurance Plan of 1961, and any slag would have been removed from here before this was developed.

The examination and analysis of the flue (and other loose) deposits faced significant technical challenges, and these could not be completely surmounted. Most of these deposits could not be mounted in epoxy resin to expose cross-sections that would allow quantitative analysis, and most were contaminated with varying proportions of soil, coal ash and/or clinker. The finite constraints on the analysis programme encouraged the focusing of resources on those samples that provided the most reliable evidence. Two samples of flue deposit (samples 7 and 8) comprised crystalline material, and in the latter case this was adhering to a refractory substrate (the remains of a brick which made up the flue?). Analysis showed that the crystals were calcium sulphates and these are likely to be gypsum ($CaSO_4.2H_2O$) or bassanite ($CaSO_4.½H_2O$), as anhydrite is soluble in water. The calcium sulphate was accompanied by small amounts of metal sulphates. The gypsum probably came from water percolation into the brick flues as the latter were underground and would have been wet. The small assay crucible (sample 18) shows that assays were facilitated by the use of soda-rich flux. The only metal prill trapped in the vitrified interior surface comprises a lead–tin alloy, but it is not clear what material(s) had been assayed in this crucible.

CHAPTER 9
ASPECTS OF MATERIAL CULTURE

Powell's Pottery Waster Dump

During the 1840s or early 1850s, a large quantity of industrial waste was dumped on Plot A to raise the ground level and create a firm, dry, yard surface. This material contained a dump of crushed 'wasters' (misfired and broken pottery) from Powell's Pottery in Temple Gate, Redcliffe. A sample of this pottery (104 sherds) was collected, some of which is marked with the impressed backstamp 'POWELL / BRISTOL' and 'POWELL / POTTER / BRISTOL' (Fig. 9.1). A single large piece of kiln furniture was also recovered. This can be identified as part of a circular sagger that would have protected vessels from direct contact with flames and smoke during firing.

The pottery includes fragments of spirit flasks, bung jars, beer and ginger beer bottles, and large flagons, including two examples impressed with the proprietary mark 'Edward Ellis / Wine & Spirit Merchant / Wimborne' on the shoulder. Edward Ellis is recorded as a wine and spirit merchant of Wimborne Minster, Dorset in 1838. He died in 1853, leaving the business to his nephews Fredrick and Charles Ellis (*Dorset County Chronicle*, 13 September 1838; 2 May 1861; 22 November 1866; *Southern Times and Dorset County Herald*, 3 September 1853).

Along with the ceramics from Powell's Pottery, the made ground contained a small quantity (37 sherds) of other common contemporary wares: coarse red earthenware; Bristol-/Staffordshire-type slipware; and mass-produced pottery including pearlware, refined whiteware and black basalt ware. This pottery represents domestic refuse that was imported onto the site along with the soil, ash and clinker used for ground raising.

Powell's Pottery, also known as the Temple Gate Pottery, was established by William and Thomas Powell in 1830. These men, who were probably brothers, had operated a nearby pottery and glassworks in St Thomas Street since 1816. They made glass bottles and brown salt-glazed stoneware, including bottles and sugar moulds for the local and export markets. Shipping records show that their pottery was exported to the Channel Islands, Ireland and the British colonies of Jamaica and Nevis. Their products were also exported to the Italian ports of Livorno (Grand Duchy of Tuscany), Naples (Kingdom of the Two Sicilies) and Genoa (Kingdom of Sardina); as well as Madeira (Kingdom of Portugal) and New York, USA. In 1831–2, William Powell ran the pottery in partnership with his brother John. The following year, William Powell became the sole proprietor (Jackson 2019). Powell is listed in subsequent directories as:

> *Brown stone ware, glass bottle and patent sugar mould manufacturer, inventor and sole manufacturer of the improved stoneware which is glazed inside and out with a glaze warranted to resist acids and will not absorb (Mathews' Directory 1836–55).*

Improved stoneware, also known as 'Bristol stoneware', was coated with a felspathic glaze that provided a hard, smooth and impervious finish. This product was extremely popular, and by the mid-19th century it had become one of the most common utilitarian wares, particularly for bottles, jars and flagons. Powell's vessels were exported throughout the British Empire (Australia, Barbados, British Guiana, Canada, Channel Islands, India, Ireland and Jamaica), as well as the Portuguese ports of Madeira and Lisbon, and various cities in the USA. Willian Powell died in 1854. The pottery was subsequently run by his sons Septimus and William Augustus Powell as William Powell

Figure 9.1 Powell's Pottery wasters: A–B) maker's marks; C) proprietary mark; D) flagon handles; E) flagon, beer and ginger beer bottle lips; F) jar rims

& Sons. Powell continued to be the main producer of Bristol stoneware throughout the 19th century, a position supported by exclusive contracts with large companies such as the food manufacturer Crosse & Blackwell (Jeffries *et al*. 2016, 52). After the death of William Augustus Powell in 1906, the company merged with Price, Sons & Co. to form Price & Powell. The Temple Gate Pottery was subsequently demolished (Jackson 2019).

Dumps of pottery wasters, often used as hardcore, are common in central Bristol. Surprisingly, however, the only previously recorded Powell's Pottery wasters comprise two sugar moulds that were found on the site of the demolished Temple Gate Pottery (Fowler 1973, 62). Powell's Pottery was an extremely prolific manufacturer and complete examples of their pottery are common in private and museum collections. All the waster sherds from Bedminster are paralleled by complete examples in such collections.

Bricks

The mid-19th-century buildings of the Bedminster Smelting Works were predominantly built of stone, while the later 19th- and 20th-century buildings were built of brick and/or concrete. Hot areas, such as furnace linings, flues and steam boiler bases were lined with firebricks. A sample of the marked firebricks (29 in total) were recovered from smelting works structures. Seven ordinary marked bricks were also collected.

Firebricks

The marked firebricks (Fig. 9.2) are all made from Coal Measures clay and have fabrics that vary from buff to pinkish buff. Twenty-two of the bricks (76%) were made in Scotland; the other seven were produced in Stourbridge, Worcestershire.

Scottish Firebricks

Nineteen of the Scottish firebricks were manufactured by the Glenboig Union Fireclay Co. of North Lanarkshire; the other three were produced at the Dykehead Fire Brick Works in Bonnybridge, Falkirk.

The Glenboig fireclay industry began in the early 1830s, but the output was modest until the second half of the 19th century. Development of the rail network and increasing industrialisation led to a huge increase in demand for high quality firebricks, and by the end of the century the Glenboig Union Fireclay Co. had become the world's largest manufacturer of fireclay products. The company prospered in the first half of the 20th century, but after World War II, declining sales led to the failure of the business. The Glenboig Old Works closed in 1958, followed by the nearby Star Works in the late 1960s (Scotland's Brick and Tile Manufacturing Industry 2024a). The Glenboig firebricks used at the Bedminster Smelting Works are all unfrogged and marked with a 'GLENBOIG' incuse on the bed. They include 11 standard-shaped bricks and eight voussoir bricks. The latter include an example of a 'Glenboig Crown' brick, which had a 'more elastic texture and higher grog content'. These were used for 'suspended arch blocks, throat bricks and all positions where freedom from spalling is specially [sic] important' (*ibid*.). Glenboig bricks were used in the flues of steam boiler bases S27 and S36, and in the fireboxes and flues of solder pots S28, S28, S30 and S50.

The Dykehead Fire Brick Works was established in 1839 by Margaret Donald and was subsequently acquired by George Turnbull and Co. The company was taken over and re-founded as the Dykehead Ganister Fireclay Co. Ltd in 1913, which was itself subsumed by the Glenboig Union Fireclay Co. Ltd in 1919.

The Dykehead works remained operational until *c.* 1962 (Scotland's Brick and Tile Manufacturing Industry 2024b). All the Dykehead bricks, which are unfrogged and marked with a 'DYKEHEAD' incuse on the bed, were recovered from steam boiler base S27.

Figure 9.2 Marked firebricks manufactured by: A–C) Glenboig Union Fireclay Co; D) Dykehead Fire Brick Works E) Harris & Pearson; F–G) Rufford & Co.; H) E. J. & J. Pearson

Stourbridge Firebricks
Four of the seven Stourbridge firebricks were made by Harris & Pearson; two were made by Rufford & Co.; and one was manufactured by E. J. & J. Pearson. One of the Harris & Pearson bricks was frogged on both sides; the others are all unfrogged.

Harris & Pearson was a fireclay mining and firebrick manufacturing company that was founded in 1852 (Grace's Guide 2024a). During the early 1930s, the company became part of E. J. & J. Pearson Ltd., though they continued trading as Harris & Pearson Ltd until they ceased production in 1968 (*ibid.*; Cooksey 2024). The Harris & Pearson firebricks, which are marked with a 'HARRIS & PEARSON / STOURBRIDGE' incuse on the bed, were used in the construction of solder pot S29, flues S12 and S21, and steam boiler base S36.

Rufford & Co. was a firebrick company that operated between 1802 and 1936. By c. 1880, the company had diversified into the production of glazed bricks and porcelain baths (Graces Guide 2024b). One of the latter bricks was used in the construction of steam boiler base S27. This brick has a white-glazed header, frogs on both beds, and is incused 'RUFFORD' on one side and 'STOURBRIDGE' on the other. The other Rufford & Co. brick, which was used in flue S4, is incused 'RUFFORD / STOURBRIDGE'.

E. J. & J. Pearson specialised in the production of firebricks for industrial applications. This company was founded in 1860, became incorporated in 1898 and was acquired by J. T. Price & Co. in 1957. The combined company was renamed Price-Pearson (Refractories) Ltd (Anon. 1903; Graces Guide 2024c). The E. J. & J. Pearson brick, which is marked with a 'E J & J PEARSON / A / STOURBRIDGE' incuse on the bed, was used in the construction of solder pot S28.

Common Bricks

One of the ordinary bricks (Fig. 9.3A) was made in Fletton, Cambridgeshire; the others are local products from Bristol and South Gloucestershire.

Fletton Brick
A single frogged London Brick Co. brick was recovered from the foundations of solder pot S30. The brick is pinkish buff and has 'LBC / PHORPRES' impressed into the frog. The London Brick Co. was founded in Fletton, Cambridgeshire, in 1889 and was incorporated in 1900. The company's 'Phorpres' (i.e., four pressed) brick was introduced in 1901 and remained in production until 1974 (Brooks 2022; Stratton and Trinder 2000, 132).

Local Bricks
The local bricks comprise three from the Cattybrook Brick Co. Ltd of Almondsbury, Gloucestershire; three from the Malago Brick & Tile Works of Shene Road, Bedminster; and one made by Scourse & Kingston Ltd of Parson Street, Bedminster.

The Cattybrook Brick Co. was founded in 1871 in anticipation of the construction of the Great Western Railway's Severn Tunnel, the route of which ran past the brickworks. The company was incorporated in 1877 (Fretwell 2014). In 1969, the company was acquired by Ibstock Bricks (Doughty and Ward 1975, 10). The Cattybrook bricks include a red example, and two pale buff or pink bricks made from Coal Measures clay. All have impressed frogs marked 'CATTYBROOK BRICK CO / LIMITED / BRISTOL'. The Cattybrook bricks were used in the construction of steam boiler base S36 and solder pot S30. This type of Cattybrook brick was sometimes used for ordinary building works, but their Coal Measures clay made them suitable for use as firebricks, and they have been found used in a steam boiler flue at the Golden Valley Old Pit in South Gloucestershire (Cornwell 1990, 15).

Figure 9.3 Marked bricks manufactured by: A) London Brick Company; B) Cattybrook Brick Co. Ltd; C) Malago Vale Colliery & Brick Works; D) Scourse and Kingston Ltd

Malago Vale Colliery was established in 1844 (*BM*, 17 August 1844; Taylor and Shapland 2012, 33). The pithead was located on the south side of West Street. Ashmead's plan of 1874 shows a large brickworks between the colliery and Shene Road; this is identified on later plans as the 'Malago Vale Works' (1885 OS plan) and the 'Malago Brick & Tile Works' (1904 and 1916 OS plans). It was also known as the Malago Vale Colliery & Brick Works, a name first documented in 1877 (*WDP*, 23 October 1877). Malago Vale Colliery closed in 1895 following an acrimonious industrial dispute, but the brickworks remained operational until 1908 (Hammersley 1992, 19). The bricks, which are red and have impressed frogs marked with a 'MALAGO COLLIERY / AND / BRICK WORKS' incuse on the bed, were used in the construction of steam boiler base S27 and solder pot S30.

Scourse and Kingston Ltd was founded in 1908 as a successor to Scourse Bros, who had operated a brickworks on Parson Street since 1898 (Hammersley 1992, 20; *WDP*, 24 September 1908). This company, which specialised in the manufacture of dry-pressed, white-glazed facing brick, closed following the death of its managing director F. W. R. Scourse in 1941 (*WDP*, 13 October 1941). These bricks, which are pale yellow and have impressed frogs marked 'SCOURSE / AND / KINGSTON LTD', were used in the foundation of solder pot S30.

Discussion

Most of the common bricks used at the Bedminster Smelting Works were unmarked. Those dating from the early to mid-19th century were handmade, whereas those dating from the later 19th and 20th centuries were predominantly press moulded. The handmade bricks are likely to have been made locally, the adjacent Bright Bow Brickyard being a likely source for the pre-1860s structures. Some of the later press-moulded bricks were marked with the names of local companies, though a few 20th-century bricks from the ubiquitous London Brick Co. were also present.

Most of the firebricks, which include handmade and press-moulded examples, were unmarked. All the marked firebricks were imported from Stourbridge and Scotland. Excavations at the former Bristol Gas Light Company's Avon Street gasworks uncovered a similar assemblage of firebricks dating from 1821–1961, the majority of which (54%) were made by Stourbridge-based companies; the others were manufactured in nearby Dudley and at Stobswood Colliery, Northumberland (Wessex Archaeology 2023, 20–2). A similar pattern can be found elsewhere in Bristol: the mid- to late 19th-century Barton Hill Pottery and Powell & Ricketts' Glassworks both made use of Stourbridge firebricks in their kilns (Mason 2017, 117; Gregory *et al*. 2018, 267).

Firebricks can be made from kaolinite, Ganister, and Windsor loam, but most are made from Coal Measures clay, which produces a far superior brick (Smith 2005, 33). Coal Measures clay can be found in various locations in and around Bristol, and several local companies produced firebricks, including Bristol Fire Clay Co., Cattybrook Brick Co. Ltd, Easton Coal Co., and the Malago Brick & Tile Works (*BM*, 2 February 1893, 4; Butterworth 2024, 5; *WDP*, 17 March 1879, 7), but it is interesting to note that apart from the Cattybrook Brick Co. Ltd bricks used in steam boiler base S36, none can be confidently ascribed to local manufacturers. This may simply be because most of the local bricks were unmarked, but an apparent preference for non-local firebricks has been noted elsewhere. For instance, industrial concerns in London are known to have imported enormous quantities of firebricks from Scotland and Stourbridge, even though they were more expensive than other sources (Smith 2005, 33). Excavations on the site of a public washhouse in Bath (built in 1846) showed that the bricks used in its boiler bases were sourced from the West Midlands (Mason 2020b, 92). The reason for choosing Scottish or West Midlands firebricks over local products may be the former's high alumina content, which gave them exceptional abilities to withstand heat. Some 19th-century Scottish scientists claimed that Scottish bricks had a higher alumina content than those from England, but recent scientific analysis has shown that some, such as the early bricks from Glenboig, were in fact comparable to those from Stourbridge (Hayward 2016, 106–7). Both may have been superior to products of the Bristol area. Development of the rail and shipping network, coupled with the economies of scale that were achieved at large Scottish and the West Midlands fireclay mines, are likely to have reduced the cost of their firebricks in the later 19th and 20th centuries. Cost may have been a consideration for Capper Pass & Son, but it seems likely that the decision to source firebricks from Scotland and Stourbridge was due to the superior quality of these bricks. Longer-lasting bricks meant that the furnaces could be kept operational for longer, thereby reducing downtime and maximising profits.

Figure 9.4 Metalworking tools: A) hoe; B) probe; C) large ladle; D) small ladle

Tools of the Trade

Methods of production at the Bedminster Smelting Works were largely manual throughout the operation of the works. Coal, ore, metal-bearing residues, slag and finished metals were all transported by horse-drawn carts and wheelbarrows, and the materials in the furnaces and melting pots were manipulated using iron tools, a selection of which were recovered during the excavation. These tools were found in amongst the 1963 demolition debris, but they are likely to have been old when they were abandoned.

All but one of the four illustrated tools have long handles (Fig. 9.4), which would have allowed workers to manipulate hot ores, slag and molten metal from a distance. The smallest tool is a ladle (Fig. 9.4D) which has a 130 mm wide bowl, with a pouring spout on one side, and a flat-sectioned 450 mm long handle that is bent back over the bowl. It is uncertain whether it was deliberately bent, perhaps to allow liquid metal on the edges of solder pots to be scooped up, or whether this is post-use damage. The second ladle (Fig. 9.4C) is much larger: it has a 230 mm wide bowl with a pouring spout, and a flat-sectioned 1230 mm long handle with small loop at the end. The ladles are likely to have been used to scoop molten solder from the solder pots into adjacent water-cooled moulds.

The other illustrated implements comprise a hoe-like tool (Fig. 9.4A) and a pointed probe (Fig. 9.4B), both of which have a 130 mm wide loop at one end. The hoe has a 1940 mm long handle and a sturdy 200 mm wide blade at the end. Identical implements were used at Melton to rake ‘yellow scum’ from a detinning furnace and clean ashes from a liquation furnace. A similar implement was also used to rake ashes from the stationary grate of a Lancashire boiler (R. Smith, pers. comm. 2024).

The probe is a 1660 mm long rod that tapers to a point. Similar implements were used for pricking tuyeres and ensuring that the blast hole between the furnace and the forehearth of the blast furnace was kept clear. Tapping and clearing of blast holes was subsequently done using oxygen lances (R. Smith, pers. comm. 2024). Similar probes were also used to clean boiler grates.

Figure 9.5 Late 1880s or early 1890s Morgan Crucible Co. fire assaying crucible from B13

Figure 9.6 Late 1950s Capper Pass & Son Ltd ore sample jars from the backfill of softening pans S40

The Science of Smelting: Assaying and Analysing

Prior to the 1860s, methods of production at Bedminster Smelting Works were somewhat haphazard. The chemical make-up of the ores and residues was largely unknown, and the refining methodologies were essentially a process of trial and error. Consequently, the refining was not always successful and the metals produced were of varying and unreliable purity. When Alfred Pass, who benefited from formal training in chemistry, came to work for his father, he implemented a programme of routine assaying of ores and invested time and resources into understanding the chemical reactions that were occurring in their furnaces. The result was a much clearer understanding of the chemistry of the complex ores and residues they processed. This gave them a commercial edge over their competitors, by allowing them to obtain metal from low-content ores and industrial waste that others were unable to refine.

A make-up deposit associated with the construction of building B13 in the late 1880s or early 1890s contained a dump of crushed assaying crucibles mixed with clinker. A sample of the crucibles was collected, including one complete vessel. The crucibles have a white fabric and measure 90 mm high and up to 90 mm wide. The complete vessel (Fig. 9.5) is incused with the image of a crucible around the words '(illegible) / CORNISH' with 'MORGAN / BATTERSEA' in small lettering below. The Powerhouse Collection holds an identical vessel, which was presented to them by the Morgan Crucible Co. in 1883 (Powerhouse Collection 2024).

Cornish crucibles, used for assaying copper, tin, silver and gold, were developed before 1862 by the Juleff family at the Pednandrea Crucible Works in Redruth, Cornwall (Anon 1862, 15). In 1880, this company was acquired by the Patent Plumbago Crucible Co. of Battersea, London (*Australian and New Zealand Gazette*, 15 May 1880; 21 August 1880, 5). This company was established by five Morgan brothers in 1856. Within five years, their internationally renowned crucibles were being used by British, Australian, French, Indian and Russian mints. They were also used at the French arsenals of Brest and Toulon, and the Royal Arsenal in Woolwich, London. The company was renamed as the Morgan Crucible Co. in 1881. In the early 1900s, the company diversified into a range of other materials, but also continued to produce crucibles. Morgan Crucible Co. Ltd ceased trading in 1961, but the multi-national parent company, known since 2013 as Morgan Advanced Materials plc, is still active (Encyclopedia.com 2019; Morgan Advanced Materials 2024). Analysis of the vitrified interior of the crucible (see Chapter 8, sample 18) showed that it contained high levels of aluminium and silicon (derived from the crucible ceramic) and sodium, which was probably used as a flux. There was a small globule of lead mixed with a tiny amount of tin embedded in the surface.

At Capper Pass & Son, this type of crucible was used for experimental work and preparing samples of bought materials such as copper and antimonial alloys. They were also used for the reduction of materials containing silver or gold: this entailed melting a 10–50 g sample with litharge and flux to give a lead button for subsequent fire assay. Another use was to reduce works intermediates such as 'heavy scum' and 'yellow scum' with potassium cyanide for process monitoring. The cyanide assay was also used at Bedminster to analyse raw materials before the introduction of wet-chemical methods and for rapid approximate analyses. It was also used for routine works analysis before the introduction of X-ray fluorescence and atomic absorption spectroscopy in the mid-20th century (R. Smith, pers. comm. 2024).

Rigorous testing was expanded under Douglas Pass's directorship, and by 1925 the company had a dedicated laboratory fronting onto Mill Lane (*WDP*, 10 March 1925, 3). The laboratory was staffed by women, who held a position of some power within the works: they could demand samples of the metal at any stage of production and every solder mix was routinely analysed (BMAG OH69.1). When the works closed in 1963, the laboratory was cleared, and some of its contents were dumped into lead detinning and softening pans S39 and S40. The contents of the southern pan (S39), which contained many test tubes and other pieces of laboratory glassware and equipment, was too contaminated to investigate (the infill material was removed by specialist contractors). The northern pan (S40) contained numerous small, machine-made, colourless cylindrical glass jars, 32 of which were collected.

The jars (Fig. 9.6) are 75–90 mm high and 26 have complete or partial paper labels marked 'CAPPER PASS & SONS LIMITED, BRISTOL', along with various typed details identifying the jars' contents and origin. The jars were all empty, but one had a surviving cork closure. Some have small pieces of straw adhering to the outside; this likely to have been a packing material used to prevent them smashing in transit. The labels show that most of the samples were taken in Bedminster or Gloucester (the port of arrival); one was taken at Melton. The labels indicate that the jars originally contained dried ores or secondaries that were sampled between 1955 and 1958. They came from a variety of sources, and probably represent samples taken to assess the metal content of raw materials prior to purchase. Identifiable contents include tin residue and hearth absorption from the Wah Chang Corporation; tin ore from Financiers Miners S. A.; tinning residues from A. E. Milner (Metals) Ltd; tin dross and flue dust from H. Hales Ltd; lead slag from Watson & Co. Ltd, and unidentified samples from C. Tennant Sons & Co. and *Corporación Minera de Bolivia* (COMIBOL); the latter is likely to have been tin ore. Three jars contained zinc oxide, tinning dross and solder residue from unknown sources. Three of the companies were British: H. Hales Ltd was a Swansea tinplate broker (*Western Mail*, 5 November 1943); A. E. Milner (Metals) Ltd was a Birmingham-based dealer in non-ferrous metals and residues (*Birmingham Weekly Post*, 5 July 1957); and C. Tennant Sons & Co. was a merchant bank that traded in metals and minerals (C. Tennant Sons & Co., 1961). Two were foreign: the Wah Chang Corporation of Oregon, USA, was founded by Kuo-Ching Li, a Chinese-American mining engineer who started out refining tungsten and antimony and later diversified into a wide range of speciality metals and alloys (*The Oregonian*, 11 May 1957 and 9 March 1961). In 1958, the Wah Chang Corporation purchased the Texas City tin smelter and adapted it for the manufacture of tungsten products and tin alloys (Anon 2024). COMIBOL was a state-owned company formed from three of Bolivia's largest tin mining companies after the National Revolution of 1952 (Burke 1987, 3).

Similar jars were also used at Melton, where the normal procedure was to take a sample (typically 10% of the parcel or consignment; primary samples of 1–5 tons were quite normal) and divide this by coning and quartering to about 100 kg. This was ground in a pan mill to pass a 30-mesh sieve and further reduced to 2–3 kg, then dried. This was milled further to pass a 60–200 mesh, depending on the type of material. It was then mixed and put into the sample jars. One was sent to the Capper Pass & Son laboratory for assay; one given to the seller or his representative; the rest was held in reserve. If the Capper Pass & Son's and seller's assays disagreed, a third sample was sent to an independent referee, the assay was settled on the middle of the three results and the referee's fee was paid by the laboratory that was furthest from the referee's result. The splitting limits (assay differences) were 0.2% Sn for low- and medium-grade ores and secondaries, 0.3% Sn for high-grade ores, 0.5% for other metals, 2 oz/ton for silver and 0.2 oz/ton for gold. Samples were thrown away after the assays were settled although one sample was retained for at least two years. Materials such as drosses could produce two or three sub-samples: metal, fines and mixed metal/fines of about 60 mesh. The metal would be supplied as a strip or sawings from a strip and the others as powders. The bottle labels showing 'Proportion %' indicates the sub-sample's proportion of the total (Smith 1978; pers. comm. 2024; Smith and Jones 1981).

CHAPTER 10
THEMATIC DISCUSSION

The Pass Family

Capper Pass I (1775–1839)

Capper Pass & Son was a family business, owned and operated by successive generations of the Pass family. The company was established by the eponymous Capper Pass I, who was born in the village of Shenstone, Staffordshire, in 1775 (Vincent 2022, 14). His parents, William and Mary Pass, were Nonconformists, and some denominations, particularly Quakers, often gave the mother's maiden name as a first name: hence the somewhat unusual name Capper (Little 1963, 4; Vincent 2022, 14). Capper Pass's mother died when he was seven. He was subsequently apprenticed to the tallow chandler (candlemaker) John Ball of Abbots Bromley when he was 15, but he did not follow this trade for long.

In 1798, Pass married Phebe Vise Tittensor in Handsworth parish church, then moved to Woods Yard in the centre of Walsall, Staffordshire (TNA IR 1/34; Vincent 2022, 15). This was a rapidly expanding market town, with established leather, limestone quarrying, malting and metalworking industries (Freeling 1838, 126). The 1801 census lists half the inhabitants of Woods Yard as metalworkers, most of whom were buckle makers. Capper Pass is listed as a victualler. The Passes had at least two children – Thomas (b. 1799) and Elizabeth (b. 1801). In March 1802, Phebe and her infant child Elizabeth died. They were buried together on the same day (Vincent 2022, 15).

Changes in fashion resulted in the replacement of buckles with laces for fastening shoes in the late 18th century and buckled breeches with trousers in the early 19th century (Planché 1836, 328; Stephens 1964). This led to a slump in the Walsall buckle trade, which, coupled with his recent bereavement, may have prompted Pass to seek his fortune elsewhere. Four months after his wife's and daughter's death, Pass married Anne Perkins at All Saint's Church in West Bromwich (Vincent 2022, 15). To modern eyes, this may seem an inappropriately short interlude, but for poor widows and widowers with young children, remaining unmarried meant destitution. Capper and Anne Pass settled in central Birmingham, where their children Harriet (b. 1803), Jane (b. 1805) and Capper Pass II (b. 1806) were born (census 1841; Vincent 2022, 15). Birmingham was a large and rapidly expanding city that was home to a vast range of industries, including cotton and chemical manufacturing, along with ferrous and non-ferrous metal smelting and foundries producing tools and machinery. Capper Pass may have learnt the smelting trade during his time in Walsall, and he is first listed as a 'metal refiner and brass caster' in 1808. The Levy Books of 1807–13 list Capper Pass's premises as 22 Lancaster Street. The property was rated at £24 a year, which was amongst the higher-valued premises on the street, though not as much as those containing furnaces and other large items of industrial plant (Little 1963, 5; Vincent 2022, 15). During his time at Lancaster Street, Pass appears to have worked in partnership with the metal refiner Thomas Evetts, though by 1814 the men had fallen out, leading Evetts to publish a notice stating:

> *NOTICE is hereby given, that after this Day I will not be accountable for any Business transacted in my Name by CAPPER PASS. Witness my Hand, THOMAS EVETTS Birmingham, Oct. 15, 1814 (Aris's Birmingham Gazette, 17 October 1814).*

The partnership with Evetts was not the only business relationship of Pass's that went sour. He also owed money to a bankrupt Birmingham tailor named Richard Blakemore. Pass was unable to pay the debt and was subsequently jailed as a debtor in the Fleet Prison, London (*Aris's Birmingham Gazette*, 15 February 1815, 1; 27 February 1815, 4; Vincent 2022, 15–16). Pass was somehow able to buy his way out of the prison, and subsequently moved to Bristol, where he re-established himself as a metal refiner. Later records indicate that the Pass family lived in a back-to-back terrace known as Marsh Buildings. This street was an offshoot of Avon Street, in the expanding industrial suburb of St Philip's Marsh (Vincent 2022, 26). The land to the north of Marsh Buildings was occupied by a sulphuric acid factory known as the Bristol Vitriol Works. Immediately to the south lay the junction of the recently built Feeder Canal and Floating Harbour, and beyond that there were scattered houses and industrial premises amongst the rough grassland of St Philip's Marsh. To the north of the acid factory were lead, glass and iron works, along with several small potteries and brickyards.

Elements of the scrap metal trade have always been a murky business: metal yards are places where stolen goods could easily be transformed into untraceable ingots or hard cash, and it seems that Capper Pass I was not averse to involvement in criminal activity. Unfortunately for him, he was caught in possession of 12 cwt (609 kg) of stolen copper valued at £3 15s. He was convicted on the 12 January 1819 and sentenced to 14 years transportation to an Australian penal colony (*BM*, 18 January 1819; Vincent 2022, 16), leaving his wife and three teenage children to fend for themselves.

Pass was initially held in the prison hulk *Justitia* in Sheerness, Kent. He was then put onboard the *Canada* for transportation to Sydney. On landing, he was assigned to work for a baker and brewer, and later for a freed-convict publican named Frances Johnson, of Cockle Bay. In 1825, Pass was given a 'ticket of leave', which afforded him some freedom and allowed him to start working as a tallow chandler in George Street, Sydney. Three years later he married his former employer Frances Johnson, who ran the York Hotel. Pass was officially freed in 1833, and in 1837 he became a licensed publican of the Royal Oak. Capper Pass was not the only member of the family to have ended up in Australia. In 1837, his son Thomas was transported for life for highway robbery. Frances Pass died in December 1837 and the following year, Capper Pass married his fourth wife, a widowed English free settler named Anne Rose. Capper Pass was an alcoholic, possibly in part due to his hard and traumatic life. This eventually took its toll, and on the 10 March 1839, The *Sydney Morning Herald* recorded that his death, aged 64, was 'accelerated by the excessive use of ardent spirits' (Vincent 2022, 16–17).

Capper Pass II (1806–1870)


Figure 10.1 Capper Pass II (1806–1870), photographed c. 1860s

Capper Pass II (Fig. 10.1) was born in Birmingham in 1806 and moved to Bristol when he was nine. Following his father's unexpected departure in 1819, 12-year-old Pass became the nominal head of the family firm. The following year, he was jointly listed with William Perkins (probably a relative of his mother Anne Pass) as occupant of a property in 'The Marsh'. It likely that Perkins was running the business at this time, possibly in conjunction with Anne Pass. Capper Pass II is also listed as the sole occupant of another nearby property owned by S. Litson. These properties, located in one of the least desirable parts of the city, had a combined rateable value of only £5. In 1826, Pass is listed as a tenant of Mr Skidmore, possibly a later owner of the same properties (Little 1963, 6–7; Vincent 2022, 17). The Pass family's smelting workshop was probably located in a walled yard at the west end of Marsh Buildings. This location backed onto the Feeder Canal, which may have allowed coal and raw materials to be transported by barge.

Industrialisation of St Philip's Marsh continued apace throughout the 1820s. The Bristol

Figure 10.2 Hannah Pass (née Coole) (1810–1873), photographed c. 1860s

Gas Light Co. built a large gasworks on the east side of Avon Street in 1821 (Wessex Archaeology 2023, 4). This was followed by the opening of Harding and Cox's Marsh Soap Works and W. D. and W. E. Acraman's Bristol Iron Works in 1828 (*BMi*, 5 April 1828, 3; 23 August 1828, 2). The Pass family lived at Marsh Buildings throughout the 1830s, and C. Pass is listed as a 'metal refiner and dealer, near the gas works, Avon Street, St Philips' in *Mathew's Directory* of 1836 and 1838.

Anne Pass died in 1835, and the following year Capper Pass II married a local woman named Hannah Coole (Fig. 10.2). Their first child, Alfred Capper Pass, was born on 20 July 1837, exactly one month into the reign of Queen Victoria.

The Reform Act 1832, which was passed partially in response to widespread civil disturbances such as the 1831 Bristol Riot, extended the right to vote to all men living in properties worth at least £10. Capper Pass II is not listed as a voter in the 1832 General Election, which suggests he was ineligible at this date. He is, however, listed as a voter in the 1837 General Election, where he opted for the winning Radical and Conservative candidates Henry Berkeley and Philip Miles Esq. (Bristol Poll Book 1837, 111).

In 1839, Capper Pass II was listed as the occupant of a 'dwelling house and manufactory' in Marsh Buildings, rated at £16 (Little 1963, 7). This was a year of great change in St Philip's Marsh. The Great Western Railway and its Temple Meads terminus were nearing completion, but of more importance to the Pass family was demolition of the Bristol Vitriol Works and Marsh Buildings to make way for a new alkali works (*BTM*, 28 September 1839, 3). The latter forced the Passes to look for a new home and workshop.

Business at Marsh Buildings had been good enough for Pass to save a little, and in 1840 he brought a vacant plot on the edge of Bedminster (Little 1963, 8). The land was bounded by Coronation Street to the west, the backs of houses fronting Paul Street to the south, and a trackway alongside the River Malago to the east. Pass built a workshop on the land and a detached house, which was completed in August 1841. Prior to its completion, the family rented a house on Richmond Terrace. This street was located on the lower slopes of Windmill Hill and was said to be 'the cleanest rank of houses in Bedminster' (census 1841; Little 1963, 9). The Poll Book for the 1841 General Election lists Pass as a chemist. He voted in this and all subsequent elections for the incumbent Radical Henry Berkeley, who served as MP for Bristol until 1870 (Kent 1885, 345–6; Little 1963, 9; Poll Book 1841, 28).

Pass's second child Lydia was born soon after moving into their new house, followed by their daughters Matilda (b. 1845) and Elizabeth (b. 1851). The smelting works was a success, and by 1845 Pass had saved enough to send his eight-year-old son Alfred to a private boarding school in Norton St Philip, Somerset (Little 1963, 10; Vincent 2022, 18). He also diversified his business interests by becoming a partner in the Great Western Coal Co., which operated a colliery in St Philip's Marsh between 1847 and 1860 (BHER 2132M; *BM*, 3 March 1860, 5).

By 1861, the Pass family had become wealthy enough to afford a resident female house servant, though they still lived next to their expanding smelting works (census 1861). Wealth brought a degree of respectability, and in 1864–6 Pass served as one of the two overseers responsible for collecting rates in Bedminster (*BM*, 2 April 1864,7; 31 March 1866, 6). By the 1860s, Alfred Capper Pass, who was more educated than his father, had become deeply involved in the running of the family business, particularly the more technical and scientific aspects of their work. It was soon afterwards that the company found a product, lead–tin alloy, commonly used as solder, that became the company's mainstay and a source of great wealth in the latter part of the century.

Increasing wealth allowed the Pass family to leave their old home in Bedminster for more salubrious accommodation in the expanding suburb of Redland. In 1866, the

Passes moved to Arundel Villa, a two-storey semi-detached property on Aberdeen Terrace (now Road). They stayed there until 1869, then moved to a three-storey townhouse at 9 Burlington Buildings (*BTM*, 30 March 1867, 7; 4 April 1867, 4; Little 1963, 10; *Mathews' Directory* 1866–70; Vincent 2022, 18).

By the late 1860s, Capper Pass II was becoming increasingly ill, but he remained actively involved in the business, and in 1869 he appeared as a witness in a court case. This involved a local metal dealer named Stephen Machin, who had attempted to sell Pass £8 of hard spelter (zinc–lead alloy). The works' foreman became suspicious when he noticed that the metal was marked with the letter L that someone had attempted to erase. This identified it as a product of John Lysaght's Galvanised Iron Works in St Philip's Marsh. Mindful of his father's fate, Pass quickly reported his suspicions to Lysaght, who confirmed that a large quantity of metal had recently been stolen from his warehouse. Machin was hauled before the court, where he claimed to have purchased the metal from a hawker named Jones. It is unclear if he was believed, but he seems to have escaped further punishment and was simply instructed to assist the police in finding the man (*BM*, 23 January 1869, 7).

Capper Pass II died at home on the 14 September 1870, aged 63, and was buried at Arnos Vale Cemetery, where his grave was marked with a large pink and grey marble obelisk. In 1900, Alfred Pass arranged for his mother and father's remains to be exhumed and reburied in the churchyard of Wooton Fitzpaine, Dorset (*BTM*, 16 September 1870; Vincent 2022, 18).

Alfred Capper Pass (1837–1905)

In many ways, Alfred Capper Pass (Fig. 10.3) was the epitome of a self-made Victorian industrialist. He was born one month into Queen Victoria's reign in a poor area of Bristol and spent his childhood living in the shadow of his father's smelting works. He subsequently became a very successful and educated businessman, who used his wealth to fund educational, arts, health and religious institutions.

Alfred Pass was born in Marsh Buildings, St Philip's Marsh, on 20 July 1837. By the time he was four, the family had moved into a newly built house next to their smelting works in Bedminster. Although the family business was only marginally profitable at this time, it was enough to support a gradual expansion of the works and to pay for Alfred's education at a small boarding school in rural Norton St Philip, Somerset. He was subsequently given chemistry lessons in Bristol (Little, 1963, 10; Vincent 2022, 18).

By 1861, Alfred was working as an assistant to his father. He gradually assumed more responsibilities, and in 1866 the business was renamed Capper Pass & Son. Although day-to-day work at the smelting works would have occupied much of his time, Alfred maintained a lifelong interest in science, particularly metallurgy, chemistry, archaeology and natural history. He read Charles Darwin's (1859) *On the Origin of Species* and, despite his strong Christian beliefs, became convinced that Darwin's

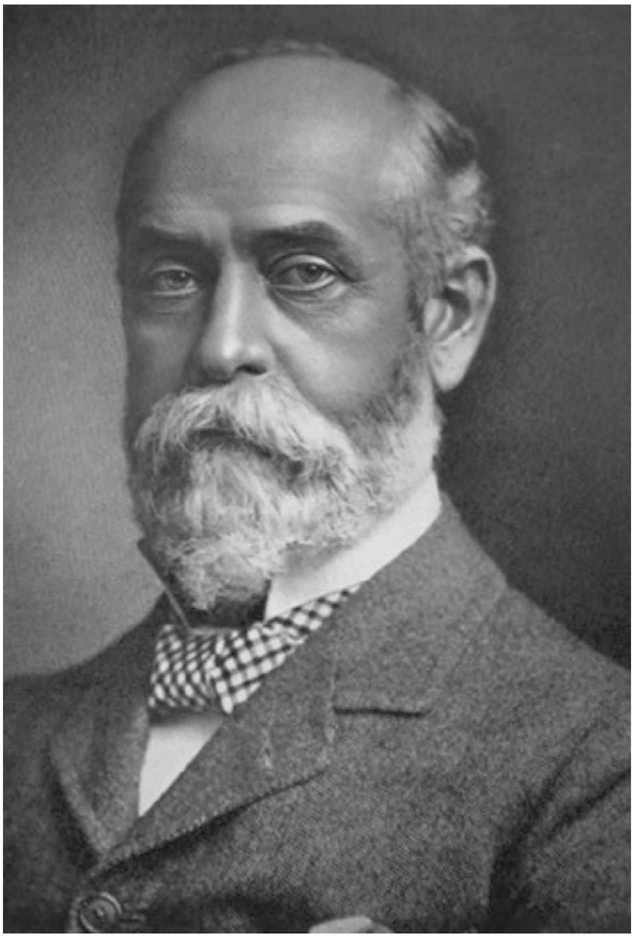


Figure 10.3 Alfred Capper Pass (1837–1905), photographed c. 1890s

theories were correct. In 1865, aged 25, he became engaged to 18-year-old Elizabeth (Lilla) Fraser. She was the third daughter of a wealthy Ipswich clothing manufacturer named William Fraser Esq. Pass's 'Darwinian views' were a source of conflict with his fiancée's father, but the two were eventually allowed to marry (*Ipswich Journal*, 13 January 1872, 8; Vincent 2022, 19)

The death of his father in 1870 left 32-year-old Alfred as head of the company. The Pass family left Bristol for a short while, and in 1871 they are recorded as residents of a lodging house at 2 Royal Terrace, Weston-super-Mare, Somerset (census 1871). Alfred and Lilla were married in Ipswich on 10 January 1872, and by 1873 they had moved to Thornbury House, Napier Road, in the Redland district of Bristol (Ipswich Journal, 13 January 1872, 8; *Mathews' Directory* 1873; Vincent 2022, 19). Alfred's mother Hannah lived on the opposite side of the street at Napier House, where she died later in 1873 (census 1871; *Mathews' Directory* 1873; WDP, 29 January 1873, 4). Alfred is listed as resident of Thornbury House until 1878, though in 1877–8 they are also listed as residents of Thornbury House, 16 Redland Park Villas, perhaps indicating that the house name was transferred to a new property (*Mathews' Directory* 1874–8).

Pass's attitude to his workers is probably best described as paternalistic. It is said that the only qualification needed for employment at the works was to 'fear God and lift a hundredweight [50.8 kg]'. He distributed free copies of *The British Workman* to his employees: this was a lavishly illustrated broadsheet newspaper that advocated temperance amongst the working class (BLT19 2023). At Christmas, Pass's male employees were each given a hard-wearing shirt, while Mrs Pass and Mrs Trapnell gave out gifts to their wives and children. Elderly local women were also given woollen garments, and the Bedminster Salvation Army provided a musical performance outside the Pass's house, for which they were given a hearty lunch and a large donation (Little 1963, 17, 20; Vincent 2022, 28).

During the 1870s, Pass obtained most of his lead ore from disused lead mines on the Mendips. This led to the discovery of Roman artefacts, mine workings and associated settlement, which spurred a lifelong interest in archaeology. He pursued this through his membership of the Bristol and Gloucestershire Archaeological Society, which he joined when it was founded in 1876 (Vincent 2022, 19). In 1886, Pass commissioned a survey and directed the first truly scientific excavations at Silbury Hill, Wiltshire, which he subsequently published (Moorhead 2013, 3–4; Pass 1887). He was also a keen member of the Bristol Naturalists' Society (founded in 1864).

Bristol's University College (which became the University of Bristol in 1909) was founded in 1876, and Pass was a significant benefactor and later a member of the University College Club and the College Council. In 1886–7, he also studied as a day student at the college (*BTM*, 7 October 1905, 18; Little 1963, 19–2).

Although the smelting works was his main business, Pass was also a director of the Bristol Gas Co., and invested in land, including a large parcel on Windmill Hill, which was subsequently used for housebuilding. The new roads – Algiers Street, Gwilliam Street, Vivian Street and Fraser Street – were all built between 1878 and 1895 (BA 40287/3/69; *BTM*, 7 October 1905, 18; Little 1963, 19; Vincent 2022, 19).

Between 1880 and 1890, the Passes lived at Rushmore House, 15 Upper Belgrave Road, Durdham Down. They are listed here on the 1881 census, along with Alfred's sister Elizabeth and their three resident servants: a cook, housemaid and parlour maid. Their only child, Alfred Douglas Pass, was born here on the 14 May 1885. Alfred Pass's brother-in-law and business partner Alfred Trapnell lived next door (Anon. 1884b, 185; 1890, 216; census 1881; Little 1963, 19; *Mathews' Directory* 1874–80).

Despite his move to a wealthy part of the city, Pass remained deeply involved in the affairs of Bedminster. In 1886, there was an explosion at the Dean Lane Colliery which killed ten young men. Pass donated money and helped run a support fund for the victims' families (*Bristol Magpie* 1886, 5; WDP, 23 September 1886, 4). The same year, he also donated land on Windmill Hill for the construction of St Michael and All Angels Church. Following the consecration of the nave in 1901, Pass donated pews in memory of his parents. He also helped fund the building of a large extension to Bristol General Hospital in Redcliffe in 1891 (Little 1963, 19; *WDP*, 30 January 1891, 4; Vincent 2022, 20).

The Passes are not listed as Bristol residents in *Mathews' Directory* of 1891. Instead, they appear as lodgers at Cambridge House, Belgrave Crescent in Torquay, Devon (census 1891). By 1893, they were back in Bristol, this time at a large suburban country house known as The Holmes, in Stoke Bishop. In 1894, Pass became a Justice of the Peace in Bristol and later in Dorset. A year later, he purchased the 1776-acre Wootton Fitzpaine estate near Charmouth, and moved into the Manor House soon after, though he still visited Bristol regularly and is recorded as a resident of The Holmes until 1898. The family's Bristol residence subsequently changed to Hawthornden, Clifton Road, where they are recorded as residents in 1898–1901 (census 1901; Little 1963, 19; *Mathews' Directory* 1891–8; Vincent 2022, 20). The 1901 census describes Alfred Pass as the 'retired owner of a smelting works'. At this date, there were seven domestic servants at Hawthornden: three housemaids, a footman, a parlourmaid, a kitchen maid and a cook. There were even more household staff at the Manor House in Wotton Fitzpaine (BM, 15 October 1898, 4; census 1901; *Mathews' Directory* 1900–5; *Western Chronicle*, 6 February 1903; *WDP*, 7 October 1902). Although Pass was officially retired, he did maintain some active business interests, and in 1903 he became a director of the Dorset Public House Trust Co. Ltd (*Western Chronicle*, 6 February 1903, 5).

By 1905, Pass had become unwell, and perhaps knowing that the end was near, he donated his collection of Roman artefacts to Bristol Museum. He also donated artworks from his collection ahead of the opening of Bristol Art Gallery in February 1905 (*BTM*, 7 October 1905, 18; *WDP*, 2 October 1905, 9). Alfred Capper Pass died at home in Wooton Fitzpaine, aged 68, on 4 October 1905 (*WDP*, 6 October 1905, 10). Amongst his many bequests, there were large donations to Bristol University College, Bristol Art Gallery, Bristol Museum, Bristol Library and Bristol General Hospital (Clifton Society, 2 November 1905, 8; *HBRMDFP*, 28 October 1905, 3).

Figure 10.4 Alfred Douglas Pass (1885–1970), photographed in 1912

Figure 10.5 Katharine Olive Pass (1889–1973), photographed in 1912

Alfred Douglas Pass (1885–1970)

Alfred Douglas Pass, who was always known by his middle name, had a very different upbringing to that of his father and grandfather. He was born in Rushmore House, 15 Upper Belgrave Road, Durdham Down, on 14 May 1885, where the family lived until he was five. His father was a successful and wealthy businessman, who provided his family with all the trappings of an upper-middle-class Victorian household. They then moved to an even larger property in Stoke Bishop, though from 1895 onwards the family spent increasing amounts of time at their new country house in Wootton Fitzpaine, Dorset, or touring Europe visiting art galleries and the like (Little 1963, 19; *Mathews' Directory* 1891–5; Vincent 2022, 20, 22).

In 1898, Douglas Pass, aged 13, was sent to Harrow School and is recorded as a boarder of Moretons House on the 1901 census. He subsequently went to Cambridge University, where he studied chemistry and metallurgy, and gained a first in natural sciences in 1907. Douglas disliked his father, and apart from a shared interest in archaeology – he became a member of the Dorset Natural History and Archaeological Society in 1914 (Symonds 1915, 20) – the men had little in common. His father's death in 1905 left Douglas as the majority shareholder of Capper Pass & Son Ltd and when he came of age in 1906, he became Lord of the Manor of Wootton Fitzpaine. Douglas Pass was a keen horse rider, cyclist and captain of the University Shooting VIII, where he became friends with the chemist Paul Gottlieb Julius Gueterbock, whom he subsequently employed at the smelting works (Freshford.com 2023; Vincent 2022, 22; Anon 1955, 35–6).

Bristol University College became a chartered university in 1909, and despite the difficult relationship with his father, Douglas Pass gave a large donation for the endowment of a chair of chemistry, known as the Alfred Capper Pass Professorship (Little 1963, 20; Penny 2005, 69). The 1911 census lists Douglas Pass and his mother Elizabeth as residents of the Manor House, along with three visitors and nine servants: a butler, footman, cook, ladies' maid, two kitchen maids and three housemaids. By this time, Pass owned a flashy de Dion-Bouton car, which he used to take Olive Heycock, his former university tutor's daughter, to the races. The two subsequently became engaged and were married on 12 January 1912. Their first daughter, Katherine, was born later that year. They subsequently had four more daughters: Diana (b. 1914), Sylvia (b. 1919), Philippa (b. 1920) and Honor Matilda (b. 1926) (Vincent 2022, 22–4).

During World War I, Pass served as a captain in the Dorset Yeomanry. This regiment was dispatched to Egypt, then Gallipoli, where he was captured by Turkish troops of the Ottoman Empire. He was subsequently imprisoned, along with 100 other officers, in Afyonkarahisar, in central Anatolia (modern Turkey). The prisoners of war were housed in an Armenian church that had been left empty following the deportation of its congregation during the Armenian Genocide. Captain Pass was imprisoned until the end of the war, but he was well treated and even acquired a pet magpie, owl and wolf (Hill 2023; Virtual Genocide Memorial 2023; Vincent 2022, 23).

After the war, Douglas Pass continued his father's support of the University of Bristol. He also became an important figure in Dorset's local government, becoming High Sheriff in 1922. From 1920 onwards, he was also heavily involved in Lieutenant-General Baden-Powell's Scout Movement, and eventually became its County President (Vincent 2022, 23–4). Although most of Pass's interests were focused on Dorset and maintaining the family company, he had not entirely forgotten their Bedminster roots, and when St Michael and All Angels Church was destroyed by fire in 1926, he paid for it to be rebuilt (Little 1963, 19; Vincent 2022, 20).

The 1939 Register lists Douglas Pass as a 'landowner and chairman of Capper Pass Smelting'. As well as the Pass family, Manor House was home to a governess and at least 10 servants. Pass was too old to be conscripted during World War II, but he did serve as the County Army Welfare Officer, with the ranks of Lieutenant Colonel and Deputy Lieutenant of Dorset. Between 1946 and 1955, he also served as chairman of Dorset County Council and, like his father, he became a Justice of the Peace. Douglas Pass retired in 1960 and died at home on the 9 March 1970 (Vincent 2022, 24).

Capper Pass & Son: Family Business to International Corporation

The Pass family's financial and social rise outlined above is in many ways the epitome of a Victorian rags-to riches story. The founder of the company, the eponymous Capper Pass, lived a precarious life. His business ventures had mixed results, and he was willing to dabble in criminality. Despite these inauspicious beginnings, Capper Pass's son and namesake was able to make a modest success of the business.

In 1839, Capper Pass II's family home and workshop in St Philip's Marsh was demolished to make way for an alkali works. Fortunately for the family, they were able to buy a vacant riverside plot on the edge of Bedminster and build a workshop and house on the site. This brought a degree of social respectability and by the early 1860s, he was able to employ a house servant. In 1866, he and his son Alfred found a product, solder, which produced high and reliable profits that grew continually until the outbreak of World War I. The growth of the company is reflected by the number of employees at the works, which grew from six in 1852 to 189 in 1914 (Fig. 9.1). The smelting workers were all male, but a few women were also employed in secretarial roles and later as laboratory workers.

During the 19th century, most of the raw materials processed at the Bedminster Smelting Works were sourced from Great Britain, but in the 1860s, Capper Pass II began to import materials from Belgium, France, Ireland and the Netherlands. His son, Alfred Pass, continued this practice, and in the mid-1890s he found a new source: tin concentrates from Bolivia.

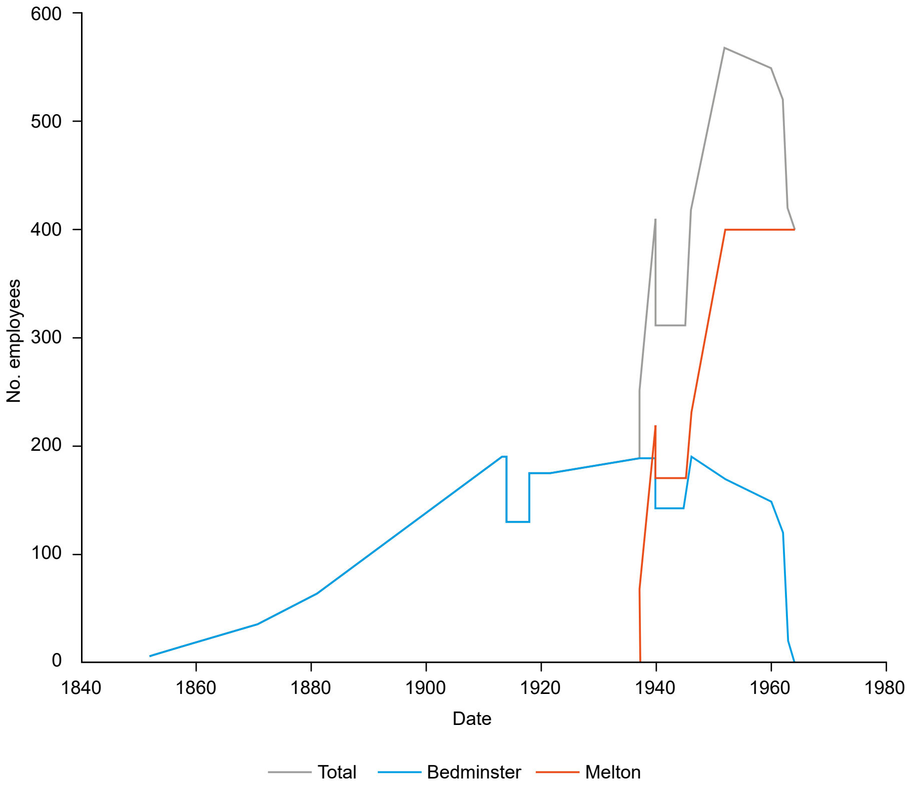


Figure 10.6 Number of employees at Capper Pass & Son, 1852–1963

Capper Pass & Son became a limited company in 1895, though to all intents and purposes it still operated as a family-owned business. Following the death of Alfred Pass in 1905, the company was run by a board of directors, though the principal shareholder, Douglas Pass, maintained a keen interest in the development of the company until his retirement in 1960.

Production at the Bedminster Smelting Works peaked in the years prior to the outbreak of World War I. Thereafter, the company faced increasing competition in the solder market, and although new technologies such as the electrorefining of Bolivian tin ore helped the company to expand into new markets, the physical location of the works was a major constraint on its expansion. The opening of a new plant in Melton, Yorkshire, in 1937 provided a much-needed opportunity for the company to expand its tin-smelting business. Bolivian tin supplies were interrupted during World War II, and again during the political upheavals leading to the Bolivian National Revolution of 1952, and for a time it seemed that Britain would lose this source of ore to American smelters. Capper Pass & Son Ltd were, however, able to use their Bolivian contacts to form long-term agreements with the state-owned *Corporación Minera de Bolivia*.

After World War II, the Bedminster Smelting Works remained focused on solder production. New staff were taken on at Melton, but there was no substantive effort to reduce the size of the Bedminster workforce. This, and the fact that the company was still making significant investments in plant and buildings at Bedminster in the late 1950s, suggests that the decision to close the works was taken after Douglas Pass's retirement in 1960. The Bedminster works closed in 1963, and four years later the company was acquired by the multi-national metals and mining corporation Rio Tinto Zinc (RTZ). The number of employees at Melton eventually reached 1090 in 1980, by which time the plant was producing 14,000 tons of tin a year, which represented 8% of world production (Litten and Strachan 1995, 28–34; R. Smith, pers. comm. 2024). The Melton works also produced silver, cadmium, lead, copper, antimony, bismuth, indium and gold (Newman 1992, 569). The collapse of world tin prices in 1985 made the Melton works unviable, and in 1991 it was permanently closed (Litten and Strachan 1995, 28–34). The Melton site was sold and decommissioned in 1995 (Vincent 2022, 33).

Why Solder?

Solder is a metallic alloy used for joining pieces of metal together: essentially a 'glue' for metal. It comes in two broad types: hard or soft, according to their melting temperature. Hard solders can be subdivided into two types: spelter, which is primarily an alloy of copper and zinc; and silver solder, made from copper and silver. The primary uses of hard solders are outlined in Table 9.1.

No.	*Name*	*Metals composing solder and their proportions*			*Uses*
		Copper	*Zinc*	*Silver*	
1	Spelter, hardest	*2*	*1*	*0*	For ironwork, gunmetal, etc.
2	Spelter, hard	*3*	*2*	*0*	For copper and iron
3	Spelter, soft	*1*	*1*	*0*	For ordinary brasswork
4	Spelter, finer	*8*	*8*	*1*	For finer kinds of brasswork
5	Silver solder, hardest	*1*	*0*	*4*	Hardest, but makes very neat joints
6	Silver solder, hard	*1*	*0*	*1*	Makes a sound joint and will not burn
7	Silver solder, soft	*1*	*0*	*2*	For general use

Table 10.1 Hard solders (after The American Engineer 1887, 65)

Capper Pass & Son produced soft solder alloys of lead and tin. These can be subdivided into three types: plumber's solder, tinman's solder, and pewterer's solder, the uses of which are outlined in Table 9.2.

No.	*Name*	*Metals composing solder and their proportions*			*Melting point (°C)*	*Uses*
		Lead	*Tin*	*Bismuth*		
1	Plumber's solder	*2*	*1*	*0*	*227°*	For joining lead pipe
2	Coarse solder	*3*	*1*	*0*	*230°*	-
3	Fine solder	*1*	*2*	*0*	*171°*	Blowpipe or gas-fitters' solder; sometimes used by tinmen
4	Fine solder	*2*	*3*	*0*	*168°*	First-class tinman's solder; also used for soldering zinc and metal wheels, floats, etc. of wet gas meters
5	Very fine solder	*1*	*3*	*0*	*180°*	-
6	Very fusible solder	*1*	*1*	*0*	*160°*	Ordinary tinman's solder
7	Very fusible solder	*1*	*1*	*1*	*95°*	Pewterer's solder

Table 10.2 Soft solders (after The American Engineer 1887, 65)

Plumbing

In western Europe, plumbing with lead water pipes was first used in the Roman period, but this knowledge was lost in subsequent centuries. During the medieval period, lead plumbing was re-introduced by monastic orders, and it was also occasionally used in towns and the homes of the wealthy. Lead pipes were more common in the post-medieval period, but most urban residents obtained their water from shared wells. This changed following the passing of the Public Health Act 1848, which established a Central Board of Health and made corporate boroughs responsible for water supply, street paving, refuse collection and improvements to drains and sewers. The reforms took many years to fully implement, but by the turn of the 20th century, most urban homes had access to piped water. Increased access to piped water created a huge demand for plumbers, lead pipes and the solder needed to join them.

Tinplate

Tinmen, also known as 'tinsmiths' and 'whitesmiths', made or repaired objects made from tinplate. These goods, made from thin sheets of iron (later steel) coated with tin to impede rusting, were produced in Bavaria from the 14th century, and were imported into England from at least 1483. There was some limited domestic production in England from c. 1670, though the industry only became firmly established c. 1730 (The Worshipful Company of Tin Plate Workers Alias Wire Workers of the City of London 2023). By the late 18th century, English tinsmiths were producing a bewildering variety of objects, as shown by a 1761 sales brochure that lists the following goods:

> *turning apple-roasters, basters, biscake frames and pans, boilers, round boxes, boxes for candles, flour, pepper, sugar and snuff, candle-safes, candlesticks, canisters, cheese-toasters, coffee-pots, covers, cullenders, funnels, globes, graters, pot kettles, kettles for fish, lanthorns, lamps, single and double ovens with grates, pans and hooks, plates for fish, porringers, rims for cakes, scales for flour and soap, scoops for coals, shovels for dust, skimmers for cream, speaking trumpets, spitting basons, spring funnels and water candlesticks (*Millington 2021, 23*).*

These objects all required soldering. During the 19th century tinplate became widely used for making boxes and toys, but it was another invention, the humble tin can, that became the mainstay of the industry from the end of the 19th century onwards. The idea of preserving food in tin cans was conceived by the French inventor Philippe de Girard, who had the English merchant Robert Durand patent the idea in 1811 (Owusu-Apenten and Vieira 2023, 8). Durand sold the patent to Bryan Donkin and John Hall, who refined the process and opened the world's first commercial canning factory in Bermondsey, London, in 1813. Their factory supplied preserved meat, soup and vegetables to the British Army and Royal Navy (Collins 2000, 1093; Drummond and Lewis 1939, 10–20). Preserving food by canning entails the killing of microbes, either by heating, or submerging in strong saline, acid, alkali or sugary solutions. The can is then closed with an airtight soldered seal to prevent leakage and, more importantly, the ingress of air and microbes.

Prior to 1850, a skilled tinsmith could produce somewhere between 50 and 100 cans a day, which was slower than traditional bottling (Anon. 1957, 18; Hunt 1902, 6; Jeffries *et al*. 2016, 48; Skrabec 2009, 74). This made canned foods prohibitively expensive, which reduced their appeal to domestic customers. The invention of the 'pendulum' press by Henry Evans of New Jersey in 1849 accelerated the canning process by a factor of ten: this reduced the cost of cans and opened the way to mass production and consumption of canned food (Volo and Volo 2007, 243). By the later 19th century, there were machines that could produce up to 120 cans *an hour* (Skrabec 2009, 74). By the 1890s, canned foods were being widely marketed to domestic consumers, though a series of food poisoning scandals created a lingering mistrust of canned food that persisted until after World War I (Jeffries *et al*. 2016, 48–9; Anon. 1993, 19). The armed forces also continued to be important consumers of canned foods, along with the shipping industry and colonial outposts. Easily transportable and storable canned foods made an important contribution to the development of European empires, and stimulated international trade by allowing otherwise perishable goods, such as meat, to be shipped across the world.

Pewter

Soft solder was also used in the manufacture of pewter objects. Like plumbing, pewter was first used during the Roman period and was re-introduced for use in jewellery and badges in the 11th century. By the 15th century, pewter had become one of England's most important industries (Hull 1999, 5–6). It was predominantly used for domestic vessels, plates and utensils, and became ubiquitous in the 16th and 17th centuries, though its use declined following the development of cheap mass-produced glass and ceramics in the 18th century (Bell 1911, 338). Cold rolling of pewter sheet, which was developed in Sheffield *c.* 1775, allowed the production of press-moulded parts that could be fabricated with solder in the same way as Sheffield plate (a bi-metal of silver and copper). This was a far more economic process than casting, which also allowed the production of complex chased forms, which were used extensively on teapots and flagons. Pewter manufactured in this way is usually referred to as 'Britannia metal'. From the mid-19th century onwards, Britannia metal was frequently electroplated with silver, though production began to decline towards the end of the century because of competition from more durable electroplated nickel silver (Hull 1999, 14–17).

Summary

Capper Pass & Son's successful production of soft solder in 1866 coincided with a boom in the use of solder for fitting indoor plumbing. At the same time, tinplate wares, particularly disposable cans, were becoming cheap and ubiquitous, providing another a large and growing market for solder. Later technological developments, particularly the circuitry of electrical equipment, provided new uses for solder, which ensured a ready market for this alloy in the 20th century.

The Second Industrial Revolution and the Technology of the Bedminster Smelting Works

The period 1870–1914 is sometimes referred to as the Second Industrial Revolution (Mokyr 2003). While the First Industrial Revolution of *c.* 1760–1840 was characterised by the development of the factory system, the use of steam power and the development of processes of mass production, the Second Industrial Revolution entailed more widespread use of steam power (railways, steamships and industrial machinery), the development of telegraphy, petroleum engines and automobiles, the beginning of electrification, and a more rigorous application of standardisation and scientific knowledge to all aspects of production. The period 1870–1914 also coincided with a phase of rapid expansion and prosperity at the Bedminster Smelting Works, and one of the key questions of the archaeological work was to determine the impact of the Second Industrial Revolution on the development of the works. The answer to this question can be found in an examination of the built remains and the processes of production at the works.

Furnaces

There were six types of excavated furnaces at the Bedminster Smelting Works, though one type (S46, S47 and S49: small, oil-fired solder melting kettles) was a very late addition dating from 1959. The remainer comprised a probable coal-fired reverberatory furnace (S20), eight coal-fired solder or lead melting pots (S28–S30, S34 and S35), three oil-fired lead detinning and softening pans (S39 and S40), and a probable blast furnace (S24), all of which were probably built *c.* 1870–1914. In addition to these, there was a small early 1850s structure (S3) that may have been the base of a pair of crucible furnaces. An additional bank of three coal-fired solder pots (S50) appear to be a direct replacement for some earlier solder pots that were demolished during a reordering of the works in 1959.

The superstructure of probable reverberatory furnace S20 was heavily truncated, and there is little to say beyond its basic identification and the fact that it was associated with a sequence of subterranean brick flues. The upper parts of the furnace would have been built of brick bound with iron stay bars to hold it together during heating and cooling. This type of furnace was developed in the 18th century and was widely used to roast and smelt non-ferrous ores. The excavated furnace, which was probably in use *c.* 1875–1910, is likely to have been a standard structure of its type. Analysis of the flue dusts suggest that it was used to roast lead, tin and copper ores or secondaries. Its final use may have been for copper ore roasting as a preliminary step in the production of copper sulphate for use as Bordeaux Mixture (fungicide).

The coal-fired solder pots, all but three of which probably date from *c.* 1890–1914, were built to a standard design that comprised a circular furnace with an associated stoking cellar to the side. The furnaces heated large hemispherical cast-iron 'pots' (similar to lead industry 'kettles') that were used to melt and combine the base metals for solder production. The lip of the solder pots would have been about waist height. This allowed the workers to stir and monitor the pot while the molten metals were mixing. This technology, which was adapted from long-established processes used by the lead industry, was very simple and remained largely unchanged throughout the lifetime of the plant (virtually identical solder pots were constructed as late as 1959). Oral history recordings show that the process of mixing the solder charges was a highly skilled task undertaken by experienced furnacemen. There was, however, little in the way of precise measurement or temperature control, and the main tools were ladles (see Chapter 9, 'Tools of the Trade') that were used to stir and scoop out liquid solder, heated to 500°C, into water-cooled moulds (BMAG OH69.1).

The first blast furnace at the Bedminster Smelting Works was installed after 1852 and possibly as late as the mid-1860s. No remains of this structure were identified, though a possible blast furnace base dating from *c.* 1870–83 was identified. Most of its superstructure would have been above ground and there is little that can be said regarding its form, apart from the observation that it was rectangular. The presence of an embedded lead pipe suggests that it was a water-jacketed furnace, though water would also have been used to quench the copious quantities of slag produced from smelting raw materials with a low metal content.

The main instrumentation on a blast furnace was a thermocouple in the furnace hood before the offtake flue and a manometer to measure pressure in the air main to the furnace (R. Smith, pers. comm. 2024). Simple manometers have existed since the 17th century, whereas the thermocouple is a much later device. The thermoelectric effect used in these instruments was discovered in the early 1820s by the German and Danish physicists Thomas Johann Seebeck and Hans Christian Ørsted, but the production and testing of thermocouples for use on blast furnaces did not occur until the early 1890s (Maw and Dredge 1892, 390; Ørsted 1823). As smelting in a blast furnace progressed, the top temperature would rise sharply as the off gases burned through. This indicated that it was time to add more charge. As smelting continued, molten slag and metal would accumulate in the forehearth and furnace and would eventually restrict air flow at the tuyeres. This would cause a rise in air pressure in the blast main which indicated the furnace was ready for tapping. A counterweighted flap in the blast main known as the 'Dolly' was designed to lift and release excessive pressure. Hearth and shaft accretions would also cause an increase in pressure, so this was a useful indicator in assessing the 'health' of the furnace. The blast main was fitted with discs which would rupture in the event of an explosion caused by stoppage of the blower and subsequent leakage of carbon monoxide back into the air main. Temperature and pressure were later recorded continuously, and this was a useful check for supervisors on the diligence of the furnace crew (R. Smith, pers. comm. 2024). The 19th-century blast furnaces used by Capper Pass & Son are likely to have been similar to those used by other contemporary non-ferrous smelters, and the company does not appear to have developed any significant new furnace designs in this period.

The final type of excavated furnace were the 20th-century rectangular oil-fired detinning and softening pans used to purify lead. These comprised brick-built subterranean pits with mounts for suspended steel-framed furnaces at the ends. Suspending the furnaces in this manner provided protection against moisture explosions and allowed inspection for leaks. The furnace would have been supported on steel joists running across the pit and would have had a steel base, lined with refractory bricks. The detinning pan (S39; Fig. 6.4; Pan 0) required good access from each side so that long-shafted rakes could be used to withdraw the 'yellow scum'. Softening pans were sited as a closely separated pair (S40; Fig. 6.4; Pans 1 and 2). One pan operated at 750°C and produced 'heavy scum' with about 45% Sb, which was molten and was tapped off on to the floor, but the antimony was incompletely removed. This metal was either ladled or pumped into the adjacent pan (hence their close separation) which operated at 800°C. After some time, the lead in the second pan became soft and could be cast into ingots (or anodes at Melton). This could be detected by casting a small strip of metal which would be bright silver in colour if hard, and dark blue/black with interference colours of gold and yellow ('colours of the rainbow' was the official term) if soft. This pan produced molten litharge containing a little antimony, which was tapped back into the first pan and, because it was an oxide, accelerated the softening process. The uses of Pan 3 and Pan 6 shown in Goad 1961 (Fig. 6.4) are not known. Pan 3 is part of a sequence, whereas Pan 6 suggests an unrelated process; it was also quite separate spatially. One of these pans would have been used to smelt 'heavy scum' to antimonial lead (R. Smith, pers. comm. 2024).

Smelting Processes

The earliest significant innovation at the Bedminster works was the P Tinalloy Process of 1866. This was a liquation process where solder of indeterminate composition (generally around Sn 45%, Sb 2%, Cu <0.3%, Pb balance) was slowly cooled to 180°C. Liquid metal was skimmed from the centre of the pot and pigs of solder on the edge were allowed to melt. The liquid had the ternary eutectic composition of Sn 54.5%, Sb 3.5%, Pb 42% that could be guaranteed. This was used as a master alloy for the making of solders and whitemetal alloys and gave the company a significant commercial advantage over its competitors (Wright 1966, 180; R. Smith, pers. comm. 2024).

Transport

The site of the Bedminster Smelting Works was probably chosen because it was cheap. There were no nearby railheads, docks or canals, which meant that the heavy materials (coal, ore, metal residues and slag) were laboriously transported from Bristol Dock and Temple Meads Goods Station by horse and cart. Some materials, such as the Mendip lead mining residues, are likely to have been hauled directly from source, also by horse and cart. What is more surprising is that the company does not appear to have made significant use of automotive transport in the early 20th century. A strike by the company's carters in 1920 brought production to a grinding halt, and the company was apparently still using horse-drawn carts as late as the 1950s (BMAG OH33). The purchase of the Malago Brick & Tile Works in 1909 provided the company with a location that could conceivably have been developed as a railway siding, but there is no evidence that this was ever attempted. Perhaps it was prohibitively expensive, or the railway company was unwilling to allow its construction.

Power

Industrial steam engines had existed since the 18th century, but their use greatly expanded in the second half of the 19th century. The first use of steam power at the Bedminster Smelting Works probably coincided with the construction of a blast furnace (which required a source of blown air) in the 1850s or 60s. Steam for the engine was provided by a large Lancashire boiler. An additional pair of Lancashire boilers was added to the north of this in the 1890s, reflecting the growing needs of the works. It is conceivable that these were added purely to provide more power for the blast furnace blowers, though given the heavy nature of the materials at the works, it seems likely that belt and shaft powered hoists and ore crushing apparatus were also powered in this way. Electricity was introduced in 1908. This provided a safe means of lighting the works at night (gas being a risky option in an environment with so many sources of ignition) and provided power for an electrostatic precipitator to recover metals from fume. After 1919, it was used for the electrorefining of tin at the Shene Road site and was probably also used to power hoists and crushing and grading equipment. Despite the introduction of steam and later electric power, it appears that most operations at the works were undertaken by hand, and wheelbarrows were still being used to transport charges to the top of the blast furnace in the 1950s (BMAG OH 33.1).

Summary

The furnaces of the Bedminster Smelting Works were typical of the period, and few of the technologies and processes of the Second Industrial Revolution had an impact on working practices until after World War I. There was, however, one very crucial new methodology that did affect how the works was run: systematic scientific analysis of raw materials and finished products (see this chapter, 'The Science of Smelting: Assaying and Analysing'). From the 1860s onwards, the company began routinely analysing their raw materials and products and invested in understanding the science of metallurgy. This constant checking meant that the metals they sold had a known and reliable composition and predictable behaviour. This type of standardisation was essential for the industries they supplied and was one of the features that distinguished materials of the Second Industrial Revolution from those of the preceding era.

Post-World War I Technologies of Capper Pass & Sons

The most significant post-World War I innovation at the Bedminster Smelting Works was the electrolytic refining of high-purity tin. This was undertaken using equipment installed in the former Malago Brick & Tile Works (Shene Road) site in 1919 (Little 1963, 27). The Chempur Process, used from 1921, had a patented sulphuric acid electrolyte as opposed to the fluosilicic acid electrolyte used by other metal refiners such as the American Smelting and Refining Co. The Chempur Process was followed, in the 1930s, by the highly secret 'P Process' that enabled tin ores to be smelted with lead to give solder and a slag with a low tin content (R. Smith, pers. comm. 2024).

The other innovative device was the hot-metal centrifuge used to separate molten solder or lead from refining drosses and therefore reduce unnecessary recycling of metal within the works. This device was a closely guarded secret and may have been one of the assets gained from the acquisition of Victor G. Stevens Ltd in the 1940s (R. Smith, pers. comm. 2024).

Several more innovations were introduced at Melton. These included two generations of unique tin fuming furnaces for solder slags and low-grade ores; a rotary liquation furnace for lead slimes; an oxygen/fuel burner for smelting antimony/lead; vacuum distillation furnaces for separating Ag and Bi; and unique processes for refining silver and gold, extracting indium from tin metal and solder electrolyte liquors, and tellurium and radioactive polonium from lead. Capper Pass & Son also pioneered the use of fluidised-bed roasters for oxidising copper alloys, extracting arsenic from lead/iron alloys and for roasting low-grade copper and lead sulphide ores, but the real ingenuity was the way in which the complex flowsheet of the company was developed to suit a wide range of materials that other smelters were unable to treat economically. The other skill, which has never been recognised, was the company's financial acumen in managing large sums of money to purchase high-value raw materials to protect itself against sharp fluctuations in metal prices (R. Smith, pers. comm. 2024).

A Dangerous Occupation?

Nineteenth- and early twentieth-century smelting works were fearsome places. The heat, sound and light of the furnaces were ever present, along with the smoke and fumes that bellowed from the chimneys and furnace openings. Huge quantities of heavy, and often hot, materials were constantly being moved (mostly by hand), and the workers were subject to extreme heat and exposure to toxic substances. So how dangerous a workplace was the Bedminster Smelting Works?

Oral history recordings note that the most common injuries were burns from flames, tools, and splashes of molten metal. To reduce the risk, men protected their hands with sacking, and workers at the blast furnace apparently doused their clothes in water and wrapped their legs in asbestos cloth, potentially substituting an immediate risk for a longer term one (BMAG OH69.1; OH39.3). In the early/mid 20th century, the usual footwear for blast furnace men were ex-army boots with very loose laces, so they could be kicked off if metal got inside. Lower legs were protected by wrapping leather sheets around trousers to cover the boot tops. These were bound with string below the knee and were known as 'Basil Skins'. When asbestos gaiters with quick-release buckles were introduced at Melton, most of the furnace crews preferred Basil Skins, which had a better seal and were easier to remove quickly. Furnacemen also used old trilby hats (sourced from church jumble sales) with the front brims cut off. These, along with a Basil Skin tucked in behind and a rag or scarf around the throat, helped protect against burns from splashes of molten metal. This danger was most apparent when 'stopping off' blast furnace tap holes, which entailed pushing a clay plug into the tap hole against the flow of molten metal and slag. The tap holes were less than 3 in (76 mm) wide and obscured with smoke and fumes. The plug was held on the end of a 5 ft (1.52 m) iron rod and if a small space was left at the top of the hole, a shower of hot metal and slag would spurt into the air. The main frontal protection was a leather apron extending from the neck to below the knees (R. Smith, pers. comm. 2024).

A more insidious risk was the long-term danger posed by smoke inhalation and chemical poisoning, particularly from lead dust and fumes. Lead-bearing dust was a ubiquitous presence, particularly in the areas where ores were crushed and screened. Molten lead is relatively innocuous at low temperatures, but when it is heated above 750–900°C (depending on purity) it begins to release fumes of volatile lead compounds. These temperatures were regularly exceeded during the roasting, smelting and refining of ore, scrap metal and other secondaries. The precipitates from these fumes contain enough lead to make their recovery economical. To do so, smelting works were often fitted with elaborate flue systems, dust chambers and bag houses, where fine metal-bearing dusts were captured for reprocessing. Emptying dust from the bag house and the cleaning of flues, which was undertaken at regular intervals, was a particularly dangerous operation, with a high risk of acute lead poisoning (Lewin 1912, 154; Meeker 1914, 6–10). This was a recognised hazard of the lead industry and in 1911, regulations were introduced that made monthly examination by a physician mandatory. Those exhibiting symptoms of lead poisoning were suspended from work until they had recovered (Meeker 1914, 95).

The most dangerous refining process is likely to have been the removal of arsenic and antimony from tin, lead or solder by adding aluminium to form a dross. It can also be used to remove gold. The dross is highly reactive when in contact with water or acids, and gaseous arsine AsH_4 or stibine SbH_4 can be generated. Because it is absorbed directly into the lungs, arsine is much more toxic than arsenic trioxide and the occupational exposure limit is over one thousand times lower. It is unknown if this process was used at Bedminster and there would have been no need for it after the introduction of electrolytic processes in 1919 (R. Smith, pers. comm. 2024).

Smelting seems like an inherently dangerous occupation; however, a review of contemporary newspapers shows that serious accidents and deaths were surprisingly rare at the Bedminster Smelting Works. Examples of these include George Vowles, who died following the explosion of a lead melting furnace in 1879 (*WDP*, 23 August 1879, 5), and Robert Passmore, who was severely injured by an explosion at one of the blast furnaces in 1890 (*BM*, 31 January 1890, 5). Though obviously tragic for the men and their families, the infrequency of these accidents compares very favourably with the local coal mining industry: at the nearby Dean Lane Colliery, there was about one death a month (BMAG 2024), and accidents with multiple fatalities were all too frequent in the district's many collieries.

So was the Bedminster Smelting Works a dangerous workplace? It certainly had its fair share of accidents: unsurprising given the nature of the work and near total absence of safety measures in any 19th-century workplace. But was it more dangerous than other local industries? Probably not. It was certainly a far safer place than the local mines, and it seems likely that a job at the Bedminster Smelting Works was a desirable position, particularly for those able to master the skills needed to become a relatively well-paid metal refiner.

Living with the River

Capper Pass II probably chose to site his home and smelting yard on the floodplain of the Malago because the land was cheap. But this came at a price: the yard was prone to flooding. To mitigate the risk, Pass imported large quantities of earth and industrial refuse to raise the ground level and subsequently erected high stone walls along the riverbank. While these efforts were successful in containing the river during normal high water, the area was still prone to flooding during exceptional downpours, especially when they coincided with high tides.

In the mid-19th century, Capper Pass made extensive use of underground brick-lined flues to channel smoke and fumes away from the furnaces. This type of flue was ubiquitous on industrial sites of the period, and lead smelting works often had deliberately long 'labyrinthine' flues designed to capture metal-bearing fume for reprocessing or sale to paint or glaze manufacturers (R. Smith, pers. comm. 2024). The underground flues at the Bedminster Smelting Works had flat bases and were just about big enough to crawl down. This may be an indication that they were designed to allow the manual recovery of the accumulated dust within them: a truly unenviable task. The use of underground flues use on such a low-lying site was, however, quite problematic: heavy rain, and any overtopping of the river walls, would have caused the flues to flood, bringing any smelting activity to an immediate halt. Before work could be recommenced, the flues would have to be laboriously pumped out, and it is possible that the presence of water caused additional problems such as the leaching of mortar and unwanted chemical reactions. By the 1890s, the subterranean flues seem to have gone out of use in favour of overhead metal flues, and it is possible that this was, at least partially, a response to flooding. Interestingly, the solder pots (some of which remained in use until 1963) were also partially subterranean. This would have presented similar problems: flooding would have instantly quenched the furnaces, potentially leading hot brickwork to explode and metal charges to fuse into an unworkable mass. The furnaces are likely to have been similarly vulnerable to damage if they were heated up too quickly after a flood. The company was evidently aware of these risks, and when flooding was expected they allowed furnaces to go out and cool, thereby reducing the risk of explosions (*WDP*, 13 March 1889, 8). The latest reverberatory furnaces, used to soften lead, were suspended on steel joists over brick-lined pits: this significantly reduced the risk of moisture explosions (R. Smith, pers. comm. 2024).

Following the demise of the former Bright Bow Brickworks in the 1860s, thousands of tons of earth and rubble were imported onto the site to raise the ground level and provide a firm base for the construction of streets and houses. This was largely successful, but the area still flooded during exceptional weather events. The houses had ground-level suspended wooden floors. These would have been difficult to dry after floods, and it is likely than many of the houses suffered from rotting floor joists. Flooding, and the proximity of a stinking tannery and the smelting works, made these houses less desirable than those on higher ground, something which is reflected in the demography of the area (see below).

The People of Percy Street

To get an understanding of the social make-up of the streets to the east of the smelting works, a rapid analysis of historic census data has been undertaken. A single, predominantly residential road, Percy Street, was chosen as the subject. This street contained 75 properties, all but two of which were residential. The non-residential buildings included the Bedminster Iron Tomb Railing and Iron Foundry and a workshop or warehouse. The street also had a public house, the Victory Tavern, on the corner of Percy Street and Clarke Street, the British Flag off-licence, a milk shop and an infant nursery. The analysis compared census data from two dates: 1871 and 1911. At the time of the 1871 census, Percy Street was not fully built: four plots remained vacant, and three houses are described as newly built, but unoccupied. The completed houses were all less than eight years old, and many of the individuals listed in the census are likely to have been the first occupants of the street. The 1911 census, taken 40 years later, captures the area on the eve of World War I.

The 1871 census records 478 people living in 72 houses. The number of occupants per house ranged between 2 and 14, with an average of 6.6 per house. Four of the houses (5.6%) contained more than one household. The inhabitants worked in a wide variety of manual trades, mostly in nearby factories and workshops (Table 10.3). By far the most common male occupation was labourer (21.4%). In some instances, their place of work is listed, but none of the labourers are identified as employees of the Bedminster Smelting Works. Two of the men had low-level clerical positions, but the overall impression is of a solidly working-class population. Although Percy Street was close to several large tanneries, a ropeworks and the smelting works, only three men appear to have been employed in these industries, and the only occupant that can be linked with the smelting works was a visiting assayer. In contrast to the residents of Coronation Street and Adelaide Place recorded in 1861 (Table 3.1), none of the residents of Percy Street were coal miners.

As was common for the period, most women and girls carried out unpaid domestic work at home. Of those who also had paid employment, 33.3% worked in occupations related to the making or mending of clothes. Working as domestic servants, paper bag makers and laundresses was also common: together these roles employed 50% of the female workforce. The size of the population of Percy Street remained largely static between 1871 and 1911: by the latter date, there were 488 people living in 71 houses. The number of occupants per house ranged between 1 and 15, with an average of 6.9 per house. There was, however, a notable change in household composition: in 1911, 30 of the houses (42.3%) contained more than one household. There was also a major change in male employment: the number of men working as unskilled labourers had increased by approximately 50%. In 1911 32% of the male workforce were unskilled labourers (Table 10.4). Ten per cent of the men worked as carters: the remaining 58% worked in a wide variety of predominantly manual trades. Two men are likely to have been employed by Capper Pass & Son: a smelting works labourer, and a retired lead smelter. The absence of smelting workers in the 1871 census could be explained by the fact that Percy Street was a new street: many of Capper Pass & Son's employees are likely to have lived in the area for a while (i.e., on other streets). Their relative absence on the 1911 census suggests that there may also have been other factors at play. Smelting workers may simply have chosen to live in streets where their colleagues lived, but it could also be due to the relatively good wages offered by Capper Pass & Son, which were apparently higher than those of local brickyards, iron works and J. S. Fry's chocolate factory (Little 1963, 17). Higher income would have given the workers more housing choices, and many may have decided to live in better-quality homes away from their workplace.

In common with the preceding period, the women and girls of 1911 were primarily engaged in unpaid work at home, but the nature of their paid work had changed significantly: 26.8% were employed as cardboard box and paper bag makers at E. S. & A. Robinson's factory on East Street, and 20.9% worked for the tobacconist W. D. & H. O. Wills, mostly as cigarette makers and packers. The rest of the female workforce was employed in other factories and more traditional roles, such as garment making and repair. Notably, none of the women of Percy Street worked as servants. By the early 1900s, the number of people employed in service had declined across the country, but the total absence of servants amongst the residents of Percy Street is probably due to the ready availability of local factory work. Put simply, these employers offered better pay and conditions and afforded more camaraderie and personal freedom than domestic service.

Analysis of the population of Percy Street between 1871 and 1911 shows that the area remained staunchly working class throughout the period, and likely remained so up until its demolition in the late 1950s. While the overall population size remained largely static, there were some significant demographic changes: the number of houses containing more than one family and the number of men working as unskilled labourers increased significantly, both of which suggest a degree of social decline. So what caused this demographic change? Percy Street was very close to the smelting works and its incessant noise and fumes. It was also near to two large tanneries and was prone to flooding. The houses, which opened directly onto the street, were also built to lower standard than the late Victorian bay-fronted terraces on the surrounding hills. Together, these factors are likely to have motivated the better paid to move to the district's expanding suburbs, leaving the less desirable streets on the valley floor to those with lower incomes.

Table 10.3 Adult occupations in Percy Street in 1871

Male occupations	*No.*	*Female occupations*	*No.*
Assayer	1	Bookbinder	1
Baker	3	Boot machinist	1
Blacksmith	1	Charwoman	1
Boot and/or shoemaker	6	Cook	2
Cabinet maker	3	Cotton weaver	1
Carpenter and/or joiner	5	Dressmaker	5
Coal hawker	1	Invalid	2
Commissioner's agent	1	Lacemaker	1
Contractor's clerk	1	Laundress	9
Dairyman	1	Machinist	2
Floorcloth weaver	1	Milliner	1
Foreman at Bristol Steam Navigation Company	1	Paper bag maker	9
General dealer	3	Servant	9
Glass fitter	1	Shirtmaker	3

Male occupations	No.	Female occupations	No.
Hammer man	1	School keeper	1
Hatter	1	Tailoress	7
Hoop maker	1		
House carpenter	1		
House painter	1		
Invalid	1		
Iron founder	1		
Iron railing manufacturer	1		
Ironmonger's assistant	1		
Labourer	19		
Lithographic printer	2		
Mason	4		
Nailer	1		
Packer	2		
Packing case maker	1		
Painter	1		
Police constable	2		
Ropemaker	1		
Sailor	1		
Sash mender	2		
Sawyer	4		
Shipwright	1		
Stationary warehouseman	1		
Sugar baker	1		
Tailor	3		
Tanner	1		
Warehouseman	1		
Wheelright	3		

Table 10.4 Adult occupations in Percy Street in 1911

Male Occupations	No.	Female occupations	No.
Account book ruler	1	Boarding house keeper	1
Beer retailer	1	Boot nail factory worker	2
Blacksmith	2	Brush drawing teacher at Blind Asylum	1
Boilermaker's assistant	1	Brush maker	1
Bonded store foreman	1	Candle maker	1
Boot maker	1	Cardboard box maker	7
Boot maker foreman	1	Charwoman	1
Butcher	2	Dress seller	1

Male Occupations	*No.*	*Female occupations*	*No.*
Cabinet maker	1	Dressmaker	1
Carman	2	Hairdresser	1
Carpenter and joiner	2	Hotel waitress	1
Carter	14	Lithographic machinist	3
Clerk	2	Milk retailer	3
Cocoa factory worker	1	Nurse maid	2
Compositor	1	Old age pensioner	7
Dairy worker	2	Paper bag maker	11
Dry salter	1	Potter	1
Engine driver and fireman	1	Sack darner	1
Errand boy	3	Shirt maker	1
Fitter's mate (mechanical engineering)	1	Shop assistant	1
Foundry labourer	1	Show card seller	1
Galvanised iron worker	1	Tailoress	3
Gear fitter (general engineering)	1	Tobacco and cigarette factory worker	14
General dealer	1	Washerwoman	1
Greengrocer	1		
Hawker of chopped wood	2		
House painter	5		
Labourer	45		
Lead smelter (pensioner)	1		
Licensed victualler	1		
Marker salesman	1		
Milk retailer	2		
Newsagent's assistant	1		
Newspaper boy	1		
Old age pensioner	1		
Paviour	1		
Picture palace attendant	1		
Plasterer	1		
Police pensioner	1		
Porter for mantle maker	1		
Potter	2		
Printing factory worker	4		
Rag and metal warehouse packer	1		
Railway clerk	1		
Road cleaner (sanitary)	1		
Sawmill worker	1		
Shipwright	1		

Male Occupations	*No.*	*Female occupations*	*No.*
Shop assistant	1		
Smelting works labourer	1		
Stoker	1		
Stone mason	1		
Tailor	2		
Tanner or currier	5		
Tobacco factory worker	2		
Warehouseman	2		
Watchman	2		
Wheelright	1		

Capper Pass & Son's Influence on the Development of Bedminster

In 1840, Bedminster was essentially a semi-rural suburb of Bristol. There were established brickworks, tanneries and other industrial sites in the northern part of the settlement, and scattered coal mines in the surrounding fields. Capper Pass II purchased a small plot on a newly laid out residential street close to the Malago. As the business grew, the Pass family bought up houses and other properties in the surrounding streets and demolished them to make way for expansions to their works. Alfred Pass also used some of his land on Windmill Hill for residential development, and several streets and a church were built on the hillside overlooking the smelting works. The expansion of the smelting works radically changed the character of the area, and by the late 19th century, it had become a dominant feature of the district. The noise and pollution of the works made nearby streets a less desirable place to live and may have contributed to the decision to demolish large swathes of nearby housing in the late 1950s. The closure and subsequent demolition of the Bedminster Smelting Works in 1963 created a vast area of undeveloped land. By 1973, a new road, Dalby Avenue, had been laid out across the former smelting works. The west side of the works was redeveloped as an office block and shopping centre, while the east side was turned into a carpark. Following the demolition of Percy Street, Clarke Street and Doveton Street, most of the land to the east of the Malago was repurposed as a light industrial zone.

The growth of Bristol University in the 21st century has created a demand for student accommodation across the city. The purpose-built flats at Metal Works have been built to meet this demand. This and the other proposed Bedminster Green developments will be a major change for the district, but change has been a key part of Bedminster's story. The settlement began life as a late prehistoric and Romano-British farmstead, which subsequently became the focus of a small Late Anglo-Saxon Christian community that later developed into a medieval village. The discovery of deeply buried coal brought collieries and industry to the area, and by the early 19th century the village became a semi-rural suburb of Bristol. By the 20th century, Bedminster had become a densely populated and heavily industrialised city district. The impact of World War II and post-war clearance programmes removed many streets of working-class housing alongside the Malago and marked the end of the heavy industry that once dominated the skyline. The tall buildings of the Bedminster Green development have once again changed the appearance of the area, but perhaps the most significant change will be the re-introduction of people to the areas that were depopulated in the 1950s. Fortunately for the new residents, however, they will not have to live alongside the sound, light and smells of the Bedminster Smelting Works.

APPENDIX 1

ARCHAEOMETALLURGICAL TABLES: ANALYSIS OF METALWORKING DEBRIS SAMPLES

by David Dungworth and Richard Smith

Catalogue of Analysed Samples

These tables accompany the analysis and discussion in Chapter 8.

Metal Sample

Analysis	*Sub-sample*	*Area*	*Si*	*Fe*	*Co*	*Cu*	*Zn*	*As*	*Sn*	*Sb*	*Pb*
46	A	Bulk	0.1	<0.1	0.1	0.2	<0.1	<0.5	1.2	2.3	95.4
48	A	Bulk	0.2	<0.1	<0.1	<0.1	<0.1	<0.5	0.8	1.6	96.9
49	A	Bulk	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	1.1	2.3	96.2
51	A	Bulk	0.2	0.11	<0.1	0.2	0.2	<0.5	0.8	1.9	96.2
53	B	Bulk	0.2	0.1	<0.1	<0.1	0.1	<0.5	<0.5	0.8	98.3
54	B	Bulk	0.1	0.1	<0.1	0.2	<0.1	<0.5	1.4	7.6	90.3
55	B	Bulk	0.4	<0.1	<0.1	<0.1	0.3	<0.5	<0.5	1.7	96.7
57	B	Bulk	0.2	<0.1	<0.1	<0.1	<0.1	<0.5	0.7	0.9	98.0
47	A	Point	0.1	<0.1	<0.1	<0.1	<0.1	29.1	45.1	4.8	20.2
50	A	Point	0.1	<0.1	<0.1	<0.1	<0.1	27.0	44.2	4.1	23.5
52	A	Point	<0.1	<0.1	<0.1	0.2	0.2	27.9	45.7	3.2	21.7
58	B	Point	0.1	0.15	0.2	<0.1	<0.1	2.1	9.0	85.1	2.3
59	B	Point	<0.1	<0.1	<0.1	<0.1	0.3	25.2	42.7	8.9	21.8
60	B	Point	0.1	<0.1	<0.1	<0.1	<0.1	25.1	42.3	7.6	23.9

Table 8.2 Chemical composition of selected areas (BULK) and points (individual phases) in sample 16

Slag Samples

Analysis	*Label*	Na_2O	MgO	AL_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	FeO	CoO	NiO	CuO	ZnO	As_2O_3	SnO_2	Sb_2O_5	BaO	PbO
28	Bulk	2.0	0.5	10.2	25.2	<0.2	1.0	2.2	1.8	0.5	<0.1	5.1	<0.2	0.2	6.0	12.9	3.0	3.9	1.9	<0.2	23.3
30	Bulk	1.5	0.5	9.8	25.2	0.3	0.6	2.2	2.0	0.4	<0.1	5.0	<0.2	0.2	7.6	11.0	3.6	3.1	2.0	<0.2	24.7
31	Bulk	1.7	0.7	9.7	25.4	0.3	0.9	2.4	1.7	0.3	<0.1	4.4	<0.2	0.2	6.2	12.2	3.6	2.9	1.9	<0.2	25.5
32	Bulk	1.5	0.6	9.6	25.1	<0.2	0.4	2.2	1.9	0.5	<0.1	4.5	<0.2	<0.1	7.5	11.3	3.5	3.0	1.7	<0.2	26.5
34	Bulk	1.9	0.4	10.7	27.4	<0.2	0.4	2.5	2.3	0.3	<0.1	4.1	<0.2	<0.1	5.9	10.7	3.4	2.4	1.6	0.3	25.2
39	Bulk	1.9	0.6	9.2	25.5	<0.2	0.9	2.2	2.6	0.6	<0.1	3.8	<0.2	0.2	6.6	10.7	3.9	2.4	1.7	<0.2	27.1
40	Bulk	1.4	0.8	9.6	30.1	<0.2	0.4	2.3	2.1	0.5	0.1	3.6	<0.2	<0.2	5.5	10.2	2.4	1.5	1.0	0.3	28.1
41	Bulk	1.6	0.6	9.4	26.5	<0.2	0.2	2.0	2.0	0.4	0.2	3.9	<0.2	<0.2	4.8	13.3	1.9	3.1	1.1	<0.2	28.5
42	Bulk	1.7	0.5	8.7	24.0	<0.2	0.8	1.9	2.2	0.4	<0.1	4.0	<0.2	<0.2	8.0	11.5	3.8	3.4	1.7	<0.2	27.3
44	Bulk	1.9	0.4	9.0	23.2	<0.2	<0.2	1.7	2.1	0.3	<0.1	5.3	<0.2	0.2	7.5	12.8	3.8	3.5	1.8	<0.2	26.1
45	Bulk	1.8	0.5	7.3	22.9	0.2	0.7	1.6	2.1	0.3	<0.1	4.3	<0.2	<0.2	7.1	12.8	3.2	3.1	1.4	<0.2	30.5
23	Matrix	1.0	0.7	3.64	26.1	<0.2	<0.2	0.2	1.6	0.4	0.2	1.1	<0.2	<0.2	3.8	7.0	2.1	<0.5	0.4	<0.2	51.1
22	Phase 1	0.3	0.7	<0.1	3.9	1.1	1.4	<0.1	13.1	0.1	<0.1	0.5	<0.2	<0.2	0.7	1.7	23.7	<0.5	1.5	0.3	50.1
24	Phase 2a	3.0	2.4	8.3	<0.2	<0.2	<0.2	<0.1	<0.1	0.5	0.2	18.1	<0.2	0.8	10.0	31.9	<0.5	14.3	10.1	<0.2	0.2
25	Phase 2b	2.2	0.8	6.1	0.3	<0.2	<0.2	<0.1	0.1	0.4	<0.1	56.2	0.7	1.1	8.5	22.7	<0.5	<0.5	<0.5	<0.2	<0.2
26	Phase 3a	2.3	<0.1	19.4	54.2	<0.2	0.2	8.6	0.4	<0.1	<0.1	0.5	<0.2	<0.2	0.3	1.1	<0.5	<0.5	<0.5	0.3	11.8
35	Phase 3b	2.1	<0.1	19.1	53.1	<0.2	<0.2	8.6	0.8	<0.1	<0.1	0.7	<0.2	<0.2	0.5	1.1	<0.5	<0.5	<0.5	0.6	13.2
37	Phase 3c	0.1	<0.1	23.4	54.5	<0.2	<0.2	19.8	<0.1	<0.1	<0.1	0.8	<0.2	<0.2	<0.2	0.4	<0.5	<0.5	<0.5	<0.2	0.4
27	Phase 3d	3.1	<0.1	18.8	46.5	<0.2	<0.2	3.9	1.6	0.2	<0.1	0.8	<0.2	<0.2	0.5	1.8	<0.5	<0.5	<0.5	<0.2	22.3
36	Phase 4	0.8	<0.1	<0.1	<0.2	<0.2	<0.2	0.1	<0.1	0.2	<0.1	0.4	<0.2	<0.2	97.0	0.5	<0.5	<0.5	<0.5	<0.2	0.2

Table 8.3 Chemical composition of selected areas (BULK) and points (individual phases) in sample 1

Analysis	*Area*	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Cr_2O_3	MnO	FeO	CoO	NiO	CuO	ZnO	SnO_2	Sb_2O_5	BaO	PbO
10	1	0.9	0.7	6.9	24.7	0.3	3.9	0.8	11.4	0.3	<0.1	0.1	45.2	0.4	<0.1	0.2	2.3	0.6	0.8	0.3	<0.2
11	2	0.9	0.6	7.3	24.3	0.3	4.0	0.8	11.1	0.4	<0.1	0.1	45.5	0.3	<0.1	0.4	2.4	0.6	0.6	0.3	<0.2
12	3	1.1	0.6	7.3	24.6	0.2	4.0	0.7	11.2	0.3	<0.1	0.1	44.8	0.3	0.1	0.4	2.4	<0.5	0.8	0.4	0.2
14	4	0.9	0.5	7.3	24.7	<0.2	4.0	0.8	11.3	0.3	<0.1	0.2	45.5	<0.1	<0.1	0.2	2.4	0.6	0.6	<0.2	<0.2
15	5	0.8	0.7	7.4	24.7	0.3	3.9	0.8	11.4	0.4	<0.1	0.1	45.4	0.3	0.1	0.3	2.1	0.5	0.6	0.3	<0.2
16	6	0.7	0.7	7.2	24.5	0.2	4.1	0.7	10.6	0.4	<0.1	0.3	46.3	0.2	<0.1	0.5	2.2	0.6	<0.5	<0.2	0.3
17	Spinel	1.2	2.0	50.0	<0.2	<0.2	<0.2	<0.1	<0.1	0.3	0.6	<0.1	35.9	0.1	<0.1	<0.1	9.7	<0.5	<0.5	<0.2	<0.2
18	Spinel	1.1	2.0	51.5	<0.2	<0.2	<0.2	<0.1	0.2	0.3	0.6	<0.1	34.0	0.2	<0.1	<0.1	9.8	<0.5	<0.5	<0.2	<0.2
19	Olivine?	0.1	1.4	<0.1	29.6	0.3	<0.2	<0.1	17.7	<0.1	<0.1	0.3	47.9	0.3	<0.1	<0.1	1.2	<0.5	0.7	<0.2	<0.2
20	Olivine?	<0.1	1.4	0.4	29.3	<0.2	0.4	0.2	17.0	0.1	<0.1	0.2	48.0	0.3	<0.1	<0.1	1.4	<0.5	0.9	<0.2	<0.2
21	Olivine?	<0.1	1.5	0.2	29.4	0.3	<0.2	0.2	16.2	<0.1	<0.1	0.2	48.9	0.3	<0.1	0.1	1.4	<0.5	0.8	<0.2	<0.2

Table 8.4 Chemical composition of selected areas (BULK) and points (individual phases) in sample 2

Analysis	Area	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	FeO	CoO	NiO	CuO	ZnO	PbO
115	Bulk	0.8	0.6	11.9	32.0	0.2	1.5	0.8	3.8	0.7	0.2	44.0	0.1	<0.1	0.4	1.7	0.5
116	Bulk	0.8	0.5	11.7	32.4	0.3	1.5	0.8	3.9	0.8	<0.1	43.6	0.2	<0.1	0.3	1.7	0.6
117	Bulk	1.1	0.5	12.1	31.3	0.4	1.7	0.7	3.6	0.7	0.2	44.7	0.1	<0.1	0.6	1.6	0.4
118	Bulk	0.9	0.5	12.7	30.6	0.3	1.6	0.7	3.6	0.7	0.2	44.2	0.2	<0.1	0.6	2.0	0.3
119	Bulk	0.6	0.5	12.7	31.4	0.3	1.7	0.8	3.6	0.5	0.2	44.2	0.2	0.1	0.6	1.6	0.3

Table 8.5 Chemical composition of selected areas (BULK) in sample 15

Analysis	Si	S	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Hg	Pb
110	<0.1	26.0	0.1	17.3	0.2	0.2	51.7	2.3	<0.5	<0.5	<0.5	0.6	0.9
111	0.2	26.0	<0.1	15.9	<0.1	<0.1	55.9	<0.1	<0.5	<0.5	<0.5	1.2	<0.2
112	0.1	25.5	<0.1	20.8	0.2	<0.1	50.4	0.1	<0.5	<0.5	<0.5	0.9	1.4
114	<0.1	26.3	<0.1	16.4	0.1	0.1	55.0	<0.1	<0.5	<0.5	<0.5	1.0	<0.2

Table 8.6 Chemical composition of selected copper-iron sulphides in sample 15

Analysis	Area	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	FeO	CoO	NiO	CuO	ZnO	SnO_2	Sb_2O_5	BaO	PbO
71	Bulk	1.0	0.9	10.9	33.4	<0.2	0.5	1.3	5.1	0.4	0.2	39.1	0.3	0.1	0.9	2.6	1.1	0.7	0.4	0.9
72	Bulk	1.0	1.0	10.9	32.8	<0.2	0.6	1.3	5.1	0.5	<0.1	40.4	0.3	<0.1	0.8	2.6	0.9	0.6	0.4	0.7
73	Bulk	1.0	0.7	10.9	32.9	<0.2	0.5	1.1	5.2	0.5	<0.1	40.4	0.3	<0.1	0.7	2.6	1.3	0.7	<0.2	1.0
74	Bulk	1.0	0.6	10.8	31.5	0.22	0.8	1.1	5.4	0.4	<0.1	41.5	0.4	<0.1	0.5	2.8	1.1	0.5	<0.2	0.9
75	Bulk	1.0	0.6	10.9	31.8	0.22	0.7	1.1	5.0	0.3	<0.1	42.0	0.3	<0.1	0.8	2.5	1.1	<0.5	0.3	0.8
77	Phase 1	0.4	2.6	0.2	27.2	<0.2	<0.2	<0.1	0.7	<0.1	0.1	65.6	<0.1	<0.1	<0.1	2.6	<0.5	<0.5	<0.2	<0.2
76	Phase 2	0.3	0.5	17.7	0.3	<0.2	0.3	<0.1	0.1	1.9	<0.1	73.2	0.7	0.2	0.2	4.0	<0.5	<0.5	0.2	<0.2

Table 8.7 Chemical composition of selected areas (BULK) and points (phases) in sample 17

Refractory Materials

Analysis	Area	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Cr_2O_3	MnO	FeO	NiO	CuO	ZnO	As_2O_3	Sb_2O_5	BaO	HgO	PbO
84	Glassy slag	0.2	3.1	23.4	38.1	<0.2	<0.2	2.8	8.9	0.8	<0.1	0.1	21.4	<0.1	0.1	0.2	<0.5	<0.5	0.3	<0.5	<0.2
85	Refractory	0.6	1.4	26.7	57.7	<0.2	0.7	3.4	0.5	0.9	<0.1	<0.1	5.0	0.2	<0.1	<0.1	1.8	<0.5	<0.2	<0.5	<0.2
88	Refractory	0.5	1.2	31.8	57.2	<0.2	0.4	4.1	0.6	0.8	<0.1	<0.1	2.3	<0.1	<0.1	0.1	<0.5	<0.5	0.3	<0.5	0.2
89	$CaSO_4$	<0.1	<0.1	<0.1	<0.2	<0.2	56.9	<0.1	40.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.5	1.5	0.2	0.5	<0.2
91	Bulk	0.7	0.3	15.6	20.0	0.4	29.6	2.6	16.8	0.4	<0.1	0.1	5.5	<0.1	0.4	0.8	4.1	0.8	0.3	<0.5	1.1

Table 8.8 Chemical composition of selected areas (BULK) and points (individual phases) in sample 3

Analysis	*Area*	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	FeO	NiO	CuO	ZnO	As_2O_5	Sn_2O_2	Sb_2O_5	BaO	PbO
67	Ceramic bulk	<0.1	0.6	29.2	63.9	<0.2	1.4	0.3	1.2	2.7	0.1	<0.1	<0.1	<0.5	<0.5	<0.5	<0.2	<0.2
68	Ceramic bulk	0.2	0.8	31.4	60.7	<0.2	1.4	0.4	1.1	3.2	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	0.3	<0.2
69	Ceramic bulk	<0.1	0.6	30.2	62.9	<0.2	1.4	0.4	1.3	2.4	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	<0.2	<0.2
70	Ceramic bulk	0.2	0.5	30.9	60.8	<0.2	1.3	0.4	1.2	3.7	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	0.3	<0.2
62	Glaze bulk	2.4	0.5	9.9	34.9	0.7	2.2	2.4	0.6	2.8	<0.1	0.7	13.3	2.2	7.8	1.8	<0.2	18.0
63	Glaze bulk	2.7	0.5	9.5	27.1	0.5	1.4	2.8	0.4	3.1	<0.1	0.8	16.4	2.7	11.9	2.6	<0.2	17.3
64	Phase 1a	3.9	0.5	43.9	0.2	<0.2	<0.1	<0.1	0.2	10.8	0.2	0.2	37.9	<0.5	1.5	<0.5	<0.2	0.2
65	Phase 1b	5.2	1.1	8.0	<0.2	<0.2	<0.1	<0.1	1.3	17.8	0.2	0.7	43.9	<0.5	12.8	8.6	<0.2	<0.2
66	Phase 2	0.2	0.1	0.7	0.6	<0.2	0.2	<0.1	0.2	0.5	<0.1	0.2	1.9	<0.5	92.1	2.8	<0.2	0.3

Table 8.9 Chemical composition of selected areas (BULK) and points (individual phases) in sample 14

Analysis	Na_2O	*MgO*	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	*CaO*	TiO_2	*MnO*	*FeO*	*NiO*	*CuO*	*ZnO*	As_2O_5	SnO_2	Sb_2O_5	*BaO*	*HgO*	*Pb0*
133 (interior)	26.7	0.5	16.2	45.3	0.3	1.0	1.1	2.0	0.5	<0.1	5.4	<0.1	<0.1	0.2	<0.5	<0.5	<0.5	<0.2	<0.5	<0.2
135 (interior)	25.3	0.6	16.7	43.6	0.5	1.3	0.7	2.5	0.6	0.1	6.9	<0.1	<0.1	0.2	<0.5	<0.5	<0.5	<0.2	<0.5	<0.2
136 (underside)	12.5	0.6	18.2	55.1	0.2	0.4	1.9	2.6	0.4	<0.1	7.3	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	<0.2	<0.5	0.2
137 (outer)	13.2	0.3	20.8	56.3	0.3	0.5	2.1	1.4	0.4	<0.1	4.5	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	<0.2	<0.5	<0.2

Table 8.10 Chemical composition of selected areas in the vitrified surfaces of sample 18

Analysis	*Area*		Na_2O	*MgO*	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	*CaO*	TiO_2	*MnO*	*FeO*	*NiO*	*CuO*	*ZnO*	As_2O_5	SnO_2	Sb_2O_3	*BaO*	*PbO*
159	Slag 1	Bulk	1.0	0.6	6.2	33.4	0.3	0.2	0.8	4.4	0.2	1.2	32.2	<0.1	1.7	7.8	<0.5	2.2	0.6	<0.2	6.4
160	Slag 1	Bulk	1.4	0.7	5.8	29.9	0.2	<0.2	0.9	3.8	0.2	1.1	38.1	0.2	1.8	7.4	<0.5	2.2	0.7	<0.2	5.2
161	Slag 1	Bulk	1.2	0.7	6.0	26.3	<0.2	<0.2	0.7	3.1	0.4	1.1	42.4	0.4	1.8	7.7	<0.5	2.3	0.5	<0.2	4.9
170	Slag 2	Bulk	<0.1	0.3	8.4	23.5	<0.2	<0.2	0.6	3.1	0.2	<0.1	6.0	1.1	42.3	1.8	1.8	1.7	1.4	<0.2	7.5
174	Slag 3	Bulk	0.5	0.4	4.6	30.2	<0.2	0.4	0.4	5.7	0.3	0.1	21.2	1.9	8.7	3.6	0.5	3.2	1.5	<0.2	16.6
176	Slag 4	Bulk	1.1	0.5	5.9	34.7	<0.2	<0.2	0.9	5.5	0.2	0.5	38.0	0.1	0.9	5.2	<0.5	1.8	0.7	0.29	3.0
177	Slag 4	Bulk	0.6	0.6	5.8	21.3	<0.2	0.4	0.5	4.4	0.6	0.4	56.2	0.2	0.5	5.0	<0.5	1.6	<0.5	<0.2	1.2
178	Slag 4	Bulk	1.0	0.7	6.5	35.5	0.2	<0.2	1.0	4.5	0.2	0.6	36.7	0.1	0.9	5.2	<0.5	1.8	0.5	<0.2	4.1
180	Slag 5	Bulk	0.4	0.3	3.4	22.1	<0.2	<0.2	0.3	4.1	<0.1	0.1	17.3	3.9	10.3	2.5	1.7	2.7	3.7	<0.2	26.3
181	Slag 6	Bulk	3.0	<0.1	7.2	24.8	<0.2	0.8	0.6	3.8	0.3	0.1	3.8	0.9	36.6	2.6	2.6	0.8	2.4	<0.2	9.2
173	Refractory	Bulk	0.2	1.3	25.4	62.0	<0.2	0.2	4.0	0.4	1.1	<0.1	4.1	0.1	0.2	0.1	<0.5	<0.5	<0.5	0.2	<0.2
168	Slag 1	Phase 1	0.7	0.3	5.9	1.0	<0.2	<0.2	<0.1	0.2	0.6	0.7	79.7	0.9	0.1	7.3	<0.5	2.2	<0.5	<0.2	<0.2
169	Slag 1	Phase 2	1.1	1.5	6.3	42.5	0.4	<0.2	1.0	6.2	0.1	1.9	27.7	<0.1	0.5	6.4	<0.5	0.9	<0.5	<0.2	2.9

Table 8.11 Chemical composition of slag and refractory inclusions (and some phases) in sample 4

Analysis	*Area*	*S*	*Fe*	*Ni*	*Cu*	*Zn*	*As*	*Sn*	*Sb*	*Hg*	*Pb*
162	Slag 1: Inclusion 1	<0.2	1.5	0.3	86.8	0.5	4.3	3.4	2.9	<0.5	0.3
163	Slag 1: Inclusion 2	0.3	1.0	0.4	87.5	<0.1	4.5	3.3	2.4	<0.5	0.3
164	Slag 1: Inclusion 3	10.5	1.4	<0.1	85.5	0.3	<0.5	<0.5	<0.5	1.3	0.4
165	Slag 1: Inclusion 4	<0.2	1.4	0.4	85.8	0.3	4.4	4.5	3.0	<0.5	<0.2
166	Slag 1: Inclusion 5	10.5	3.1	<0.1	84.0	0.3	<0.5	<0.5	<0.5	1.2	<0.2
179	Slag 4: Inclusion 1	10.1	0.9	0.3	84.7	0.4	1.2	<0.5	<0.5	1.2	0.6
171	Metal 1	<0.2	0.1	<0.1	0.2	0.1	0.2	<0.5	12.7	<0.5	86.3

Table 8.12 Chemical composition of metallic droplets within sample 4

Analysis	*Area*	Na_2O	*MgO*	Al_2O_3	SiO_2	P_2O_5	SO_3	*Cl*	K_2O	*CaO*	TiO_2	*FeO*	*NiO*	*CuO*	*ZnO*	SnO_2	Sb_2O_5	*BaO*	*HgO*	*PbO*
145	1	0.2	0.4	2.3	9.9	<0.2	33.4	5.9	0.3	21.1	<0.1	1.3	0.2	17.2	3.1	<0.5	0.8	<0.2	0.6	2.7
146	2	0.5	0.3	1.5	4.6	<0.2	38.8	4.4	0.3	24.6	<0.1	1.6	0.3	15.3	3.5	0.7	1.5	0.3	<0.5	1.7
148	3	<0.1	0.3	0.9	3.1	<0.2	27.0	6.8	0.2	17.3	0.2	1.2	0.2	35.3	5.1	<0.5	1.1	<0.2	<0.5	0.9
149	4	<0.1	0.2	1.7	4.4	<0.2	19.7	8.8	0.2	11.2	<0.1	1.4	0.3	45.5	3.3	<0.5	0.7	<0.2	<0.5	2.0
150	5	<0.1	0.2	4.2	10.0	0.3	33.6	3.7	0.6	21.0	0.2	2.2	0.2	18.4	1.7	0.8	1.0	<0.2	<0.5	1.4
151	6	<0.1	0.3	2.0	4.9	<0.2	38.1	3.3	0.3	26.0	<0.1	1.2	<0.1	17.7	1.5	<0.5	1.2	<0.2	0.6	2.4
152	7	<0.1	0.6	1.4	4.0	<0.2	25.4	6.1	0.2	15.3	0.1	1.7	0.1	38.2	4.0	<0.5	0.6	<0.2	<0.5	1.9
153	8	<0.1	0.4	2.3	6.0	<0.2	24.9	5.3	0.4	16.1	0.2	2.4	<0.1	32.6	3.5	0.7	1.4	<0.2	<0.5	3.2
154	9	<0.1	0.7	3.7	7.8	<0.2	27.5	4.6	0.6	16.6	0.2	3.0	<0.1	27.6	2.5	0.7	1.0	<0.2	<0.5	3.4
155	10	<0.1	0.5	2.7	10.0	<0.2	30.6	5.3	0.6	20.2	<0.1	2.3	<0.1	21.6	1.8	<0.5	<0.5	<0.2	<0.5	2.9
156	11	<0.1	0.4	1.7	7.1	0.3	36.1	6.7	0.2	23.0	0.3	1.3	0.1	16.9	1.3	<0.5	0.8	<0.2	0.6	2.9

Table 8.13 Chemical composition of sample 5 (Areas 1–11 in sequence from the top to the bottom of the sample)

Analysis	*Sample*	*Description*	Na_2O	*MgO*	Al_2O_3	SiO_2	P_2O_5	SO_3	*Cl*	K_2O	*CaO*	TiO_2	*FeO*	*NiO*	*CuO*	*ZnO*	As_2O_3	SnO_2	*Sb2O3*	*HgO*	*PbO*
95	7	Tin sulphate?	0.1	<0.1	0.3	2.8	<0.2	8.1	0.4	0.5	0.4	<0.1	0.4	0.2	<0.1	1.6	4.6	62.6	1.8	2.5	13.2
96	7	Lead sulphate?	<0.1	<0.1	0.1	0.4	<0.2	26.3	<0.2	0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.2	<0.5	0.7	<0.5	<0.5	71.5
103	8	Refractory	0.4	0.5	15.8	70.5	<0.2	4.1	0.3	4.3	0.3	1.0	1.4	<0.1	<0.1	<0.1	0.5	<0.5	<0.5	<0.5	0.3
104	8	Gypsum?	0.3	<0.1	2.8	3.1	0.2	48.0	0.4	1.2	33.6	0.2	2.1	<0.1	0.2	0.2	1.5	1.4	3.6	0.6	0.4

Table 8.14 Chemical composition of samples 7 and 8

Analysis	*Sample*		Na_2O	*MgO*	Al_2O_3	SiO_2	P_2O_5	SO_2	*Cl*	K_2O	*CaO*	TiO_2	*MnO*	*FeO*	*NiO*	*CuO*	*ZnO*	As_2O_3	SnO_2	Sb_2O_5	*BaO*	*PbO*
138	6	Bulk	1.7	1.9	11.3	33.6	0.5	0.4	0.3	1.0	3.9	0.3	0.3	7.4	0.2	4.8	16.5	5.3	1.7	0.9	0.2	8.0
139	9	Bulk	0.3	1.5	22.4	56.5	0.3	1.7	<0.1	4.1	2.2	0.9	0.2	6.3	<0.1	0.6	0.2	0.5	<0.5	1.1	<0.2	0.7

Table 8.15 Chemical composition of samples 6 and 9

Bibliography

Abbaschian, R. and Reed-Hill, R. E. 2008. *Physical Metallurgy Principles*. Boston (MA): Cengage Learning.

Anaconda Copper Mining Company 1897. *Catalogue No. 1, Presented by the Anaconda Copper Mining Co., Foundry Department, Manufacturers of Mining, Milling, Concentrating and Smelting Machinery*. Anaconda (MT): Standard Publishing Company.

Anon. 1862. *The Illustrated Catalogue of the International Exhibition*. London: William Clowes and Son.

Anon 1884a. *The Homes of the Bristol Poor. By the Special Commissioner of the Bristol Mercury*. Bristol: William Lewis & Sons.

Anon. 1884b. 'List of members', *Proceedings of the Somersetshire Archaeological and Natural History Society* 30, 177–89.

Anon. 1890. 'List of members', *Proceedings of the Somersetshire Archaeological and Natural History Society* 36, 206–20.

Anon. 1903. 'Stourbridge industry, E. J. & J. Pearson, Limited, fireclay mines and works', *The Industry & Railways of the South West Black Country*. https://www.harrisandpearson.info/stbrindustry.htm (accessed 23 January 2024).

Anon. 1955. 'Paul Julius Gottlieb Gueterbock', *Transactions of the Institute of Mining and Metallurgy* 64. https://www.nmrs.org.uk/resources/obituaries-of-members/g/paul-julius-gottlieb-gueterbock/ (accessed 2 January 2024) https://www.ask.bristol.gov.uk/17627/widgets/50083/documents/29805.

Anon. 1957. 'Food for history', *JS Journal, February 1957*, 12–19. London: J. Sainsbury Ltd.

Anon. 1993. 'Archives: how packaging became part of the service', *JS Journal, May Issue 1993: financial results special*, 18–19. London: J. Sainsbury plc.

Anon 2017. *Note on Historic Tidal Floods in Bristol*. https://www.ask.bristol.gov.uk/17627/widgets/50083/documents/29805 (accessed 18 January 2024).

Anon 2024. 'Tin smelting', *Handbook of Texas Online*. https://www.tshaonline.org/handbook/entries/tin-smelting (accessed 18 October 2024).

Anstie, J. 1873. *The Coal Fields of Gloucestershire and Somersetshire, and their Resources*. Bath: Kingsmead Reprints.

Avon Archaeological Unit 2005. *Site off Kent Street, Bedminster, Bristol: archaeological excavation project*. Bristol: unpublished report.

Avon Archaeological Unit 2006a. *45–53 West Street, Bedminster, Bristol: archaeological excavation assessment report and updated project design*. Bristol: unpublished report ref. BSMR 22276.

Avon Archaeological Unit 2006b. *Archaeological Excavations on the Former Mail Marketing International Site, West Street, Bedminster, Bristol: excavation assessment report and updated project design*. Bristol: unpublished report ref. BSMR 24797.

Avon Archaeological Unit 2006c. *The Former Robinson Building and Nos. 157–159, East Street, Bedminster, Bristol: archaeological evaluation project*. Bristol: unpublished report ref. 2006/16.

Avon Archaeological Unit 2009. *The Former Baptist Church, No. 177 East Street, Bedminster, Bristol: archaeological recording and monitoring*. Bristol: unpublished report.

Bates Harbin, E. H. (ed.) 1912. *Quarter Sessions Records for the County of Somerset, Volume 3: Commonwealth 1646–1660*. London: Somerset Records Society.

Baughton, J. 2014. *The Knowle West Estate, Bristol: 'the difficulties in rehousing the slum population'*. https://municipaldreams.wordpress.com/2014/06/03/the-knowle-west-estate-bristol-and-the-difficulties-in-rehousing-the-slum-population/ (accessed 21 November 2023).

Baughton, J. 2018. *Municipal Dreams: the rise and fall of council housing*. London: Version Books.

Beaven, A. B. 1899. *Bristol Lists: municipal and miscellaneous*. Bristol: T. D. Taylor, Sons and Hawkins.

Bell, M. 1911. 'Pewter', in *The Encyclopaedia Britannica: a dictionary of arts, sciences, literature and general information, Volume 21* (11th edition). New York: Encyclopaedia Britannica Inc. https://en.wikisource.org/wiki/1911_Encyclop%C3%A6dia_Britannica/Pewter (accessed 9 October 2023).

Bettey, J. H. 1978. *The Rise of a Gentry Family: the Smyths of Ashton Court c. 1500–1642*. Bristol: Bristol Branch of the Historical Association Pamphlet 43.

Biswas, A. K. and Davenport, W. G. 1976. *Extractive Metallurgy of Copper*. Oxford: Pergamon Press.

BLT19 2023. 'British Workman', *Nineteenth-Century Business, Labour, Temperance, & Trade Periodicals*. https://www.blt19.co.uk/periodicals/british-workman/ (accessed 24 November 2023).

Bray, J. L. 1947. *Non-Ferrous Production Metallurgy* (2nd edition). London: Chapman & Hall.

Bristol and Bath Heritage Consultancy Ltd. 2020. *Student Accommodation and Flexible Workspace at Dalby Avenue and Whitehouse Lane, Plot 3, Bedminster, Bristol, Heritage Statement*. Chippenham: unpublished report ref. 18031.

Bristol and Region Archaeological Services 2004. *Archaeological Evaluation of Land at Squire's Court, Bedminster Parade, Bedminster, Bristol*. Bristol: unpublished report ref. 957/2004.

Bristol and Region Archaeological Services 2014. *Archaeological Evaluation, St Catherine's Place, Bedminster, Bristol*. Bristol: unpublished report ref. 3034/2014.

Bristol Archives 2016. *The Bristol Blitz: sources for research*. https://archives.bristol.gov.uk/guides/Bristol%20Archives%20-%20Bristol%20Blitz%20source%20guide.pdf (accessed 1 February 2024).

Bristol City Council (BCC) 2023. *Level 1 – Citywide Strategic Flood Risk Assessment*. https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR040011/TR040011-001045-AS%20North%20Somerset%20District%20Council%20-%20ISH3%20Bristol%20Stategic%20Flood%20Risk%20Assessment%202020.pdf (accessed 20 November 2023).

Bristol City Council (BCC) 2024. 20/05811/F | *Proposed redevelopment of the site, including demolition works, to provide mixed use development comprising student accommodation (84 cluster units and amenity spaces) and ground floor business space (628sqm GIA) together with associated parking and vehicle servicing arrangements, public realm and landscaping, and associated works. (Major) | Dalby Avenue And Whitehouse Lane Bristol BS3 4DJ*. https://pa.bristol.gov.uk/online-applications/applicationDetails.do?keyVal=QKR5KVDNoDG00&activeTab=summary (accessed 25 January 2024).

Bristol Museum and Art Gallery (BMAG) 2024. *Coal Mining in Bristol* https://museums.bristol.gov.uk/narratives.php?irn=2979 (accessed 22 January 2024).

Bristol Poll Book 1781. *The Bristol Poll Book: being a list of persons who voted at the election for the member to serve in parliament with Matthew Brickdale Esquire, for the City and Council of Bristol, in the room of Sir Henry Lippincott, Bart., deceas'd, began at the Guildhall of the said city, Wednesday, January 31, 1781, and ended Saturday, February 24, following.*

Bristol Poll Book 1830. *The Bristol Poll Book: being a list of the freeholders and freemen, who voted at the General Election for the members to serve in parliament, for the City and Council of Bristol, which commenced Friday, July 30, and terminated Thursday, August 5, 1830.*

Bristol Poll Book 1832. *The Bristol Poll Book: being a list of the householders, freeholders, and freemen, who voted at the General Election for the members to serve in parliament, for the City and Council of Bristol, which commenced on Wednesday, December 12th, and terminated on Thursday, December the 13th 1832.*

Bristol Poll Book 1837. *The Bristol Poll Book: being a list of the householders, freeholders, and freemen, who voted at the General Election for the members to serve in parliament, for the City and Council of Bristol, which took place, July 24th, 1837.*

Bristol Poll Book 1841. *The Bristol Poll Book: being a list of the householders, freeholders, and freemen, who voted at the Parliamentary Election, Tuesday, June 29, 1841.*

Bristol University 2024. *Metal Works Bedminster*. https://www.bristol.ac.uk/accommodation/about/residences/metal-works/ (accessed 5 November 2024).

British Geological Survey 2023. *BGS Geology Viewer*. https://www.bgs.ac.uk/map-viewers/bgs-geology-viewer/ (accessed 10 October 2023).

Brooks, G. 2022. *Bricks*. http://www.solwaypast.co.uk/index.php/14-brick (accessed 24 January 2024).

Buchanan, R. A. and Cossons, N. 1969. *The Industrial Archaeology of the Bristol Region*. Newton Abbot: David & Charles.

Burke, M. 1987. 'The Corporacion Minera de Bolivia (Comibol) and the Triangular Plan: a case study in dependency', *Latin American Issues 4*. https://sites.allegheny.edu/latinamericanstudies/latin-american-issues/volume-4/ (accessed 20 January 2024).

Butt R. V. J. 1995. *The Directory of Railway Stations: details every public and private passenger station, halt, platform and stopping place, past and present* (1st edition). Sparkford: Patrick Stephens Ltd.

Butterworth, J. 2024. *Easton Colliery*. https://maps2.bristol.gov.uk/server2/rest/services/ext/kyp_new_contributions_bristol/FeatureServer/0/1164257/attachments/853043 (accessed 11 February 2024).

Central Intelligence Agency 1948. *World Tin Situation*. Declassified CIA intelligence report SR-27. https://www.cia.gov/readingroom/docs/CIA-RDP78-01617A001600050001-8.pdf (accessed 17 November 2023).

Clarkebond 2020. *Phase 2 Ground Investigation: student accommodation and flexible workspace at Dalby Avenue and Whitehouse Lane, Plot 3, Bedminster, Bristol.* https://pa.bristol.gov.uk/online-applications/files/4EC04B3BDCF241307F79280885BCDC35/pdf/20_05811_F-PHASE_2_GROUND_INVESTIGATION_ATTACHMENT_4-2811301.pdf (accessed 13 July 2022).

Collins, E. J. T. (ed.) 2000. *The Agrarian History of England and Wales. Volume 7 1850–1914 (Part 2).* Cambridge: Cambridge University Press.

Collinson, J. 1791. *The History and Antiquities of the County of Somerset.* Volume 2. Bath: R. Cruttwell.

Collyns, D. 2022. *How Bolivia's Ruthless Tin Baron Saved Thousands of Jewish Refugees*. https://www.theguardian.com/world/2022/aug/11/bolivia-tin-baron-moritz-hochschild-saved-thousands-of-jewish-refugees (accessed 17 November 2023).

Cooksey, J. 2024. *Harris & Pearson*. https://www.harrisandpearson.info/jcookseyhistory.htm (accessed 23 January 2024).

Cornwell, J. 1990. 'Excavation and conservation works at the Golden Valley Colliery, Bitton', *BIAS Journal* 23, 2–25.

Costen, M. 2011. *Anglo-Saxon Somerset*. Oxford: Oxbow Books.

Cotswold Archaeology 2017. *St Catherine's Place, Bedminster Bristol: archaeological evaluation*. Cirencester: unpublished report ref. 17655.

Cotswold Archaeology 2018. *Sites at Dalby Avenue and Whitehouse Lane, Bedminster, Bristol: heritage desk-based assessment.* Cirencester: unpublished project ref. 6759.

Crew, P. 2021. *Perforated Tiles from Grain Drying Kilns and Malt Kilns – an introduction*. https://www.academia.

edu/5296626/A_catalogue_of_perforated_tiles_from_grain_drying_kilns_and_malt_kilns_v_8_2021_ (accessed 23 October 2023).

C. Tennant Sons & Co. 1961. *C. Tennant Sons & Co., of New York.* https://credo.library.umass.edu/view/pageturn/mums700-b0001-f012-i077/#page/1/mode/1up (accessed 20 January 2024).

Doughty, M. and Ward, O. 1975. 'Shortwood Brickworks', *BIAS Journal* 8, 10.

Drummond, J. C. and Lewis, W. R. 1939. 'Historical introduction', *Historic Tinned Foods* 85 (2nd edition). Greenford: International Tin Research and Development Council.

Dungworth, D. 2008. 'Glass-ceramic reactions in some post-medieval crucibles: an instrumental analysis study of archaeological samples', Glass Technology: *European Journal of Glass Science and Technology Part A* 49(4), 157–67.

Dungworth, D. 2013. 'Examination of samples of tin slag from St Just', 214–15, in Lawson-Jones, A., 'Discoveries along the North Land's End pipeline', *Cornish Archaeology* 52, 197–222.

Dunning, R. 1983. *A History of Somerset*. Chichester: Phillimore & Co.

Earl, B. 1991. 'Tin preparation and smelting', in Day, J. and Tylecote, R. F. (eds), *The Industrial Revolution in Metals*, 37–83. London: Institute of Metals.

Encyclopedia.com 2019. *The Morgan Crucible Company plc*. https://www.encyclopedia.com/books/politics-and-business-magazines/morgan-crucible-company-plc (accessed 31 January 2024).

Farthing, D. J. 2005. 'Differentiation of British blast and reverberatory furnace slag using morphology, mineralogy, and chemistry', in Kars, H. and Burke, E. (eds), Proceedings of the 33rd International Symposium on Archaeometry, 22–26 April 2002, Amsterdam, 335–8. Amsterdam: Vrije Universiteit.

Ford, B. M. 2017. 'Chapter 1: introduction', in Ford, B. M., Brady, K. and Teague, S., *From Bridgehead to Brewery: the medieval and post-medieval archaeological remains from Finzel's Reach, Bristol*, 1–24. Oxford: Oxford Archaeology.

Fowler, P. J. 1973. 'Post-medieval period', *Archaeological Review* 8. Bristol: CBA and University of Bristol.

Freeling, A. 1838. *Freeling's Grand Junction Railway Companion to Liverpool, Manchester, and Birmingham Guide*. London: Whittaker and Co.

Freshford.com 2023. *Alfred Capper Pass and Family*. https://www.freshford.com/pass.htm (accessed 24 November 2023).

Fretwell, M. 2014. *Carwarden Reclamation Yard, Rugeley, Staffs*. https://uknamedbricks.blogspot.com/2014/ (accessed 11 May 2022).

Gaskell, M. 1990. *Slums*. Leicester: Leicester University Press.

Graces Guide 2024a. *Harris and Pearson*. https://www.gracesguide.co.uk/Harris_and_Pearson (accessed 23 January 2024).

Graces Guide 2024b. *Rufford and Co*. https://www.gracesguide.co.uk/Rufford_and_Co (accessed 23 January 2024).

Graces Guide 2024c. *E. J. and J. Pearson*. https://www.gracesguide.co.uk/E._J._and_J._Pearson (accessed 23 January 2024).

Gregory, R. A., Dungworth, D., Wild., C. and Hughes, V. 2018. 'Exploring Bristol's historic glass industry: archaeological investigations at the Soap Boilers' and Hoopers' glasshouses, and Powell & Rickett's Bottle Works, Avon Street, Glass Wharf, Bristol', *Post-Medieval Archaeology* 52/2, 256–99.

Hallett, M. 2015. *War Grade Beer Bottle Stopper* https://talesfromthesupplydepot.blog/2015/06/08/war-grade-beer-bottle-stopper/ (accessed 6 December 2023).

Hammersley, E. 1992. 'The brickmakers of Avon: the quarry and checkweigher returns', *BIAS Journal* 25, 17–20.

Hatcher, J. 1993. *The History of the British Coal Industry Volume 1. Before 1700: towards the age of coal*. Oxford: Oxford University Press.

Harding, N. D. 1930. *Bristol Charters 1155–1373*. Bristol: Bristol Record Society.

Hayward, K. 2016. 'That prised global commodity – Glaswegian kiln bricks', in Nevell, M., *The Birth of Industrial Glasgow: the archaeology of the M74*. Edinburgh: Society of Antiquaries of Scotland, 106–8.

Hill, P. 2023. 'Part 3: Family Life at Wootton – Phillipa Hill', in *Alfred Capper Pass and Family*. https://www.freshford.com/pass.htm (accessed 22 November 2023).

Hillman, J. 1990. 'Bolivia and British Tin Policy, 1939–1945', *Journal of Latin American Studies* 22, 289–315. Cambridge: Cambridge University Press.

Historic England 2024. *Aerial Photo – raf_106g_uk_1415_rp_3001* https://historicengland.org.uk/images-books/archive/collections/aerial-photos/record/raf_106g_uk_1415_rp_3001 (accessed 22 January 2024).

Hudd, A. E. 1888. 'The Hospital of St Katherine, Brightbow, near Bristol', *Proceedings of the Clifton Antiquarian Club* 1, 256–76.

Hull, C. 1999. *Pewter*. Princes Risborough: Shire Publications Ltd.

Hunt, A. L. 1902. 'Fruits and vegetables, fish, and oysters, canning and preserving', *Twelfth Census of the United States. Census Bulletin* 209, 5–53. Washington: United States Census Office.

Huxtable, S.-A., Fowler, C., Kefalas, C., Slocombe, E. 2020. *Interim Report on the Connections between Colonialism and Properties now in the Care of the National Trust, Including Links with Historic Slavery*. https://www.courthousenews.com/wp-content/uploads/2020/09/colonial-uk-report.pdf (accessed 23 October 2023).

Jackson, R. 2019. *Bristol Potters and Potteries*. https://www.bristolpottersandpotteries.org.uk (accessed 21 November 2023).

Jeffries, N., Blackmore, L. and Sorapure, D. 2016. *Crosse and Blackwell 1830–1921: a British food manufacturer in London's West End*. London: MOLA.

Kent, O. 2017. *Another Kiln: The Pott House, Bedminster, Bristol*. https://drojkent.wordpress.com/2017/05/28/another-kiln-the-pott-house-bedminster-bristol/ (accessed 3

January 2024).

Kent, W. C. M. 1885. 'Berkeley, Francis Henry Fitzhardinge, M. P.', in Stephen, L. (ed.), *Dictionary of National Biography* 4, 345–6.

Latimer, J. 1970. *Annals of Bristol, Volume 1, Sixteenth and Seventeenth Century* (reprint of 1900 edition). Bath: Kingsmead Reprints.

La Trobe-Bateman, E. 1999. *Bedminster: extensive urban survey*. English Heritage and Avon County Council.

Lewin L. 1912. 'Die Bedingungen für die Bildung von Bleidampf in Betrieben', *Zeitschrift für Hygiene und Infektionskrankheiten* 73, 154–60.

Lewis, S. (ed.) 1831. *A Topographical Dictionary of England, Volume 1*. London: Lewis and Co.

Lewis, S. (ed.) 1835. *A Topographical Dictionary of England, Volume 1* (3rd edition). London: Lewis and Co.

Litten, J. and Strachan, A. M. 1995. 'Aspects of the closure of Capper Pass and Son', *Minerals Industry International* 26 (16), 28–34.

Little, B. 1963. *Capper Pass: the first hundred and fifty years*. London: Newman Neame Ltd.

Lockie, R. 2013. *Zion Chapel (Church of the Vow), Bedminster, Bristol*. https://churchdb.gukutils.org.uk/GLS1369.php (accessed 21 November 2023).

MacDermot, E. T. 1927. *History of the Great Western Railway, Volume 1*. London: Great Western Railway.

MacDermot, E. T. 1931. *History of the Great Western Railway, Volume 2*. London: Great Western Railway.

Malham, A., Aylett, J., Higgs, E. and McDonnell, J. G. 2002. 'Tin smelting slags from Crift Farm, Cornwall, and the effect of changing technology on slag composition', *Historical Metallurgy* 36, 84–94.

Mantell, C. L. 1949. *Tin, its Mining, Production, Technology and Applications*. New York: Reinhold.

Mason, C. 2017. 'Barton Hill Pottery and the post-medieval redware industry in Bristol', *Post-Medieval Archaeology* 51(1), 108–31.

Mason, C. 2020a. 'The medieval hospital of St Katherine: excavations at Factory No. 1, Bedminster, Bristol, 2015–18', *Transactions of the Bristol and Gloucestershire Archaeological Society* 138, 217–51.

Mason, C. 2020b. *Bath Quays Waterside: the archaeology of industry, commerce and the lives of the poor in Bath's lost quayside district*. Salisbury: Wessex Archaeology.

Massheder-Rigby, K. 2018. *The Housing Experience of the Working Classes 1790–1970: the potential of the combined approach of archaeology, the historical record and oral history*. University of Liverpool: unpublished PhD thesis

Matthews, A. F. 1946. *Minerals Yearbook 1946*. Washington: United States Department of the Interior.

Maw, W. H. and Dredge, J. (eds) 1892. 'Furnace temperature regulators', *Engineering: an Illustrated Weekly Journal* 56, 390.

Meeker, R. 1914. 'Lead poisoning in the smelting and refining of lead', *Bulletin of the United States Bureau of Labor Statistics* 141, Industrial Accidents and Hygiene Series 4. Washington: Government Printing Office.

Millington, L. (ed.) 2021. *The Worshipful Company of Tin Plate Workers Alias Wire Workers of the City of London Founded in 1670. The Company Today: in celebration of the company's 350th anniversary*. https://tinplateworkers.co.uk/wp-content/uploads/350th-Anniversary-History.pdf (accessed 8 October 2023).

Mitre, A. 1981. *Los Patriarcas de la Plata: estructura socioeconómica de la minería Boliviana en el siglo XIX*. Lima: Instituto de Estudios Peruanos.

Mokyr, J. 2003. *The Second Industrial Revolution, 1870–1914*. https://faculty.wcas.northwestern.edu/jmokyr/castronovo.pdf (accessed 22 January 2024).

Moorhead, S. 2013. *Silbury Hill, Wiltshire: Roman coins from the Silbury region*. English Heritage Research Department Report Series 102-2011.

Morgan Advanced Materials 2024. *History*. https://www.morganadvancedmaterials.com/en-gb/who-we-are/history/ (accessed 31 January 2024).

Murray, T. and Mayne, A. 2001. 'Imaginary landscapes: reading Melbourne's "Little Lon"', in Mayne A. and Murray T. (eds), *The Archaeology of Urban Landscapes: explorations in slumland*, 89–105. Cambridge: Cambridge University Press.

Muspratt, S. 1860. *Chemistry. Theoretical, Practical and Analytical*. Glasgow: Mackenzie.

Newman, H. R. (ed.) 1992. 'United Kingdom', *Minerals yearbook. Mineral industries of Europe and central Eurasia 1992, Volume 3*. US Bureau of Mines.

Owusu-Apenten, R. and Vieira, E. R. 2023. *Elementary Food Science* (5th edition). Cham: Springer Nature Switzerland.

Ørsted, Hans C. 1823. 'Nouvelles expériences de M. Seebeck sur les actions électro-magnétiques', *Annales de Chimie et de Physique* 22, 199–201.

Page, W. (ed.) 1911. *A History of the County of Somerset: Volume 2*. London: Victoria County History.

Pass, A. C. 1887. 'Recent excavations at Silbury Hill', *The Wiltshire Archaeological and Natural History Magazine* 23, 245–54.

Penny, J. 2001. *Luftwaffe Operations Over Bristol 1940/44*. Bristol: Bristol Branch of the Historical Association Pamphlet 85.

Penny, J. 2005. *Bristol at Work*. Derby: Breedon Books.

Percy J. 1861. *Metallurgy: the art of extracting metals from their ores*. London: John Murray.

Percy, J. 1870. *The Metallurgy of Lead, Including Desilverization and Cupellation: the art of extracting metals from their ores*. London: John Murray.

Planché, J. R. 1836. *History of British Costume*. London: Charles Knight.

Powerhouse Collection 2024. *Crucibles made by Morgan Crucible Co.* https://collection.powerhouse.com.au/object/1820 (accessed 31 January 2024).

Ramsey, K. 2003. *The Bristol Coal Industry*. Bristol: Bristol Branch of the Historical Association Pamphlet 106.

Rand, J. 2023. *1945 August 20-26: How Tin Cans Helped Win the War* https://www.lacrosselibrary.org/sites/default/files/u117/34-how_tin_cans_helped_win_the_war_0.pdf (accessed 14 December 2023).

Sanders, I. J. 1960. *English Baronies: a study of their origin and* *decent 1086–1327*. Oxford: Clarendon Press.

Scotland's Brick and Tile Manufacturing Industry 2024a. *Glenboig Union Fireclay Company, Glenboig, North Lanarkshire – History*. https://www.scottishbrickhistory.co.uk/glenboig-union-fireclay-company-glenboig-north-lanarkshire-history/ (accessed 23 January 2024).

Scotland's Brick and Tile Manufacturing Industry 2024b. *Dykehead Fire Brick Works, Bonnybridge, Falkirk, Stirlingshire*. https://www.scottishbrickhistory.co.uk/dykehead-fire-brick-works-bonnybridge-falkirk-stirlingshire/ (accessed 23 January 2024).

Skrabec, Q. R. 2009. *H. J. Heinz: a biography*. North Carolina: McFarland & Co. Inc.

Smith, R. 1978. 'Tin in copper base alloys', in Price, J. W. and Smith, R. (eds), *Tin*, 199–200. Berlin: Springer Verlag.

Smith, R. 1996. 'An analysis of the processes for smelting tin', in Newman P. (ed.) *The Archaeology of Mining in South West Britain*, 91–9. London: Historical Metallurgy Society.

Smith, R. and Jones, G. V. 1981. *The Sampling of Bulk Materials*. Analytical Sciences Monograph No. 8. London: The Royal Society of Chemistry.

Smith, T. P. 2005. 'Aspects of the site: the materials used to construct the kilns, the kiln furniture and the products', in Tyler, K., Brown, J., Smith, T. P. and Whittingham, L., *The Doulton Stoneware Pothouse in Lambeth: excavations at 9 Albert Embankment, London*, 32–42. London: Museum of London Archaeology Service Archaeology Studies Series 15.

Smyth, J. 1883. *The Berkeley Manuscripts: the lives of the Berkeleys, lords of the honour, castle and manor of Berkeley, in the county of Gloucester, from 1066 to 1618*. Gloucester: John Bellows.

Solari, E.-M. 2001. 'The making of an archaeological site and the unmaking of a community in West Oakland, California', in Mayne A. and Murray T. (eds), *The Archaeology of Urban Landscapes: explorations in slumland*, 22–38. Cambridge: Cambridge University Press.

Stephens, W. B. (ed.) 1964. 'Economic and social history: industry and trade, 1500–1880' in, *A History of the County of Warwick: volume 7, the city of Birmingham*. British History Online. https://www.british-history.ac.uk/vch/warks/vol7/pp81-139 (accessed 17 October 2024).

Strachey, J. 1731. 'An alphabetical list of the religious houses of Somerset', in Hearne, T., *Walteri Hemingford, Historia De Rebus Gestis Edvardi I, Edvardi II, & Edvardi III. Volumen Secundem*, 643.

Stratton, M. and Trinder, B. 2000. *Twentieth Century Industrial Archaeology*. Abingdon: Taylor and Francis.

Symonds, H. (ed.) 1915. 'List of members of the Dorset Natural History and Antiquarian Field Club', *Proceedings of the Dorset Natural History Society* 36, 20.

Tait, J. 1898. 'Stafford, Henry (1454?–1483)', in Lee, S. (ed.), *Dictionary of National Biography* 53, 448–50.

Taylor, M. and Shapland, M. 2012. *Bristol's Forgotten Coalfield, Bedminster. A Detailed History of the Coal Mines*. Bristol: South Gloucestershire Mines Research Group.

Teague, S. 2017. 'The development of the suburb in the early 12th century', in Ford, B. M., Brady, K. and Teague, S., *From Bridgehead to Brewery: the medieval and post-medieval archaeological remains from Finzel's Reach, Bristol*, 125–6. Oxford: Oxford Archaeology.

The American Engineer 1887. 'Composition and uses of solder', in *The American Engineer: an illustrated weekly journal* 13. Chicago: The American Engineer Publishing Co.

The Worshipful Company of Tin Plate Workers Alias Wire Workers of the City of London 2023. *History and Heritage*. https://tinplateworkers.co.uk/about-the-company/history-and-heritage/ (accessed 8 October 2023).

Tuck, H. 1848. *The Railway Shareholder's Manual; or Practical Guide to all the Railways in the World, Completed, in Progress, and Projected; Forming an Entire Railway Synopsis, Indispensable to all Interested in Railway Locomotion* (9th edition). London: Effingham Wilson

Tylecote, R. F. 1992. *A History of Metallurgy*. London: Institute of Materials.

Tylecote, R. F., Photos, E. and Earl, B. 1989. 'The composition of tin slags from the south-west of England', *World Archaeology* 20, 434–45.

University of Bristol 2024. *Ceremonial Mace*. https://www.bristol.ac.uk/centenary/look/cabinet/mace.html#:~:text=Badock%20was%20Chairman%20of%20Capper,University%27s%20Council%20at%20various%20times. (accessed 15 April 2024).

Ure, A. 1839. *A Dictionary of Arts, Manufactures and Mines*. London: Longman, Orme, Brown, Green and Longmans.

Vincent, B. 2022. *The Pass Family and Smelting Industry in Bristol*. Bristol: ALHA Books 35.

Virtual Genocide Memorial 2023. *Sanak Afyonkarahisar Nikopolis*. https://virtual-genocide-memorial.de/region/the-black-sea-marmara-and-aegean-littorals-eastern-thrace-and-central-anatolia/bursa-prousa-vilayet-province/sancak-afyonkarahisar-nikopolis/ (accessed 22 November 2023).

Volo, J. M. and Volo, D. 2007. *Family Life in 19th-century America*. New York: Bloomsbury Publishing USA.

Ward, J. C. 2008. 'Berkeley, Elizabeth, countess of Warwick (c. 1386–1422), magnate', *Oxford Dictionary of National Biography*. https://doi.org/10.1093/ref:odnb/56573.

Wessex Archaeology 2022. *Plot 3, Bedminster Green, Dalby Avenue and Whitehouse Lane, Bedminster, Bristol: post-excavation assessment and updated project design*. Bristol: unpublished report ref. 253160.2.

Wessex Archaeology 2023. *Bristol Digital Futures Institute, 65 Avon Street, St Philip's Marsh, Bristol*. Bristol: unpublished report ref. 223262.3.

West Country Bottles 2023. *Bedminster Brewery at East Street*. http://westcountrybottles.co.uk/mike4/Companies/Bristol_Companies/BedminsterB1.html (accessed 21 November 2023).

Wilkinson, K., Jones, B. and Meara, R. 2013. *Distribution and Significance of Urban Waterlogged Deposits in Bristol*. Cirencester: Cotswold Archaeology report 13014.

Williams, B. 2005. 'Review of Archaeology 2003–2004', *Bristol and Avon Archaeology* 20, 128.

Williams A. and Martin G. H. (eds) 1992. *Domesday Book: A Complete Translation*. Alecto Historical Editions. London: Penguin.

Willies, L. M. 1991. 'Lead: ore, preparation and smelting', in Day, J. and Tylecote, R. F. (eds), *The Industrial Revolution in Metals*, 84–130. London: Institute of Metals.

Willies, L. M. and Cranstone, D. 1992. *Boles and Smeltmills*. London: Historical Metallurgy Society.

Wright, P. A. 1966. *The Extractive Metallurgy of Tin*. London: Elsevier.

LIST OF MAPS AND PLANS CONSULTED

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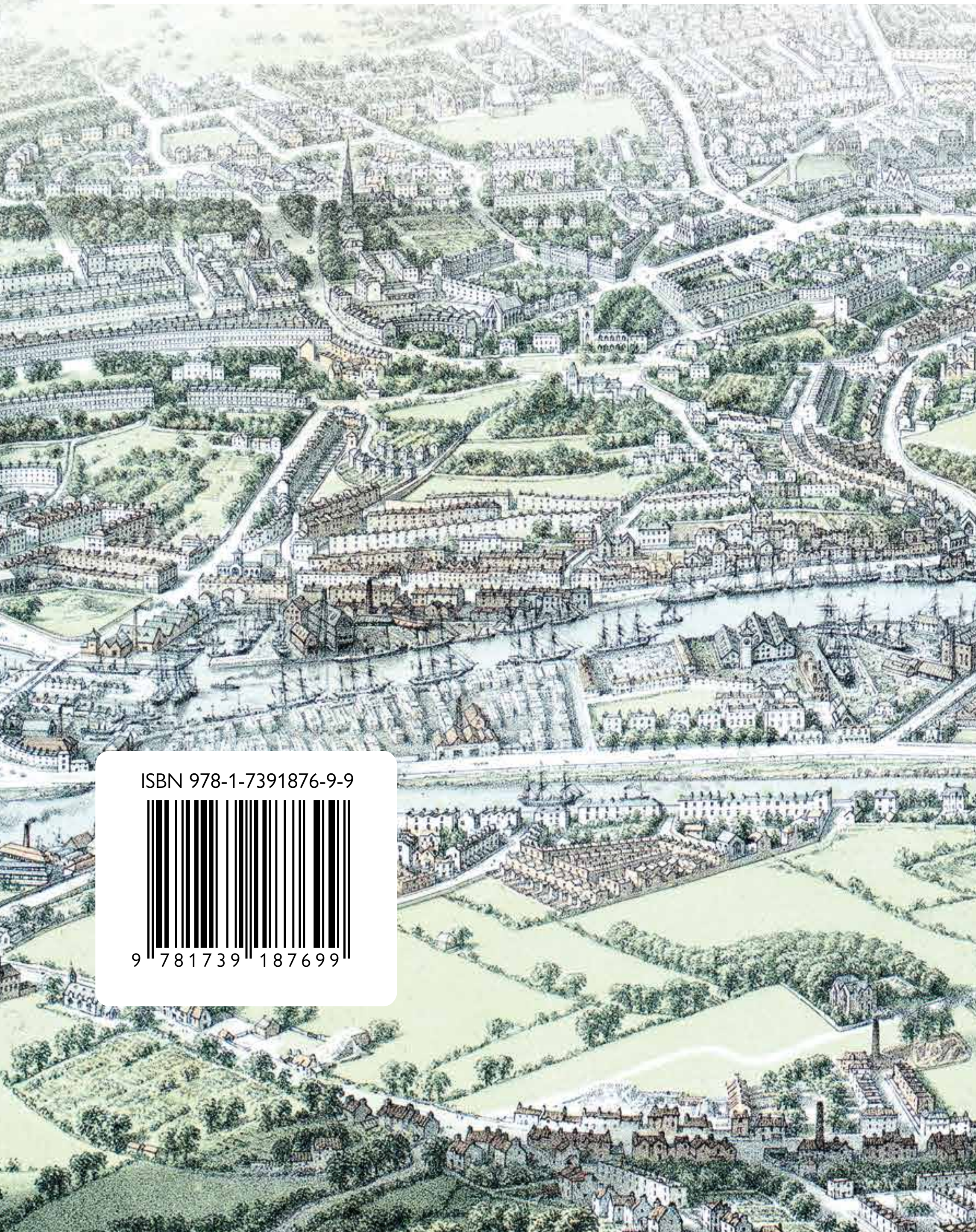
Excavations ahead of the Metal Works development in the Bedminster district of Bristol provided an opportunity to investigate a specialist non-ferrous smelting works that flourished during the Second Industrial Revolution of 1870–1914.

The company originated as a backyard operation run by the eponymous Capper Pass in late 18th- and early 19th-century Walsall, Birmingham and Bristol. Small and unreliable profits led Pass to dabble in criminality, something that resulted in his permanent transportation to Australia in 1819. The family's fortunes were revived by his son and namesake Capper Pass II, who in 1840 established a new smelting yard in Bedminster. Although modestly successful, the business remained small until 1866, when he and his son Alfred Capper Pass discovered a product – solder – that produced reliable and increasingly large profits. As the company grew, adjacent streets were subsumed by the smelting works. Twentieth-century innovations, such as the use of electrorefining to process Bolivian tin ore, helped keep the company afloat during the inter-war period, but its location, hemmed in on all sides by streets of terraced housing, hampered further expansion. In 1937, the company opened a new works in Melton, Yorkshire, and in 1963, the Bedminster works closed.

Archaeological excavation has revealed complex and hitherto unknown details of the smelting works, including the remains of numerous buildings, furnaces and associated cellars and underground flues, and the remains of 19th-century terraced houses. Metallurgical and technological analysis has uncovered aspects of production processes, whilst artefacts and documentary records reveal evidence of global trading links, and how the smelting works affected the social makeup and development of Bedminster in the 19th and early 20th centuries.



ISBN 978-1-7391876-9-9