CORNING'S GLASSWORKS,

LISBURN TERRACE,

SUNDERLAND

TYNE AND WEAR

Final Excavation Report

Oxford Archaeology North

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SUMMARY

Outline planning permission (ref 10/01549/OUT) has been obtained by St Modwen Ltd for the redevelopment of the site of the former Corning's Glassworks, situated in the Millfield area of Sunderland, Tyne and Wear (centred on NGR 438359 557345). A desk-based assessment of this *c* 6.75ha former industrial site, carried out by Under Construction Archaeology in 2009, highlighted the potential for the remains of two sites of archaeological interest to survive: the Wear Flint Glassworks (taken over subsequently by Corning); and the Wearside Pottery. Intrusive evaluation work carried out by Pre-Construct Archaeology (PCA) in 2010 confirmed that important buried remains of these two former industrial sites survived *in-situ*. Further excavation of the glassworks and the pottery was carried out subsequently, comprising the mechanical excavation of demolition rubble and overburden from the areas of identified archaeological interest. However, manual clearance and detailed archaeological recording of the exposed remains was not carried out, leaving conditions attached to the outline planning consent unfulfilled.

In March 2011, Oxford Archaeology North (OA North) was commissioned by Prospect Archaeology Ltd, acting on behalf of St Modwen Ltd, to complete the archaeological investigation on the site, which was carried out during April and May 2011. This necessitated the excavation of three targeted areas: Area 1 was focused on the remains of the Wearside Pottery; and Areas 2 and 3 examined elements of the Wear Flint Glassworks.

The earliest remains exposed during the excavation represented elements of the Wear Flint Glassworks, as depicted on the Ordnance Survey map of 1897. The remains of one of the four square flues for the glass-melting furnaces were identified, in addition to associated flues and the external walls of the glasshouse. The development of the glassworks through the late nineteenth and twentieth centuries can be traced through the remodelling of the historic fabric revealed during excavation. This mirrors the technological developments of the industry in general at this time, with the original pot kiln in the south-western corner of the site firstly being replaced with a continuous Siemens-type regenerative furnace, and subsequently by an end-port recuperative borosilicate furnace for the production of Pyrex in the early twentieth century.

Fragmentary glass vessels were recovered across the glassworks site, samples being obtained of various deposits and industrial residues. The well-preserved foundations of a mid-twentieth-century pottery kiln were also exposed during the excavation.

A post-excavation assessment of the dataset was compiled following the completion of the fieldwork. This concluded that elements of the dataset had good potential to address several regional and national research aims, unique to the work undertaken in Sunderland, and merited further analysis (OA North 2012). In particular, the assemblage of glass fragments recovered from the excavation was considered worthy of chemical analysis, whilst the stratigraphic data had good potential to yield further detail of the developmental sequence of the glassworks. This report summarises the results of this analytical programme.

ACKNOWLEDGEMENTS

OA North wishes to thank Nansi Rosenberg of Prospect Archaeology Ltd for commissioning and supporting the project on behalf of St Modwen Ltd. Thanks are also expressed to Jennifer Morrison, the Archaeology Officer for Tyne and Wear, for her guidance and advice. OA North is also grateful to Dr David Dungworth for providing advice on glass-sampling strategies, and for carrying out the post-excavation assessment and analysis of the glass recovered from the excavation. Further thanks are offered to Hawk Demolition Ltd for logistical support throughout the fieldwork programme, and to Greg Colley of Suave Aerial Photography for taking high-level photographs of the archaeological excavation.

The fieldwork was directed by Chris Wild (Project Officer), who was also responsible for the site survey. The fieldwork was completed by Andrew Frudd (Supervisor), Phil Cooke, Paul Dunn, John Onraet and Aiden Parker. This report was written by Chris Wild, Ian Miller and Andrew Frudd, with contributions on the glass from Dr David Dungworth, and on the other material categories from Christine Howard-Davis. The illustrations were produced by Mark Tidmarsh. The report was edited by Ian Miller, who was also responsible for project management.

1. INTRODUCTION

1.1 CONTRACT BACKGROUND

1.1.1 This document presents the results obtained from the post-excavation assessment and subsequent analysis of the archaeological dataset generated by the fieldwork undertaken by Oxford Archaeology North (OA North) on the site of the former Corning's Glassworks in Sunderland, Tyne and Wear (Fig 1). The archaeological work was required to satisfy three conditions attached to outline planning permission (ref 10/01549/OUT) for a proposed residential redevelopment of the site by St Modwen Ltd. The planning conditions stated:

> 12) No development shall commence until a programme of archaeological fieldwork (to include evaluation and where appropriate mitigation excavation) has been completed. This shall be carried out in accordance with a specification provided by the Local Planning Authority. The investigation is required to ensure that any archaeological remains on the site can be preserved wherever possible and recorded, in accordance with UDP policies B13, B14, and B15;
>
> 13) No more than 20 dwellings shall be occupied / brought into use before the final report of the results of the archaeological fieldwork undertaken in pursuance of archaeological conditions has been submitted to and approved in writing by the Local Planning Authority;
>
> 14) No more than 20 dwellings shall be occupied/brought into use into use before a report detailing the results of the archaeological fieldwork undertaken has been produced in a form suitable for publication in a suitable and agreed journal and has been submitted to and approved in writing by the Local Planning Authority prior to submission to the editor of the journal. The publication of the results will enhance understanding of and will allow public access to the work undertaken in accordance with advice handed down in PPS5 and to comply with policies B11, B13 and B15 of the UDP.

1.1.2 In line with Condition 12, a series of evaluation trenches was excavated by Pre-Construct Archaeology in 2010, which identified buried remains that merited further excavation in advance of development. Following consultation with the Tyne & Wear Archaeology Officer (TWAO), the archaeological advisor to Sunderland City Council (SCC), Prospect Archaeology Ltd devised an appropriate scheme of mitigation excavation (*Appendix 1*).

1.1.3 In March 2010, OA North was commissioned by Prospect Archaeology Ltd, acting on behalf of St Modwen Ltd, to undertake the specified archaeological investigation, which was carried out during April and May 2011. This allowed for the detailed archaeological investigation of three targeted parts of the site: Area 1 was focused on the remains of the Wearside Pottery; and Areas 2 and 3 examined elements of the Wear Flint Glassworks.

1.1.4 A post-excavation assessment the project archive was compiled following completion of the fieldwork (OA North 2012). This concluded that elements of the dataset merited further analysis, the results of which are presented in this document.

1.2 SITE LOCATION AND GEOLOGY

1.2.1 ***Location:*** the scheme area (centred on NGR 438359 557345) lies to the west of Sunderland town centre, and covers approximately 6.75ha. The northern boundary of the site is formed by Pallion New Road and some industrial premises in the north-west corner (Plate 1). Lisburn Terrace forms the western boundary, whilst the Tyne and Wear Metro train line represents the south-western boundary (Fig 1).

1.2.2 ***Geology:*** the site lies on Dolostone bedrock of the Roker Formation. This is overlain mainly by Pelaw Clay, with the extreme north and west of the site being Devensian Glaciolacustrine deposits (Under Construction Archaeology 2009).

Plate 1: Aerial view of the study area prior to demolition

1.3 HISTORICAL OVERVIEW

1.3.1 Whilst a settlement at Sunderland is referred to in documents as early as the twelfth century, the early history of the area is of little relevance to the present study; an account of the historical development of Sunderland is presented in the desk-based assessment of the site (Under Construction Archaeology 2009). It is of note, however, that Wearside experienced significant growth from the mid-seventeenth century, based largely on an expansion of the area's coal-mining industry and associated development of the shipping and ship-building trades (Milburn and Miller 1988). The availability of a local source of cheap coal, moreover, acted as a catalyst for the development of other industries. Amongst those that had emerged as being important locally by the end of the seventeenth century were the salt industry and glass manufacturing (Baker 1984).

1.3.2 Notwithstanding the emergence of Sunderland as an industrial town during the post-medieval period, the present study area remained undeveloped in the mid-nineteenth century, as shown on the Ordnance Survey map of 1858 (Plate 2). The land formed part of the estate of Diamond Hall, situated immediately to the north-west of the study area boundary.

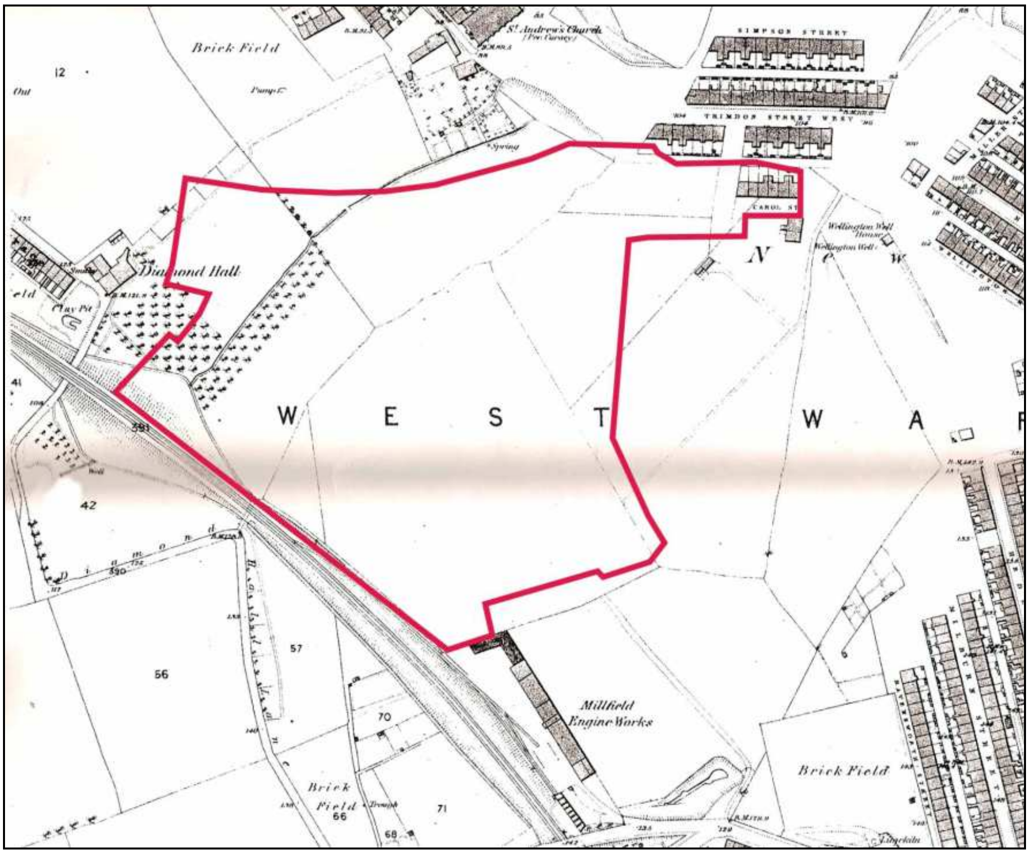

Plate 2: Extract from the Ordnance Survey map of 1858, with the study area boundary superimposed

1.3.3 Industrial development of the site was stimulated by the construction of a railway line, which was laid along the western boundary of the scheme area in 1852-4 (Under Construction Archaeology 2009). Thereafter, the site was developed for industrial usage. Notwithstanding the development of the Millfield Engine Works shown on the Ordnance Survey map of 1858 (Plate 2), the first industry to occupy the scheme area was the Wear Flint Glassworks, which was established by James Angus and Henry Greener. This partnership's first glassworks was on Harrison Street in Millfield, moving to the study area following the death of Angus in 1869 (*Section 1.5.6 below*). Greener's new works was erected across the southern part of the present study area, as shown on the Ordnance Survey map of 1897 (Fig 2).

1.3.4 The subsequent edition of Ordnance Survey mapping, published in 1919 (Fig 3), shows that the Wearside Pottery and an engineering works had been established immediately to the north-west of the glassworks. The pottery and the glassworks were both extended during the following years, and had infilled the southern part of the site completely by 1941 (Fig 4).

1.4 DEVELOPMENT OF THE ENGLISH GLASS INDUSTRY

1.4.1 Glass-making was introduced to Britain by the Romans, although the character and scale of glass production during this period is poorly understood. It is unclear whether glass was made from raw materials, or melted from imported pre-manufactured material (Angus-Butterworth 1958). During the Middle Ages, the industry was concentrated in heavily forested areas, as glass-makers required a ready supply of wood to fuel their furnaces, and bracken as a source of potash. The traditional centre of glass-making was the Weald of Sussex and Surrey (Ashmore 1969, 123), although there were smaller local production areas, such as the Forest of Dean, and there is some evidence for glass-making in Bristol and Gloucester during the early fourteenth century (Grimke-Drayton 1915). Glass production during this period was carried out on a fairly small scale, and the glass was of a poor quality, reflecting the simple furnace design of the time, and the impurities within the potash that was used (Dungworth 2003, 2). The quality of glass improved dramatically during the late sixteenth century as a result of the influence of immigrant French glass workers (Vose 1980, 106-10).

1.4.2 In 1615, James I banned wood as a fuel for glass furnaces, forcing glass-makers to consider redesigning their furnaces to operate on coal. This required a solution to several technical difficulties; coal burns with a shorter flame than wood and therefore requires the heat source to be closer to the glass melting pots, and the burning of coal also demands much larger volumes of air. These requirements led to the introduction of furnaces with grates and deeper flues (Crossley 1990, 232-5). The use of coal necessitated modifications to furnace superstructures to facilitate the efficient venting of sulphur produced from burning coal, leading to the development of the English glass cone furnace, designed to remove smoke and soot, and to create a stable atmosphere, in addition to increasing the size of glass furnaces. This structure comprised an open-ended cone around and over the furnace, increasing the draught through the grate, whilst maintaining a steady working temperature around the furnace (Parkin 2000, 8). After its introduction in the late seventeenth century, the cone furnace became widely recognised as a classic symbol of the English glass-making industry (Plate 3).

1.4.3 The sudden change of fuel source, from wood to coal, also resulted in a shift in the focus of the industry, from the traditional centres in the south of the country to those with accessible coalfields (Ashmore 1969, 123). Hence, Bristol, Stourbridge, Newcastle upon Tyne, Wearside, South Lancashire and South Yorkshire all developed as important glass-making centres during the seventeenth century, although London also boasted a considerable number of glass cones.

1.4.4 Whilst it has been argued that Britain became a net exporter of glass and was at the forefront of European glass-making during the seventeenth century (Charleston 1984), the finest colourless glass was still produced by Venetian workers and imported to Britain until the later part of the century. In 1676, however, George Ravenscroft succeeded in producing good-quality colourless glass in England by introducing lead in addition to potash as a flux.

1.4.5 The invention of colourless lead glass, which is also known as lead crystal or flint glass, had a profound impact on glass manufacture (Dungworth 2003, 5). Upon the expiry of Ravenscroft's patent in 1681, the production of lead glass was taken up by numerous glass-makers; in a list of 88 glasshouses compiled by John Houghton in 1696, 27 were producing 'flint glass' (Vose 1980, 198-9). Houghton's list also indicates that Tyneside had 11 glasshouses at this time, with only Stourbridge (17) having more. The development of the glass industry on Tyneside certainly began earlier than those of other large cities, such as Birmingham, Manchester and Liverpool, which date from the eighteenth century (Dodsworth 1982).

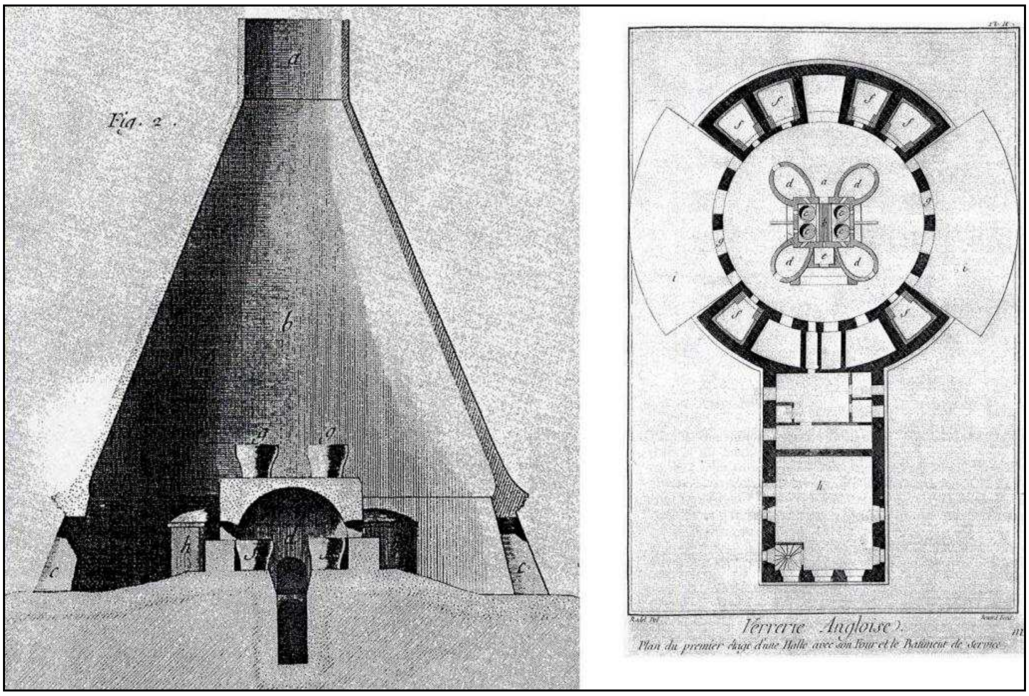

Plate 3: Section and plan of an eighteenth-century glass cone (taken from Diderot 1771)

1.4.6 It is widely thought that covered glass-making crucibles were introduced shortly after Ravenscroft's development of lead glass, although there is no historical or archaeological evidence to support this conjecture (Vose 1980, 147). However, during the mid-seventeenth century, Merrett described open crucibles that were 20 inches wide at the rim and narrowed down towards the base (Neri 1662). Crucibles were often referred to as pots, and were either manufactured on site from imported raw clay, or were imported from the Midlands, where the clays were particularly suitable for producing heat-resistant refractory bricks and crucibles.

1.4.7 Glass was produced in three main types during this period (Wills 1974), the simplest being bottle glass, which used less-expensive ingredients and was often dark greens and browns, sometimes referred to as 'black' glass. Ornamental and table glass, usually referred to as 'flint' or 'lead' glass, was pale or colourless, and manufactured using higher-quality, more expensive, ingredients. The third type of the period was window glass, also known as crown glass (Powell 1925, 214). In all cases, the raw materials, referred to as 'batch', were placed into the pots and gradually heated from the furnace.

1.4.8 The raw materials could include silica, often in the form of sand; alkali from sources such as potash, kelp ash, and soda ash; lime derived from either limestone or high-lime sand; colouring agents; and often 'cullet', which was reused and reheated. Once the batch was heated and the chemical processes under way, the material became known as 'metal', and it was imperative to keep it free from smoke, grit or other impurities (Angus-Butterworth 1958). Higher temperatures were required to melt the batch fully, and once this was achieved, the metal was allowed to cool slightly so that it was workable. Glass-making operations varied according to the types of glass being made, but all were originally based on glassblowing (Plate 4), whereby a quantity of molten glass was picked up on the end of a long metal tube, and then blown to the required shape and size (Chaloner and Musson 1969).

Plate 4: Glassworking in the mid-eighteenth century (taken from Chaloner and Musson 1969)

1.4.9 A major advance in the industry was an improvement in the production of plate glass, whereby molten glass was poured onto a metal casting-table and then flattened into thick plates or sheets by heavy rollers (Plate 5). The glass was finished by grinding and polishing. The first company for the manufacture of English plate glass was established in 1773, and commenced its operations at Ravenhead, near St Helens (Redding 1842, 89). The workmen for this enterprise were brought over from France, but by the mid-nineteenth century, 'the great majority of persons employed are Englishmen' (*op cit*, 90). Redding also claimed that English glass of the nineteenth century was superior to that of either the French or Venetian artisans as a direct result of 'the application of chemical and mechanical science to the improvement of several processes', but noted that 'great jealousy is manifested by the proprietors in keeping secret the details of their processes' (*ibid*).

1.4.10 The round reverbatory furnaces of the early nineteenth century generally contained either two, or four, crucibles, with the period 1835-50 seeing enlargements to accommodate eight or ten crucibles, each with a capacity of up to 5cwt of molten glass (Parkin 2000, 14). The circular nature of the early eighteenth-century furnaces and cones allowed a number of pots/crucibles to be placed around the heat source. However, the pots and central furnace system were not an efficient use of fuel and the melting was problematic.

1.4.11 The concept of a tank and furnace system was proposed as early as 1769 (Cable 2000), but it was not until 1840 that a more workable system was initiated by Joseph Crossfield. The demand for a new type of furnace was driven by the window-glass sector of the industry, which, by the mid-nineteenth century, had become monopolised by three large concerns: Chances, in Birmingham; Pilkingtons, in St Helens; and Hartleys, in Sunderland. Each attempted to gain temporary advantage by technological innovation. Windle Pilkington was keen to economise the use of fuel, and was drawn to the work of William and Frederic Siemens, who had been working on such a task for the reduction of fuel used in iron furnaces (Nagel 1909).

1.4.12 Following the Salford-based physicist James Joule's discovery, in 1845, that the mechanical equivalent of heat could quantify how heat could be converted into mechanical work, several of his contemporaries saw its potential for application to industry. Among them was Carl Wilhelm Siemens (later Sir (Charles) William Siemens), a German, working in England for his elder brother Ernst's communications technology company. His first attempt in heat conservation was to construct a regenerative condenser, providing superheated steam to a four horse-power steam engine belonging to John Hick of Bolton in 1847. A modified version was applied to the steam engine of Messrs Fox, Henderson, and Co, of Smethwick, in 1849, and although both had limited success, Siemens was awarded a gold medal by the Society of Arts in 1850 for his endeavour, acknowledging the value of the principle. During the early part of the next decade, he, and younger brother Frederic, changed the focus of their work to furnace design. Working initially with the iron industry, the brothers adapted the principles of their regenerative condenser to create a regenerative furnace (Krupa and Heawood 2002).

1.4.13 As outlined in the original patent of 1856 (British Patent 2861), entitled '*Improved arrangement of furnaces which improvements are applicable in all cases where great heat is required*', the furnace worked by:

> 'arranging smelting and heating furnaces....that the products of combustion on their passage from their place of combustion to the stack or chimney shall pass over an extended surface of brick, metal or other suitable material imparting heat thereto...The result of this arrangement is that the air or other materials of combustion are nearly heated to the degree of temperature of the fire itself, in consequence whereof an almost unlimited accumulation of heat or intensity may be obtained' (British Patent 2861).

1.4.14 This original furnace design contained two pairs of regenerative chambers beneath the furnace, each packed with bricks in open Flemish bond, *ie* a chequer-pattern of unbonded brick, stacked in such a way that gases could pass through. Hot exhaust gases leaving the furnace flowed downwards through one pair of regenerative chambers, imparting a substantial part of their heat to the brick chequerwork, on their way to the chimney, Once the bricks were sufficiently hot, the direction of gas flow in the system was reversed by a series of valves to allow the hot bricks to heat up the gas and air entering the furnace via the other pair of chambers, whilst the exhaust gases reheated the opposing pair. This pre-heating of gases gave a considerable reduction in fuel, William Siemens suggesting that the figure was as high as 70-80% (British Patent 1320).

1.4.15 It was this original design that stimulated the interest of Windle Pilkington, who realised that the furnaces for iron smelting and glass production were not dissimilar. In 1857, the Siemens brothers obtained a further patent (British Patent 1320), entitled '*Improvements in Furnaces and in the Application of Heated Currents*', which specifically mentions the potential use of the furnace for 'melting glass'. Such a furnace was installed in a glassworks in Rotherham in 1860 (Krupa and Heawood 2002, 10).

1.4.16 A second breakthrough in the Siemens redesigning of the furnace was the removal of the coal-powered fireplace, and its replacement with a gas supply, located away from the furnace. Both the modifications to the furnace and method of gas supply were patented by the Siemens brothers in 1861 (British Patent 167, 1861), the specification in the patent referring specifically to 'furnaces for melting glass or for other purposes', demonstrating that the technology was now being driven by the glass, rather than iron industry.

1.4.17 The use of producer gas brought several improvements to the production of glass, mainly economic, but also introducing better quality and reliability. There was a further increased saving in fuel costs, even over the remarkable saving of the original furnace of 1856, as the gas-producer units could be fuelled with 'slack', the lowest grade of extracted coal, available far more cheaply than the higher grades required previously. This had a benefit not only in the areas of the coalfields, like St Helens and Bristol, where huge quantities of slack could be procured extremely cheaply, but also areas like South Staffordshire, where only the lower grade could be mined in any quantities, reducing the cost of fuel from 12s 6d per ton to 3s or 4s (Siemens 1862, 35).

1.4.18 Gas producers also used less fuel. By way of an example, a steel-smelting furnace in the Gorton area of Manchester in 1865, which had previously been utilising 7cwt of coal, only required 4cwt, 1qtr, 5lbs of slack to produce the same quantity of steel (Brown 1866, 142). The slack, coal, or alternatively even coke dust, lignite, or peat (Siemens 1862, 26) was heated gently on an inclined fire-grate, fed from above with slack, via a hopper onto an inclined brick plane. An arch of firebrick above the grate, and heated by it, imparted heat to the new coal slack as it travelled down the incline, beginning the decomposition process before it reached the grate itself. When mixed with air rising through the grate, these gases formed carbonic acid gas (H_2CO_3), which then rose through the partially decomposed material above, onto which droplets of water were added via a small pipe, the resultant gas comprising carbon monoxide (CO) and hydrogen. This then rose into a flue linked to the regenerative chambers.

1.4.19 Not only did this produce a great economic saving in fuel costs, but the use of gas rather than a solid fuel also improved the working of the furnace. By introducing dampers into the air and gas channels, the quantity and quality of the flame within the furnace could be regulated 'to the utmost nicety' (British Patent 167). A further advantage of using gas instead of solid fuel was that the lack of any solid particles or ash in the working chamber of the furnaces enabled the use of open crucibles. 'We are thus enabled to melt flint and other superior qualities of glass in open pots' (*ibid*). Siemens also claimed that:

> 'fewer pot breakages also occur, less repairs are required, and the amount of waste has decreased; moreover, the glass metal is obtained from a cheaper composition than that hitherto used, and proves to be of a far superior quality. The pots last fully double the time, and melt more than three times the quantity of material, whilst the furnace itself stands for three years; that is, it lasts six times as long, and melts more than nine times the quantity of material it did previously to its reconstruction' (Siemens 1873, 5).

1.4.20 The new furnace proved popular and, significantly, was immediately trialled by the Chance Brothers in Birmingham in 1861, under close monitoring by the Siemens brothers. Pilkingtons, based in St Helens, quickly followed suit, installing a similar furnace in 1863 (Krupa and Heawood 2002, 13). Thus, by the end of 1863, England's two largest glass-manufacturing firms were operating Siemens' gas-powered furnaces.

1.4.21 Despite the exceptional economic savings of this early Siemens furnace, it still operated essentially in the same manner as the traditional glass furnace, production being stifled by the limited number of pots (crucibles) that could be heated, and the cycle of heating, working, cooling, and recharging the pots, which took between two and three days for each batch (Krupa and Heawood 2002, 10). It appears to have been the Pilkington family that seized the initiative from the Chances, working at first independently, but then in conjunction with the Siemens brothers, who had been attempting to develop a cistern or tank furnace for several years (Cable 2000). This was first presented in a patent of 1870 (British Patent 1513, 1870), which was concerned mainly with improvements to gas producers, mentioning improvements to pots, and the introduction of tanks almost as a footnote.

1.4.22 This provided the basis for continuous working of the furnace, with the tank divided into three compartments: one receiving raw materials; a central 'clarifying' compartment; and a semi-circular working end. Each compartment was separated by refractory brick walls, with inter-connecting channels, to allow flow through the solid brick tank. Heat was applied at different intensities along the tank, with higher temperatures required to melt the 'batch' (raw materials), than the 'metal', with a further reduced temperature required for the 'gathering' at the working end (Parkin 2000).

1.4.23 The design was perfected by 1872, when a further patent was granted for the continuous tank furnace (British Patent 1513, 1872). The main improvement was the replacement of the three compartments with only two: a melt end; and a working end, separated by a floating bridge (Plate 5). The Siemens brothers had observed that the remnants of imperfectly melted batch floated above molten glass, and thus could be held back from the working end by a floating barrier. This improvement was also facilitated by a change in the heating of the tank; rather than heating the tank to a much greater degree where the batch was added, a hot spot was created approximately two-thirds of the way along the length of the tank, with the material essentially flowing towards it, becoming increasingly more refined, and emerging beyond the bridge in a form suitable for gathering (Parkin 2000). This process relied on the varying density of the melting materials to help their movement through the tank, and to aid this, various supplementary elements were tried, such as partition walls, and floating refractory rings, all with the aim of preventing the metal from devitrifying.

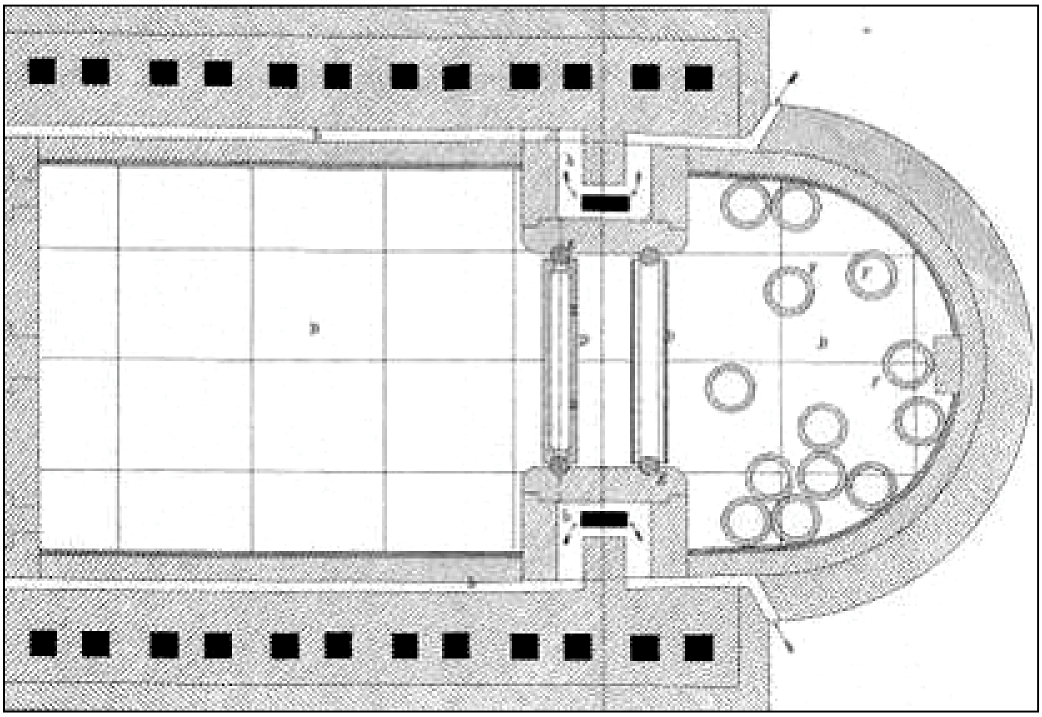

Plate 5: Plan view of a continuous tank furnace from William Siemens' patent of 1872 (British Patent 1513)

1.4.24 Construction of such a tank was commissioned by Pilkingtons at their St Helens works a week prior to the publication of the patent, demonstrating their close working relationship with Siemens (Barker 1960, 147). The furnace was operational in April 1873, with an announcement to the Board of Directors three days later that it was 'beating any pot furnace on the ground' (Minutes of the Board 17/4/1873). However, the following day, the tank leaked badly, causing a fire that destroyed the furnace building (Barker 1977, 134). Despite this setback, Pilkingtons rebuilt quickly, and following better success with the replacement tank, they installed 12 tanks within four years (*ibid*).

1.4.25 A further improvement in tank design was prompted by the introduction of the flat-drawn glass process, and comprised a tank of approximately double the size, split by a bridge, as before, into a large 'melt end' tank, and a similarly sized 'working end'. This was, however, superfluous to the needs of the bottling industry, where the semi-circular 'working end' was retained.

1.5 DEVELOPMENT OF SUNDERLAND'S GLASS INDUSTRY AND THE WEAR FLINT GLASSWORKS

1.5.1 Glass had first been made on Wearside in the time of Bede, and the industry revived in the late Middle Ages with the availability of sand ballast. Later, specialist glassmaking sand was imported, especially white sand from King's Lynn, and soapers' ashes from Yarmouth and London, serving as ballast and sometimes bartered for Sunderland coal. It is likely that the Company of Glass Owners of Sunderland was responsible for the first 'industrial' glass house in the area, which was established in the 1690s at Southwick, adjacent to the ferry landing on the River Wear. This was intended primarily to produce glass bottles. Other glass houses were established within a few years, including those at Ayres Quay in Deptford, and at Panns, and glass bottles were exported from Sunderland in bulk during the seventeenth century (Ross 1982).

1.5.2 The first flint glass factory in Sunderland opened in 1769, with others being established during a boom in the 1790s. By 1820, there were two bottle houses at Ayre's quay, two bottle and one brown glass house at Panns, a flint glass and a bottle house at Deptford, a bottle-house at the Hope Quay, and a crown glass house at Southwick. It was also in 1820 that Henry Greener was born into a family of glass makers at Deptford. At the age of 12, he was apprenticed to John Price, glass manufacturers at Pipewellgate (Thompson 1989, 8).

1.5.3 In 1863, John Collingwood Bruce remarked that 'probably no section of the manufactures of the Tyne and Wear has experienced more marked changes during the last 25 years than that of glass' (Collingwood Bruce 1863, 21). One significant development that gathered momentum during the 1850s was a shift in the favoured location of the industry to the coastal towns of South Shields and Sunderland. The result is shown clearly on Ordnance Survey mapping published in 1858, which depicts a considerable number of glassworks on either side of the River Wear in Sunderland, with a preponderance of glass-bottle works. Indeed, according to John Scott of the Ayres Quay Bottle Company in 1863, 28 out of the 50 bottle houses in the north-east were situated on the River Wear (Ross 1982).

1.5.4 The bulk of the glassworks in Sunderland as depicted on the Ordnance Survey map of 1858 are shown to have been situated on the southern side of the river, and included the Diamond Bottle Works of *c* 1855 immediately to the west of the present study area (Ross 1982), the Wear Bottle Works to the north, and the Wear Glassworks to the south-east. Others include John Candlish's Londonderry Bottle Works of 1853, the Ballast Hills Co's Bottle Works and the Ayres Quay Bottle Works on the bank of the river, Horn & Scott's Bottle Works, and the Sunderland Glass Co's Bottle Works (*ibid*).

1.5.5 A major development of the region's glass industry was the growth of the pressed glass branch of the industry. The use of press moulding had begun in Britain in the first half of the nineteenth century, and allowed the cheap production of glass vessels that could imitate cut glass. The expansion of the middle class in the nineteenth century, and its increasing use of material culture (and associated changes in fashion) to mediate a range of social relationships (Miller 1987), provided a steady demand for press-moulded glass.

1.5.6 The later nineteenth century saw production of much press-moulded glass in England shift to the North East. It has also been suggested (Latimore 1979, 32) that at least some of the success of the press-moulded glass industry there rested on its use of 'semi-lead glass', which contained less lead and a proportion of sodium and barium. Latimore has suggested that, while American and European manufacturers succeeded in using soda-lime-silica glass in England, this recipe was deemed insufficiently durable for press moulding. However, there are at present insufficient data available on the chemical composition of press-moulded glass which would allow these suggestions to be verified (D Dungworth *pers comm*).

1.5.7 The Sowerby firm of Gateshead was of central importance to the pressed-glass industry in the North East (Thompson 1989), not least because many of the other firms in the area were established by men who gained their knowledge of the trade by working at Sowerbys. One example was Nicholas French, the manager of the blown glass department at Sowerbys during the 1840s, who established his own glassworks on Harrison Street in Sunderland in 1852 (Ross 1982). However, French was unsuccessful in his venture, remaining in business for only six years.

1.5.8 Following French's failure in 1858, the Harrison Street glassworks was taken over by James Angus and Henry Greener, who formed a partnership for the manufacture of blown and press-moulded tablewares in colourless and coloured glass (Latimore 1979, 74–87). Angus was a one-time glass merchant who had recently occupied the flint glasshouse at Bill Quay, whilst Greener, like French, had previously been an employee of Sowerbys, where he had been taken on following the completion of his apprenticeship with John Price. The firm of Angus & Greener's first recorded design was for a dish registered in December 1858, followed by a butter dish in August 1866, and a sugar basin and a raised dish in 1867 (Plates 6 and 7). In total, the firm registered ten designs between 1858 and 1869 (Ross 1982).

Plate 6: Sugar basin registered by Angus & Greener in June 1867

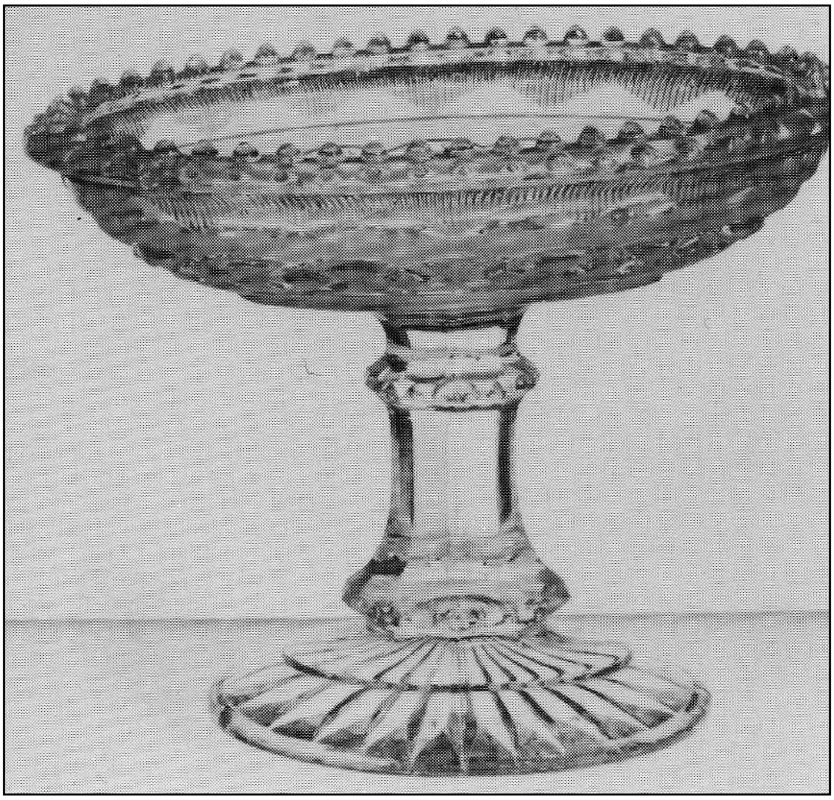

Plate 7: Raised dish registered by Angus & Greener in June 1867

1.5.9 Angus and Greener remained at Harrison Street until Angus' death in 1869, when Henry Greener expanded operations and established a new glassworks housing five ten-pot furnaces at Lisburn Terrace in the Millfield area of Sunderland. Greener's glassworks rapidly became one of the largest of Sowerby's rivals (Ross 1982). Like all of the other glass-manufacturing firms in north-east England, Greener's designs did not approach Sowerbys in originality, but he certainly produced a large range of goods and patented several important new production techniques (Thompson 1989). These included a method of producing glass letters for shop windows, which was patented in 1874, and the manufacture of glasses with angular prisms for use as carriage roof lamps. Greener also registered numerous designs, some 29 between 1869 and 1882 (*ibid*). The first design Greener registered under his own name was the 'Gladstone for the Million' teaset in July 1869, to commemorate Gladstone's appointment as Prime Minister (Plate 8). In 1875, he registered the trademark of a demi-lion holding a star (Plate 11). He also built up a wide range of colours, such as green, blue, puce (a fleshy pink), black majolica, malachite and amber (Plates 9 and 10). From 1878, however, the company put more effort into making less-intricate items, such as pavement lights and slabs of glass. This may have been driven in part by a spate of strikes that beset the company during this period (*Sunderland Daily Echo* 1874).

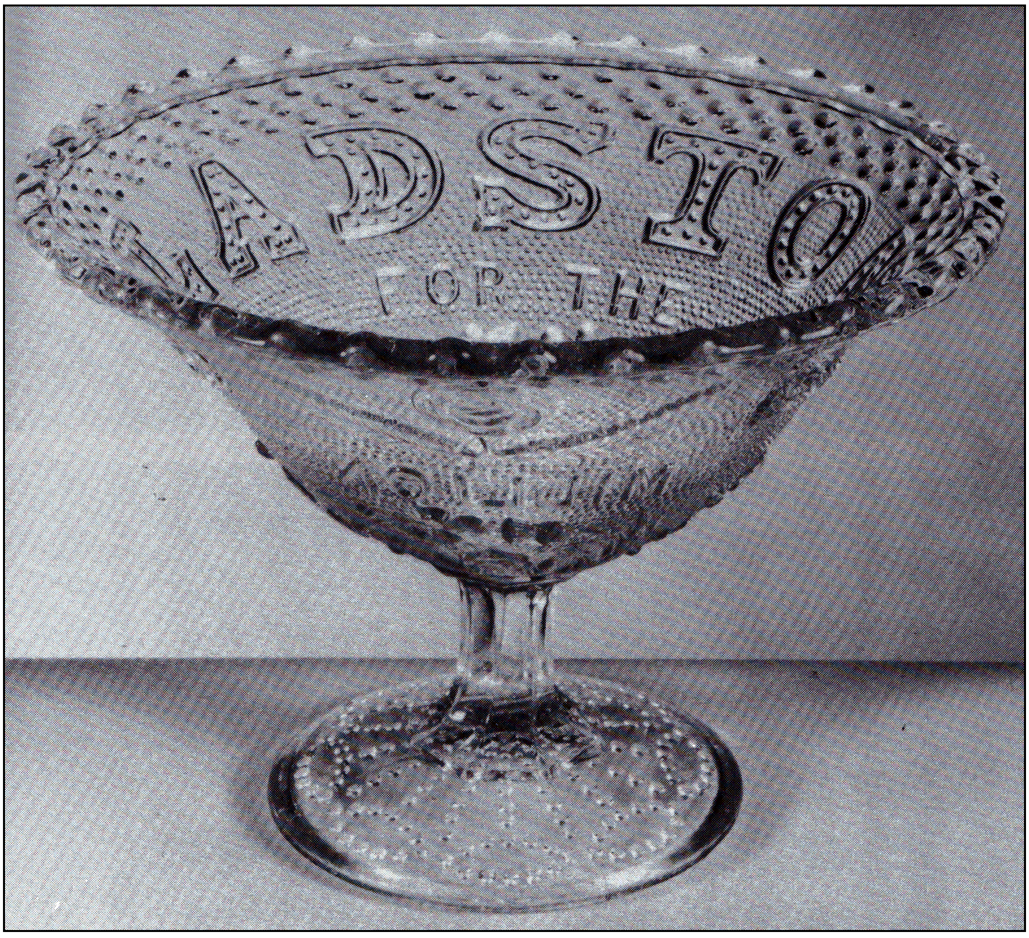

Plate 8: Sugar bowl produced by Henry Greener in 1869 as part of the 'Gladstone for the Million' set

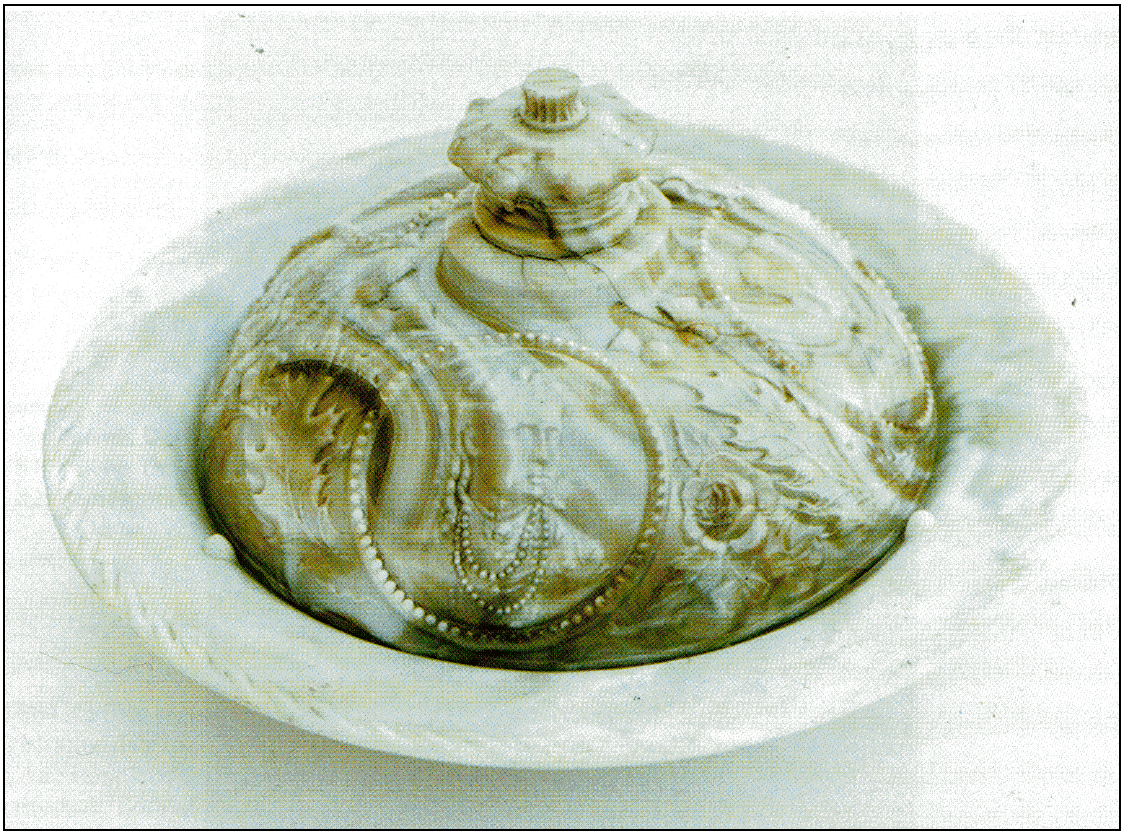

Plate 9: Butter dish in pale green marble produced by Henry Greener in 1878

Plate 10: A sugar bowl produced by Henry Greener in c 1880, probably for the Christmas market

1.5.10 During the 1870s, Henry Greener placed advertisements for the Wear Flint Glassworks in trade directories and local newspapers. These indicate that the firm maintained an office and showroom in Birmingham in addition to their manufacturing premises in Sunderland (*Birmingham Daily Post* 1875).

1.5.11 Henry Greener died in 1882 leaving his company in financial difficulties (Ross 1982). His son, Edward Greener, was among the executors and honoured his request to keep the factory in the family. All of the designs registered during this period were for pavement lights and slabs of glass (Thompson 1989, 12), implying that the firm was increasing moving away from producing finer items. However, with falling sales and increasing debts, and further strikes amongst the workforce (*Sunderland Daily Echo* 1884), the firm was taken over in 1885 by James Augustus Jobling, a wealthy Newcastle chemical merchant. Jobling owned the Tyne Oil and Grease Works, supplied the glass-making materials to Greener, and was also the major creditor to Greener's failing business.

1.5.12 With this change of ownership, the registration mark was modified to a demi-rampant lion holding a halberd (Plate 11), although the firm continued to trade as Greener & Co. Whilst the range of products appears to have remained largely the same, there was a return to producing fine tablewares (Plates 12 and 13). The main emphasis was on press-moulded colourless and coloured domestic glass: the colours included translucent blue, green, brown and yellow, as well as jade-coloured glass, and the range of forms included bowls, jars, vases, candlesticks, dressing-table sets, flower rings and posy bowls (Latimore 1979, 74–87). In 1888, the design pattern of the silver wedding plate for the Prince and Princess of Wales was registered, together with two patterns with an aesthetic Japanese influence. A design for a rustic handle that was applied to baskets was also registered in 1888 (Plate 12), together with a bowl with shell shapes and chain decoration, and a plate with cornucopia, flowers and fruit (Thompson 1989, 12). Throughout the 1890s, Greener & Co produced many designs imitating the contemporary, brilliant cut glass, whilst few other local firms, with the sole exception of George Davidson & Co, attempted to produce these complex designs (*op cit*, 13).

Plate 11: Trade marks of Henry Greener (1875-c 1885) and Greener & Co (c 1885–1900)

Plate 12: Cake basket in flint glass produced by Greener & Co in 1888

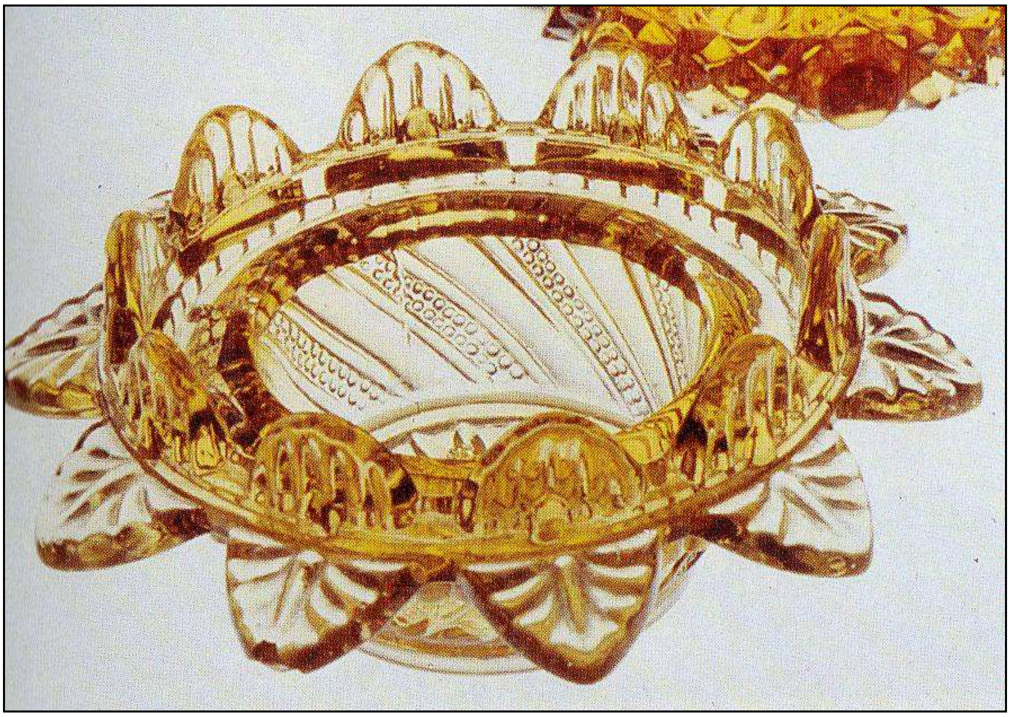

Plate 13: A night-light holder produced in amber by Greener & Co in 1891

1.5.13 An advertisement dating to the late nineteenth century included a useful illustration of the glassworks (Plate 14). This depicts a large, rectangular glasshouse with five large flues protruding through the roof, presumably representing the five ten-pot melting furnaces. The glasshouse is shown to have been served by a private railway siding along the southern side of the building. A railway locomotive, seemingly delivering a consignment of coal for the furnaces, is shown on this siding, suggesting that the southern part of the site was used for stockpiling fuel. A smaller chimney, clearly for industrial use, is shown at the south-western corner of the glasshouse, perhaps indicating the position of a fritting furnace. A larger chimney is shown immediately to the north of the buildings, and was presumably associated with the glassworks. A two-storey range forming the eastern side of the works, and facing the main entrance, is likely to have been the main office and warehouse. At the southern end of the office block is a single-storey building with a bow window, probably representing the watch house. The northern part of the works appears to have been given over largely to a single-storey structure, possibly fitted with a north-light roof to provide even natural lighting inside. This is almost certainly the main production area, where molten glass from the furnaces was worked into the finished products. The layout of the works is confirmed by the detail provided by the Ordnance Survey 25": 1 mile plan of 1897 (Fig 2).

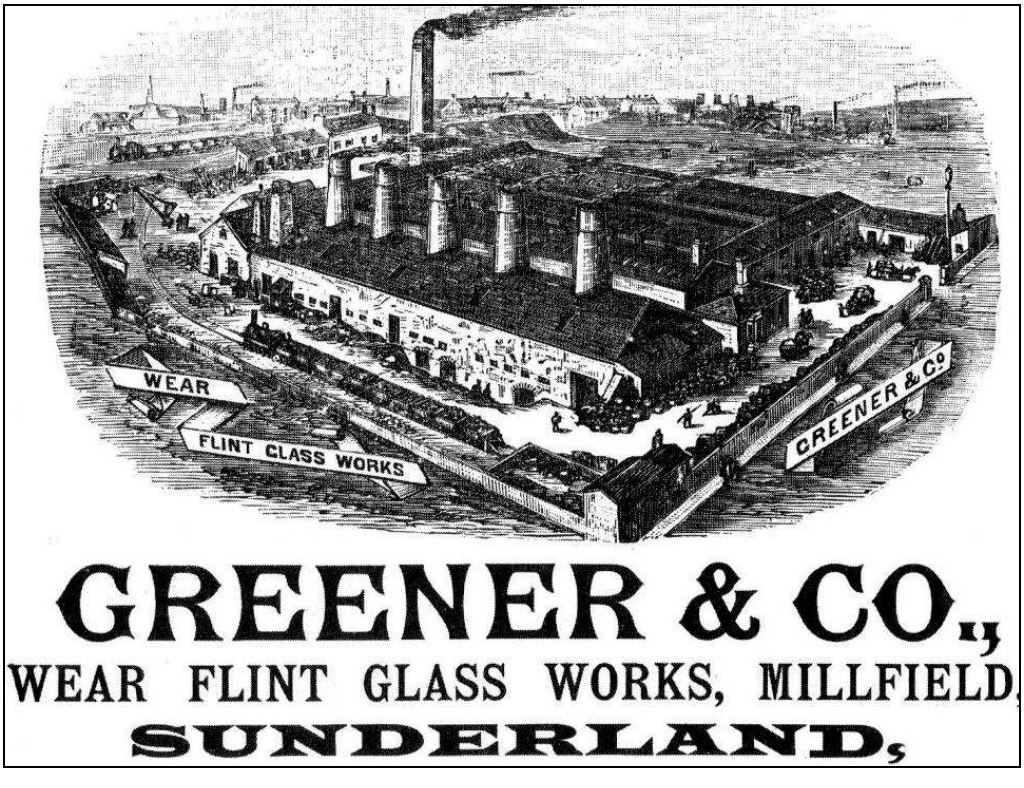

Plate 14: A late nineteenth-century advertisement for the Wear Flint Glassworks

1.5.14 James Jobling continued to register new designs, but did not spend the time required to grow the company, and financial problems beset the firm towards the end of the nineteenth century. These were overcome in 1902, when Ernest Jobling Purser, nephew of James Jobling, joined the firm and immediately introduced technological improvements from Germany and America. The company was then renamed James A Jobling & Co (Ross 1982).

1.5.15 The next detailed plan of the glassworks is provided by the Ordnance Survey 25": 1 mile plan of 1919 (Fig 3). This shows the footprint of the works to have remained largely unaltered. It is notable, however, that this map only depicts four flues along the southern part of the glasshouse, suggesting that at least one of the melting furnaces had gone out of use.

1.5.16 The most beneficial of the improvements introduced by Ernest Jobling Purser was the licence from American manufacturers Corning & Co to produce and sell Pyrex, the well-known heat-resistant glass, to Britain and the Empire (except Canada) in 1921. This allowed Jobling to expand this suite of glass products throughout the depression years, when other companies were suffering; between 1926 and 1940, 42 designs were registered, many of which facilitated the production of dinner sets to match the ovenware (Hibberd 2007). The technical aspects of early Pyrex production are very poorly understood. Pyrex was initially a borosilicate glass but later specifications indicate a silicate glass with 13wt% boron oxide (B_2O_3), 4wt% soda (Na_2O) and 2.3wt% alumina (Al_2O_3). The techniques developed during the twentieth century to enhance the thermal properties of Pyrex and produce the opacity and range of colours employed are not well known (D Dungworth *pers comm*).

1.5.17 In 1932, Jobling began to imitate the decorative glassware that was made famous by Lalique and the Paris Exhibition of 1925. These art deco and art nouveau designs were cheaper than that of Lalique, and also more appealing than the flint designs from the other companies and thus warranted a higher price. The glass was typically an opalescent colour called Opalique, but they also reproduced colours that Greener had used in the 1880s (Hibberd 2007).

1.5.18 The extent of the glassworks during this period is captured on an aerial photograph (Plate 15).

Plate 15: Aerial view across the expanded Wear Flint Glassworks in 1937, looking north (© English Heritage (Aerofilms Collection))

1.5.19 Combined with the inability to make a profit from this range, and the outbreak of Second World War, the firm stopped production in order to concentrate on their Pyrex range and other glass for the war effort. In 1949, Ernest Jobling Purser sold the company to Pilkington Brothers. The 1950s saw the development of an opaque white Pyrex (Opalware, later called Tableware), which was even more resistant to changes in temperature. Opalware was used extensively for the production of dinner sets, and these were produced increasingly with screen-printed enamel patterns (Hibberd 2007).

1.5.20 Pilkington sold 60% of its shares to Thomas Tilling, and 40% to Corning. In 1973, Tilling sold his shares to Corning, and the company was renamed as Corning Ltd. This firm employed some 3000 people at their sites in the Millfield and Deptford areas of Sunderland, although this number was reduced to *c* 1200 when Corning sold their laboratory division in 1982 (Roberton 2005). In 1994, the Millfield factory was sold to Newell Ltd, and then to Arc International (*Sunderland Echo* 2006). Production ultimately shifted to France in 2007, marking the end of glass manufacture in Sunderland.

1.6 Background to the Wearside Pottery

1.6.1 The significant benefits afforded by a cheap supply of coal, and excellent transport links via the sea, stimulated the development of a pottery industry in Sunderland. Brown clay suitable for producing earthenware was available locally, whilst white clay for finer wares was imported from Dorset, Devon and Cornwall, often brought as ballast in colliers. In addition, the flint required for tempering the clay was available from nearby Beamish and Fence Houses (Roberton 2005, 145-8).

1.6.2 The production of brown earthenware commenced locally in the 1720s, when two potworks were established at Newbottle, some 7km to the south-west of Sunderland. The introduction of a flint-crushing mill at Newbottle in *c* 1740 enabled these potteries to manufacture white earthenware, and the ensuing success stimulated a growth of the area's pottery industry (Manders 1973, 63). Several notable potworks were opened during the following decades, including Maling's North Hylton Pottery, Dawson's Low Ford Pottery at South Hylton, the Wear Pottery in Southwick, and the neighbouring potworks of Anthony Scott, where the successful Haddon brown pattern was produced.

1.6.3 Another group of potworks had been built at Monkwearmouth by the mid-nineteenth century, as Sunderland emerged as an important pottery-manufacturing centre with a reputation for producing fine pink lustre wares and transfer-printed whitewares. In addition to a burgeoning local demand for brown earthenwares and a valuable export trade that served northern Europe, a popular market also grew in souvenir transfer-printed pieces (Ball 1908). However, the industry declined rapidly from the middle of the nineteenth century, and only two of Sunderland's firms survived the first decade of the twentieth century: the Ball Brothers' Deptford Pottery on St Luke's Road in Millfield, although this closed in 1918 (Brears 1971, 179-80); and Snowdon & Co's Bridge End Pottery at Sheepfolds. In the face of a virtual collapse of Sunderland's pottery industry, it is perhaps remarkable that Alderman W Walker, Digby Nelson, Frederick Nelson, HE Pitt and AP Pitt formed the Sunderland Pottery Company in 1913. Their new works in Millfield had commenced production by 1914 (Kelly 1914), and the layout was reported to be well-planned and equipped with modern machinery (Baker 1984, 68).

1.6.4 Initially, the firm continued nineteenth-century traditions, and produced a range of brown earthenwares from local clay, although twentieth-century items such as lamp reflectors for street lights were also made. The range was soon diversified, however, and yellow and white wares began to be produced using clay imported from Wareham in Dorset.

1.6.5 The earliest plan of the potworks is provided by the Ordnance Survey 25": 1 mile map of 1919, which depicts a T-shaped block occupying the eastern side of the site, and a detached range along the boundary with the adjacent engineering works (Plate 16). The main entrance to the potworks appears to have been in the north-eastern corner, between the two building ranges. The various components of the potworks are not identified by the Ordnance Survey, although it is reasonable to suggest that the square projection against the north/south-aligned range housed the kiln.

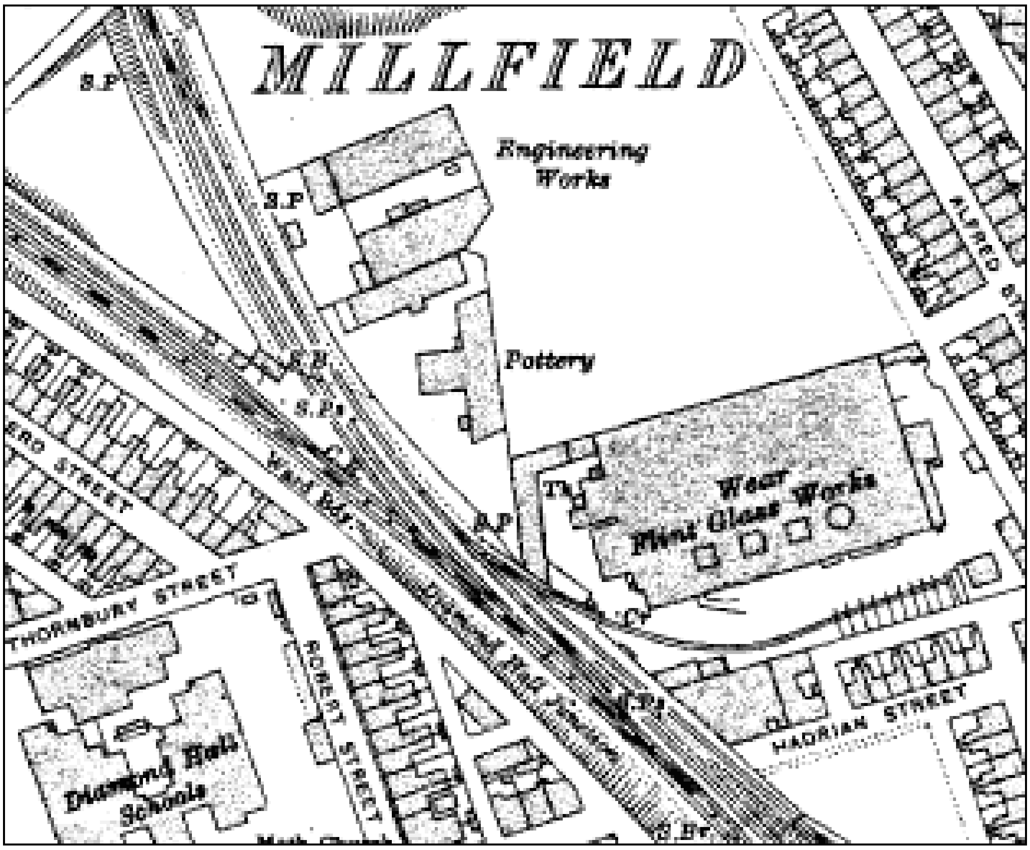

Plate 16: Extract from the Ordnance Survey map of 1919, showing the newly established Wearside Pottery situated between the Wear Flint Glass Works and an engineering works

1.6.6 Following the death of Alderman Walker, one of the Company directors, it was resolved at an extraordinary meeting in 1927 that the Sunderland Pottery Company should file for voluntary liquidation. The principal concern of the remaining directors was that the Company could not continue by reason of its liabilities (*London Gazette*, 16 December 1927). However, the business was reconstructed subsequently by Messrs D and J Crombie under the name of the Wearside Pottery Company. Electrically powered machinery was installed during the following year, and the firm expanded its repertoire, specialising in the manufacture of fireproof ivory-coloured cooking ware and ornamental ware.

1.6.7 This evidently led to an expansion of the potworks, and whilst the Ordnance Survey map published in 1938 does not depict any changes to the layout of the site, several additional structures are shown clearly on a series of oblique aerial photographs taken in 1937 (Plate 17). The original kiln is visible on these photographs, and was seemingly of a design typical to nineteenth-century bottle-shaped pot ovens (Baker 1991, 6). The original ranges were clearly of two storeys, with the exception of the southern end of the north/south-aligned range, which was of a reduced height. The aerial photographs also show a tall chimney at the northern end of this range, together with three kilns in the north-western part of the site, which are not marked on the sequence of historical maps.

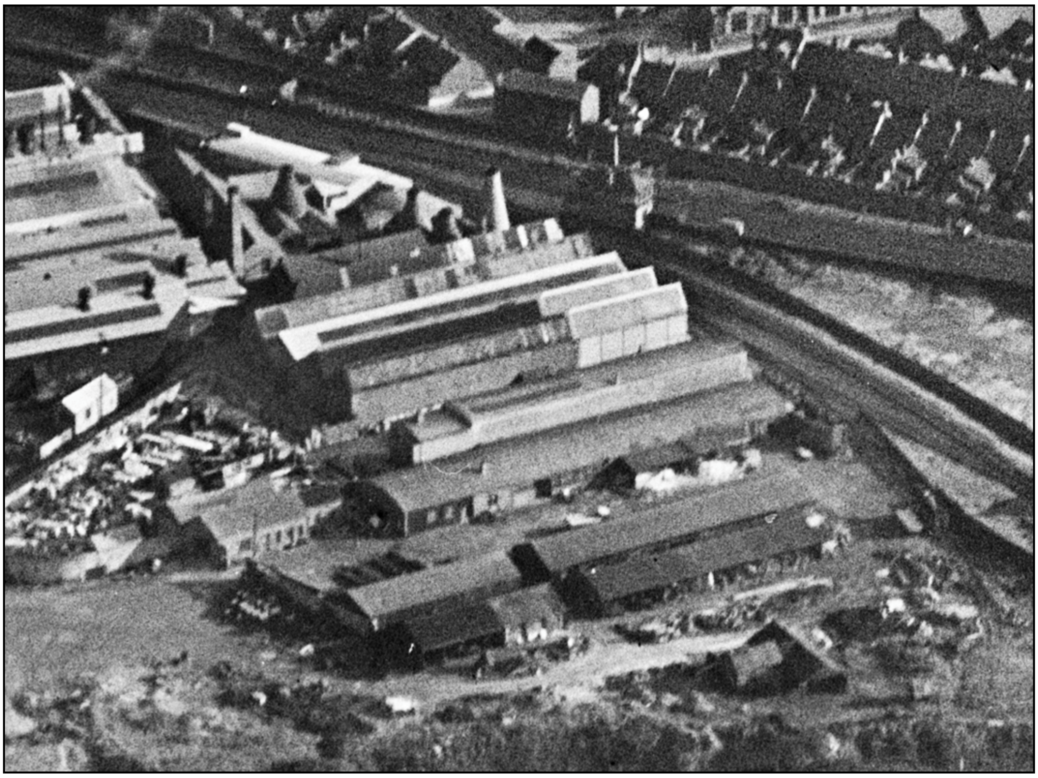

Plate 17: Aerial photograph of 1937, showing the Wearside Pottery (© English Heritage (Aerofilms Collection))

1.6.8 The expanded layout of the potworks is captured on the Ordnance Survey map of 1941, the year in which Snowdon & Co's Bridge End Pottery closed (Brears 1971, 179), leaving the Wearside Pottery as the last potworks in Sunderland. By the 1950s, the company had restricted its range of products to yellow wares for kitchen use, and specialised in manufacturing lined mixing bowls that were supplied to home and export markets. However, the firm ceased production at Millfield in February 1957 and relocated to a new site in Seaham, which remained in production until 1984 (*London Gazette*, 27 April 1984). The equipment at the Millfield site was sold by auction in March 1957 (Milburn and Miller 1988, 24), and the buildings were cleared subsequently to enable an expansion of the adjacent glassworks.

2. RESEARCH PRIORITIES AND OBJECTIVES

2.1 RESEARCH PRIORITIES

2.1.1 The original research priorities of the excavation were specified in the Written Scheme of Investigation, and fell within 'PMii Industrialisation' and 'MOi Industry' of the *North-East Regional Research Framework for the Historic Environment* (NERRF; Petts and Gerrard 2006). These were to:

- produce a record of the form of the nineteenth- and twentieth-century glassworks (PMii);
- identify and record the evidence of changes in glass-production technology (PMii);
- assess differences in glass composition over time and type (PMii);
- produce a record of the form of the twentieth-century pottery works, and the kiln's relationship to other associated structures (MOi);
- identify the fuel used in both pottery and glass production (PMii and MOi);
- determine the impact of technological change on the wider community (PMii).

2.1.2 The original research aims for the project remained valid following the post-excavation assessment of the dataset, but were updated with new aims and objectives:

- how did the layout and character of the glassworks develop through the late nineteenth and twentieth centuries?
- what evidence is there for developments in engineering and methodology in the glass industry?

2.2 OBJECTIVES

2.2.1 In order to meet the aims stated above, the post-excavation assessment identified the principal objectives of the analysis of the dataset:

- to characterise the nature of the main phases of activity, and to detail the technological development of the site.;
- to determine the phasing of the structures on the site to set its development within an historical context;
- to detail the construction methods and materials, including adaptations and rebuilds, for all the structural features within the site;
- to provide sufficient research in order to place any findings in context;
- to produce a detailed analytical report in accordance with English Heritage guidelines (2006), and to create an ordered archive of the work, to be housed in a public repository.

3. SUMMARY OF THE RESULTS OF THE FIELDWORK

3.1 EVALUATION

3.1.1 The archaeological potential of the site, highlighted in a desk-based assessment compiled by Under Construction Archaeology (2009), was corroborated via the excavation of a series of evaluation trenches in 2010. This initial intrusive investigation of the site, carried out by Pre-Construct Archaeology (PCA), demonstrated that extensive buried structural remains of the Wear Flint Glassworks and the Wearside Pottery survived *in-situ*. These remains included walls, flues, culverts, chimney bases, and the well-preserved remains of a mid-twentieth-century pottery kiln base.

3.1.2 Following on from the evaluation trenching, three targeted areas of the site were stripped of modern surfacing and overburden by a mechanical excavator operating under close archaeological supervision. However, manual cleaning of the exposed remains and detailed archaeological recording was not undertaken at this stage; this was carried out by OA North between April and May 2011.

3.2 EXCAVATION

3.2.1 A total area of 2838m², divided into three separate areas, was subject to detailed archaeological excavation (Figs 2-4). The scope of the archaeological works undertaken by OA North provided only for the cleaning and recording of the features already exposed, with no remit for further excavation within or beyond the limits of excavation defined by the previous works.

3.2.2 Area 1 measured 705m², and was targeted on the site of the former premises of the Wearside Pottery. Area 2 measured 1877m², and investigated the best-preserved elements of the Wear Flint Glassworks, which included the remains of the glass-melting furnaces. Area 3, which measured 256m², investigated more poorly-preserved elements of the glassworks. Detailed results of the investigations are presented for each area below.

3.2.3 ***Phasing:*** as part of the post-excavation assessment process, each of the deposits and structures encountered during the investigation was ascribed to one of three broad phases of activity. This phasing is provisional, as is appropriate for an assessment of the site, and may be refined in the light of evidence produced from detailed analysis of the dataset:

- Phase 1: nineteenth century (1869 – 1912);
- Phase 2: early twentieth century (1913 – 1946);
- Phase 3: later twentieth century (1947 – present).

3.2.4 For the purposes of this report, however, a summary of the excavation results is presented by individual structures or areas, with a description of how these developed through the three identified phases of activity.

3.3 AREA 1

3.3.1 Area 1 measured approximately 705m^2 (Plate 18), and was targeted on the structural remains of the Wearside Pottery, which traded from 1913 to 1957 (*Section 1.6 above*). Surprisingly, only a few artefacts were recovered from the excavation of this area, although these included clear evidence for pottery manufacturing (*Section 5.2.2 below*).

Plate 18: General view across the excavated remains of the Wearside Pottery (Area 1)

3.3.2 The excavation revealed the well-preserved remains of the kiln base, numerous walls representing different developmental stages in the evolution of the pothouse and ancillary buildings, and associated floors (Plate 18). The earliest remains (Phase 2: 1913-46) included the footprint of the walls depicted on the Ordnance Survey map of 1919, comprising a rectangular north/south-aligned range occupying the eastern boundary of the site, with a central, square-shaped projection on its western side (Fig 3). The excavation indicated that the main north/south-aligned range (***109***; Fig 5) had probably been divided into three distinct processing areas, whilst the square-shaped structure (***104***) against the western side of the building, shown on the Ordnance Survey map of 1919, had evidently housed a kiln. The excavated kiln base (***105***), however, had clearly been rebuilt in the mid-twentieth century (Phase 3: 1947-present; *Section 3.3.7 below*).

3.3.3 The surviving kiln base was placed slightly to the south of the centre of Room ***104*** (Fig 5), which was square in plan, measuring 30ft^2 (9.13m^2). The brick-built walls of Room ***104*** were heavily remodelled, but appeared to have originally comprised only one full-brick thickness, laid in English bond.

3.3.4 Whilst these walls survived to varying degrees in the south, east, and west, the northern wall and the eastern end of the southern wall only survived as a row of header bricks at floor level. The east wall retained a man-door into the main structure (Room ***109***), although this may have been remodelled. The north wall retained evidence for a possible doorway towards its western end. This would have formed an external doorway, and had perhaps been intended to provide access from the range of buildings to the north-west.

3.3.5 The west wall had been rebuilt in one and a half-brick thickness at its northern end, but retained three brick piers to the south, presumably strengthening the relatively thin external walls, and providing a stable base for the cone above the kiln. The south wall also retained two brick piers, although these were offset to the south of the original wall face, and appeared to represent the insertion of a relatively wide doorway from an extension of the structure to the south (Phase 2; Fig 5).

3.3.6 Kiln base ***105*** (Plate 19) survived only at floor level, and measured 25½ft (7.77m) externally, with the kiln floor itself measuring 13ft (3.96m). Ten tapering channels, each a maximum of 19in (0.49m) wide, led from floor level within Room ***104*** below the kiln floor, representing ash pits placed below the waist-height stoking holes. The layout of the base was consistent with a coal-fired bottle kiln, which had probably been surrounded by a tall brick hovel or cone, of typical bottle shape.

*Plate 19: General view across kiln base **105**, looking west*

3.3.7 The surviving floor at the base of kiln ***105*** was of three courses, the lower being randomly laid, reused and broken bricks, comprising both regular and refractory bricks (Plate 20). The two upper courses comprised similar material, but laid in a more regular radial pattern. All courses were set in compacted sand, and placed on a concrete base, providing the foundation onto which the kiln was constructed (Fig 6).

*Plate 20: Detailed view of a quadrant of kiln base **105***

3.3.8 The concrete base for the kiln had a maximum thickness of 1m, and comprised three distinct layers (Fig 6). The lower layer contained several large brick fragments, whilst the upper layers contained smaller fragments of crushed brick, and steel reinforcement bars. A date of 1947 inscribed into the floor adjacent to the kiln (Plate 21) provided a construction date for the upper level of concrete and the surviving kiln base, although those below may date from an earlier build. Access to the interior of the kiln was afforded via the 'wicket', which was presumably located on the eastern side, adjacent to the entrance from the main structure. Interestingly, although the remains survived below the level of the wicket from the latest kiln, the ash pit nearest the position of the doorway into Room ***109*** was infilled with brick, which possibly indicating the position of the wicket.

*Plate 21: Date cast into concrete foundation for kiln base **105***

3.3.9 Room ***109***, situated to the east of kiln ***105*** (Fig 5), comprised the majority of the original structure, but had a continuous floor from Room ***104***, suggesting that it too had been remodelled latterly. A 6ft (1.83m) wide doorway afforded access between the two rooms, and it is probable that the area immediately to the east of the kiln would have required an open space for access along its western side. This wall was constructed of wire-cut bricks, bonded in three-stretcher English Garden Wall bond, using a sandy cement mortar. Both long walls were augmented with internal buttresses, 10ft (3.05m) apart, each two-bricks wide, and projecting one brick into the room (Fig 5). These appeared to be original features, and presumably formed piers supporting trusses for a pitched roof, as the external walls themselves were of only a single-brick thickness.

3.3.10 Adjacent to the third pier from the northern end, the floor scar of a cross-wall survived within the later concrete floor (Fig 5). This comprised only a single-skin wall, with a 2ft 6in (0.76m) man-sized doorway towards its western end. The area to the north probably originally served as a drying area. Within the floor of both areas, several I-section stanchions and changes in the concrete flooring suggest the position of machinery (Fig 5).

3.3.11 On the southern side of a brick-built partition within Room ***109***, and abutting the eastern side of the buttress in the eastern wall, was what appeared to be the remains of a hearth (***110***). This may have provided the heat for a drying rack.

3.3.12 Room ***101*** comprised the southern part of the original north/south range, and was formed by an L-shaped wall. This differed from those elsewhere, having a thickness of one and a half-bricks, as opposed to the single-brick external walls. This implies that a structural load was applied to the wall.

3.3.13 Room ***101*** contained a series of small, linked concrete tanks, cast within the floor, and extending southwards beyond the footprint of the original structure, demonstrating them to be of a later date. A shallow channel cut into the floor led into the largest and deepest of these tanks, the base of which was 0.67m below the floor surface. The inclusion of these tanks suggests that Room ***101*** may have been used as a primary processing area, possibly housing a blunger or, more probably, a pugmill. Two raised, large concrete machine bases, and two I-section steel stanchions, representing attachment points for machinery, were also revealed to the east of the concrete tanks (Plate 22). However, these had formed part of the adjacent glassworks, rather than having been associated with the potworks, and had presumably been installed during the second half of the twentieth century.

*Plate 22: General view across Room **101***

3.3.14 Within the original building to the west was a narrow corridor (***102***), which was only 10ft (3.05m) wide (Fig 5). The floor sloped from south to north, forming a ramp into Room ***109***. The west wall retained brick piers on the internal face, matching those to the north in Room ***109***, and was truncated at its northern end by a concrete ramp, presumably affording access in a later phase from an expansion of the structure to the west (Fig 5). This created an L-shaped pair of ramps, descending to the level of Room ***109***, along the exposed eastern and southern boundaries of a much larger room, comprising level platform containing a concrete machine base, not dissimilar to that at the northern end of Room ***101*** (Fig 5). The eastern wall of the original corridor had been rebuilt, probably during this remodelling, and most probably that of Room ***101***, and comprised machine-pressed bricks in three-stretcher English Garden Wall bond. Several of the component bricks had a 'BACKWORTH' stamp, suggesting a construction date in the 1930-40s (*Appendix 3*).

3.3.15 The pottery had been expanded with the addition of a narrow room (***103***) immediately to the south of the kiln, and three rooms to the north. The footprint of Room ***103*** does not correspond to any structures depicted on the Ordnance Survey map of 1919 (Fig 3), but is incorporated into a larger building shown on Ordnance Survey mapping of 1941 (Fig 4). The room was only 12ft (3.66m) wide (Fig 5), and had no apparent access into Room ***109***, suggesting that its function related solely to the kiln itself. The room retained a concrete flagstone floor, comprising three rows of rectangular flags (Fig 5), perhaps representing the oldest surviving floor within the pottery kiln complex. A wide doorway between Rooms ***103*** and ***104*** was placed centrally in the dividing wall, with square, two-brick wide pillars on either side, suggesting that it was an open doorway. However, the position of kiln base ***105***, offset towards the southern side of Room ***104***, almost entirely blocked the doorway, and it is probable that the wall between the doorway and the original structure to the east was removed to provide access to the repositioned, or possibly enlarged, kiln. A third brick pier, placed adjacent to the external wall of Room ***109***, probably formed the jamb of this later doorway. It was placed directly onto the flagstone floor, demonstrating it to be a secondary insertion.

3.3.16 The north wall of Room ***103*** was augmented with a single skin of machine-made bricks, many bearing a 'LONDONDERRY' stamp, indicating a post-1909 construction date (*Appendix 3*). The south wall was of similar construction, and retained regularly spaced brick piers, presumably supporting tie beams for a lean-to roof against the earlier structure. The room may have served as a green house, where newly-made vessels were placed to harden before biscuit firing. This preliminary firing was intended to make the vessels hard enough to handle for further work, such as glazing and decoration, reflecting the production of ornamental wares that were introduced by the Wearside Pottery Company.

3.3.17 An extension to the site on the northern side of the kiln infilled the angle between this and the northern part of the main structure (Fig 5; Rooms ***106***, ***107***, and ***108***). This extension post-dates the publication of the Ordnance Survey map of 1941, since this does not show it (Fig 4). The northern end of this extension, and Room ***109*** to the east, were truncated by a wall on a different alignment to the pottery (Fig 5). This was of a late twentieth-century date, with its footings cut through the concrete floor (Plate 23).

3.3.18 The extension was divided into three rooms (***106***, ***107*** and ***108***) by full-brick thickness partitions, laid in three-stretcher English Garden Wall bond. The majority of the extension comprised a single room (***106***), placed on its western side, and comprising slightly more than half of its width. Six sockets were observed in its western wall, placed slightly above the concrete floor. These possibly suggest the incorporation of a timber floor, the joists of which would have been housed in such sockets, but no corresponding sockets were observed in the western wall. However, several sockets within the concrete floor on both the western and eastern sides of the room may have been associated. A row of four sockets was visible alongside the western wall, and it is noteworthy that the southern buttress of this wall had been enlarged, breaking the line of the sockets.

3.3.19 Further sockets were placed in the floor on the eastern side of the room. Two were placed in the south-east corner, adjacent to a doorway into Room ***107***, which formed the south-eastern part of the extension (Fig 5). The other four sockets were placed around the return of the north wall of Room ***107***, and adjacent to the offset western wall of Room ***108***, which was the smallest of the three rooms, in the north-eastern corner of the extension.

3.3.20 The western wall of Room ***106*** appeared to have been truncated by the later structure to the north in the position of a doorway. No evidence for the truncated wall was observed beyond a vertically-set I-section rolled steel joist (RSJ), which appeared to have been placed as a door jamb of a wide doorway.

3.3.21 Room ***107*** had five sockets set into the floor, three along the north wall and two along the east. Doorways, probably dating to the original construction when this area had presumably been a yard, had been blocked up in the south and east walls. These had been replaced by two doorways in the western wall. The northern one had a strip of iron set into the floor, representing a runner for a sliding door, with the threshold ramped down slightly into Room ***106***. The southern doorway was also slightly ramped, demonstrating a lower floor level than in the original building within the western part of the extension, and had been broken through the wall.

3.3.22 Room ***108***, to the north of Room ***107***, had no surviving evidence for a doorway, although it is likely that the truncated northern part of the room originally had a doorway into Room ***106***, the southern jamb being retained at floor level. A blocked doorway in the eastern wall may have afforded access from Room ***109***, or possibly represented an earlier doorway that was blocked during the construction of the extension. The floor of Room ***108*** retained five irregularly shaped sockets within the concrete floor, with some associated rust-staining. Their exact purpose remains unclear, but they almost certainly represented the footings for either machinery or racking units (Plate 24).

3.3.23 At the southern end of Area A, the excavation area extended beyond the east wall of the potworks (Fig 5). Two concrete machine bases surrounded by an ashy clinker deposit were revealed within this area, and whilst their proximity to the large concrete tanks within Room ***101*** may suggest that the two were associated, the historical mapping clearly demonstrates that they formed part of the larger glassworks depicted in this position on Ordnance Survey mapping of 1941.

Plate 23: Late twentieth-century wall cutting across the northern part of the extension

*Plate 24: Sockets set in the concrete floor of Room **108***

3.4 AREA 2

3.4.1 Area 2 measured approximately 1877m^2 (Fig 7; Plate 25), and was targeted on the footprint of the western and south-eastern parts of the Wear Flint Glassworks, as depicted on the Ordnance Survey map of 1897 (Fig 2). Three broad phases of activity were revealed during the excavation, and the component structures are described in this broad chronological sequence below.

Plate 25: High-level view of Area 2 fully excavated

3.4.2 ***Phase 1 – The Flint Glass Works:*** several features that have been interpreted as belonging to the primary phase of the glassworks have been identified. Those that can be ascribed with most confidence to this phase comprised a series of brick- and stone-built walls, several of which correspond to those shown on the Ordnance Survey map of 1897 (Fig 2). Many of the areas adjacent to these walls had been machined down to the level of natural clay, suggesting that no floor surfaces had survived, with the stone portions of the walls probably representing foundational levels. Whilst the thickness of these walls varied between one and one-and-a-half-brick thickness, the construction style comprised three-stretcher English Garden Wall bond, with a pale lime-based mortar, above a wider foundation plinth, comprising typically two courses of irregular sandstone blocks, also bonded with a lime mortar (Plate 26).

*Plate 26: Typical section of Phase 1 wall (**246**), comprising bricks laid on a stone plinth*

3.4.3 Ten such walls were identified, with the majority continuing beyond the limit of excavation. Wall ***249*** formed the northern wall of the glassworks, and wall ***251***, placed on a perpendicular alignment in the western part of the excavation area (Fig 7), appeared to have formed a substantial dividing wall between two distinct elements of the glassworks. The area to the east appeared to have housed furnaces in its southern part, and possibly storage and preparation areas to the north, whilst to the west of wall ***251***, the structures seemingly comprised a possible power plant, and an annealing house.

3.4.4 The remaining walls identified by their stone foundation appear to have formed internal partitions within the main part of the structure. The most substantial of these was a 33m-long, north/south-aligned wall (***246***), which returned eastwards at its southern end to link with wall ***245***. This appeared to delineate the northern extent of the furnaces, of which five are shown on the Ordnance Survey plan of 1897 (Fig 2).

3.4.5 The fragmentary remains of wall ***245*** appeared to continue into the eastern section of the trench, suggesting that it originally formed a continuous partition to the north of the furnaces. To the north, two parallel walls, ***224*** and ***248***, formed rooms of 25' (7.62m) width (Fig 7). Both comprised brick walls above stone foundations, with the southern wall (***248***) being of a much more substantial two-brick thickness, apparently laid in English Garden Wall bond, with that to the north being of only 1½-brick thickness (Fig 7). Wall ***248*** also had the narrow stone foundation of a keyed return wall (***247***) on its southern side, forming a room of approximately 25' x 15'6" in the angle between walls ***245*** and ***246*** (Fig). Two close-set walls (***252*** and ***253***), both of 1½-brick thickness, and placed between the north/south-aligned walls ***246*** and ***251*** (Fig 7), probably represented the foundation for a passageway between the two distinct eastern and western components of the glassworks.

*Plate 27: Stone foundations of walls **247** and **248***

3.4.6 *Original 10-pot furnace:* to the south of wall ***245***, elements of several phases of furnace were identified (Fig 8). The earliest elements comprise two sections of 4' (1.21m) wide wall placed towards the eastern end of Area 2. The two sections of walls, ***222*** and ***229*** (Fig 8; Plates 28 and 29), almost certainly represent the same wall within the original construction, either side of a wide flue (***226***; Plate 30). The wall was constructed of similar red brick to the major structural walls detailed above (*Section 3.4.3*), and was also bonded in a very pale, whitish lime mortar (Plates 28 and 29). It was observed to a height of up to 12 courses (Plate 30), and was cut into the natural plastic clay, being deeper in its central section, either side of the flue, flanked by approximately 3' (0.91m) wide walls set higher on the clay. The eastern side of the wall certainly formed a face, although to the south of flue ***226***, it appeared to have continued to the north below the foundational level of the wall face (Plate 29).

3.4.7 Both walls had projecting returns on their western faces (Plate 28), each comprising large quantities of broken bricks within their 'core', and were of similar depth to the outer walls. These walls were partially overlain or destroyed by a dump of redeposited natural clay, presumably associated with the remodelling of flue ***226***, with the crown being rebuilt during the insertion of a Siemens furnace immediately to the west (Plate 30). The return walls also overlay orange-stained natural clay, which was much more friable than the surrounding natural soils, typical of the effect of having undergone sustained exposed to great heat, further suggesting that the furnace lay to the west of the extant walls.

3.4.8 The central passage (***226***) identified between walls ***222*** and ***229*** (Fig 8) almost certainly represented the sub-surface flue that would have been placed centrally beneath the furnace, providing sufficient room for the workmen, known as teasers, who cleared out ash and clinker from beneath the grate. The flue would also have incorporated a door, or shutter, placed within the passage to the east of the furnace, which had been intended to regulate the flow of air into the furnace. Closure of this shutter will have reduced combustion in the furnace to a minimum, allowing the melting pots to be filled with a fresh batch of raw materials. Fragments of a crucible recovered from Area 3 suggest that all the original furnace heated crucible pots from which the metal was drawn.

*Plate 28: Northern element of the east wall (**229**) of the original pot furnace*

*Plate 29: Southern element of the east wall (**229**) of the original pot furnace*

*Plate 30: Contemporary central flue (**226**) between walls **222** and **229***

3.4.9 The extant remains of flue ***226*** were 5'6" (1.68m) wide, and comprised a full-brick thickness of hand-made red brick, laid in four-stretcher English Garden Wall bond, using a pale lime mortar, similar to that observed in the earliest fabric elsewhere. To the west of walls ***222*** and ***229***, the flue was rebuilt, using machine-made bricks, bonded in a sooty greyish-black mortar, and associated with a later furnace placed to the west. At its eastern end, the flue returned southward to the external elevation of the building (Fig 8). The bull-nosed inner return of the wall survived extant (Plate 31), and had a constructional break in the upper courses almost immediately to the south of the return, but the outer return had been removed for almost its entire length, for the insertion of a later furnace, visible in the eastern section of the trench. At its southern end, further late remodelling of the flue had preserved its eastern wall, and part of the crown (Plate 32). At this southern end, a similar contemporary tunnel (***228***) was placed on a parallel alignment (Fig 8), sharing the western wall of flue ***226***, which was thickened to two bricks at this point (Plate 32). Both were of 5' (1.52m) width on this axis, with a full-brick thickness, arched crown, that of the western tunnel, ***228***, surviving at its southern end (Plate 32). This southern end appears to have formed part of the external south wall of the glass house, with a flush pier between the two tunnels, and a westward return of the west wall of ***228***. The east wall of ***226***, however, continued further to the south (Fig 8), presumably forming part of an external stair down, clearly shown on the Ordnance Survey edition of 1897 (Fig 2). Tunnel ***228*** appears to have had a westward return inside the building, with a possible stub of its return visible beyond a rectangular chamber inserted into the northern part of the extant tunnel and associated with the later remodelling of both tunnels (Plate 33). This suggests that the tunnel formed access to the main floor level within the glass works, either via stairs, or more likely a ramp, in order for coal from the yard to be delivered to the furnace, as well as the raw materials for the production of glass.

*Plate 31: Return of flue **226**, with furnace wall **229** behind*

*Plate 32: Flue **226** (right) and flue/passage **228** (left) with later remodelling **227***

*Plate 33: Remodelled return of passage **228***

3.4.10 At the western end of the building, placed against the original external wall of the glassworks (***251***) was a further vaulted passage, ***252*** (Fig 8; Plate 34). This was of similar size and construction to flue ***226***, but retained its full-brick thickness crown at its western end (Plate 34), and almost certainly forming part of the same flue as ***226***, giving a through draught from the exterior, and providing additional access. The flue appears to have been remodelled subsequently, solely into an access passage, with a curving wall at the eastern end of its northern side, and a straight return on the southern side, apparently affording access to the switch room of the secondary regenerative furnace (*Section 3.4.13*, below).

*Plate 34: Flue / access passage **252***

3.4.11 By the date of construction of the glass works in the late 1860s, the Frisbie furnace feeder had been adopted at many glass-manufacturing sites, representing a new improved method of charging the furnace from below. Whilst the uptake of this new technology was relatively rapid, with over 30 having been installed in Birmingham by the middle of the following decade (*Scientific American* 1876), it is unlikely that such a system was in place at Greener's Wear Flint Glassworks in its original construction.

3.4.12 The remains of the furnace align with the western of the square furnaces marked within the building on the Ordnance Survey plan of 1897 (Fig 2). The late-nineteenth century engraving of the works (Plate 14) also depicts several sub-floor openings in the south wall, presumably affording access into the furnace flues. The coal yard is also shown on this side of the works, ideally placed for feeding the furnaces, either from pot level, or through the flues, if Frisbie feeders had been introduced by that date.

3.4.13 ***Phase 2 - Siemens-type tank furnace:*** the original pot furnaces were inefficient in producing large quantities of glass; not only could the pots not hold sufficient metal to supply the increasing demands as the business grew, but also there were significant gaps in production, when the furnace was being recharged. The regenerative furnaces developed by the Siemens brothers in the mid-nineteenth century had been further developed and improved, with a combination of advances in glass technology around the turn of the twentieth century, notably by mass-producers such as Pilkingtons in St Helens. This lead to the development of continuous tank furnaces for cheap production, and these soon proved to be the ideal choice for twentieth-century production (Krupa and Heawood 2002). This allowed production to be increased on a massive scale, reducing the manufacturing costs within a highly competitive industry. It was during this period that the Wear Flint Glass Works shifted production to mass-produced wares. It is unclear at what date the original 10-pot furnaces, although it is probable that the individual furnaces were replaced over a period of time, rather than during a single episode of remodelling.

3.4.14 Despite a later remodelling of the furnaces, several distinct elements indicative of a Siemens-type furnace survived within the western part of Area 2 (Fig 8). The most substantial fabric comprised a large wall (***230***) of 3’ (0.91m) thickness (Fig 8), surviving to a similar height (Plate 35). Its basal courses comprised standard red brick to a height of approximately 4’ (1.21m), capped at the north and south ends by up to seven courses of refractory brick (Plate 36). However, in the central 12’ (3.65m), the base was covered with 2’6” x 9” x 5” refractory blocks, placed transversely across the wall, with 7” (0.18m) wide air gaps between (Fig 8; Plate 37).

3.4.15 Two courses of mixed refractory and standard brick were placed above these blocks, below a further row of blocks, laid directly above those below (Plate 37). These were capped with a surface of more yellow, softer refractory slabs, that appear to have been approximately 3 x 1’ (0.91 x 0.30m), but which were heavily degraded (Plate 38). Several of these slabs had evidence for vitreous splashes on their upper surface (Plate 38), suggesting that this represented the working floor level of the furnace at this time.

3.4.16 The blocks beneath the slab floor butted the rear of a wall formed of large refractory blocks, typically 2’^{2} (0.61m), and 18” (0.46m) high (Plate 36), bonded with a narrow bead of unfired clay. This formed the end of a tank furnace, with chamfered blocks in the upper course representing ‘tuckstones’ (Plate 36), which formed the interface between the tank, containing the glass metal, and the crown above. In the centre of this tank wall, a 3’ (0.91m) wide column rose above the wall either side (Plate 36). The inner face was heavily corroded and glazed by the glass metal (Plate 36), and its exact purpose remains unclear, although it was possibly related to the framing of a gathering port, several of which would have been placed around the working end of the tank. The surface of the pier was also coated with pools of vitreous waste, possibly as a result of spillage during gathering, which would have taken place from the adjacent floor.

Plate 35: Remains of the Siemens-type furnace

Plate 36: Large refractory blocks forming the end-wall of the tank of the Siemens-type furnace

*Plate 37: Vitreous deposits on the upper surface of refractory blocks **230***

3.4.17 Although the subsequent remodelling of the furnace for the production of Pyrex led to the removal of the original switch room, several of the regenerative flues may have been preserved, some being remodelled for later use. Remodelled access hatches, associated with dampers within the switch room, allow the layout of the furnace to be inferred with some confidence Fig 9).

3.4.18 The arrangement of flues in a horizontal regenerative furnace, for either pots or a tank followed a very similar arrangement, with a pair of central gas flues placed beneath the furnace, flanked by a pair of slightly wider air flues. An access passage, or 'cave', was often incorporated between the gas flues, not only to allow access below the 'switch room' floor, but also to prevent the furnace from overheating, providing a buffer of cooler air between the two pairs of chambers. Other furnaces, however, such as that excavated at the Powell & Rickets Glass Works in Bristol (OA North 2009), had the 'cave' placed along the rear edge of the furnace. The 'switch room' was placed at one end of the furnace, and comprised several valves and dampers, and the control mechanism to allow the flow of air and gas to be reversed with the exhaust approximately every 30 minutes.

Plate 38: Aerial view of the south-western part of Area 2 showing the Siemens and Pyrex furnaces

3.4.19 Three apertures in the floor (***215***, ***218***, and ***254***) were arranged in a typical arrangement for switch room access hatches within the air and gas flues of a horizontal regenerative furnace. The two square chambers, ***218*** and ***254***, were placed to the rear of the smaller, angular hatch, ***215*** (Fig 8; Plate 38), and represent the access into the air flues, which ran along the outer sides of the narrower gas flues (Fig 9). Flues would have led from the eastern side of both openings, on an angle demonstrated by the western side of ***215*** (Fig 8), which represented the northern of a pair of access hatches for the gas flues (Fig 9). Short flues would have led from each pair to a further central aperture, that would have housed the switching valves / dampers, allowing the flow or air and gas to be reversed between each pair of flues (Fig 9).

3.4.20 The linear passage, ***221***, on the north side of the furnace (Fig 8), almost certainly represented the remains of the northern air flue, remodelled to provide an access passageway following the replacement of the furnace. The northern gas flue appears to have re-used the central flue of the earlier furnace (***226***), although it would have probably been narrowed for re-use within the regenerative furnace (Fig 9).

3.4.21 The late nineteenth-century engraving of the glassworks (Plate 14) shows two tapering square-section chimneys in the south-western corner of the complex. The smaller, western of these appears to relate to a boiler, placed in adjacent structure, whilst the larger chimney appears to be located within the main glassworks building, and is therefore likely to have related to the exhaust from the western regenerative furnace. Although subsequently remodelled and truncated, a two-brick thick curving wall (***231***; Fig 8) was of refractory brick construction (Plate 39), typical of a flue leading to a chimney. Its position, to the north of the probable switch room (Fig 9), was suitable for an exhaust flue from the switch gear, leading to a chimney placed at its western end adjacent to the external wall ***251*** (Fig 8).

3.4.22 A dog-legged, refractory brick wall, ***256*** (Fig 8), placed at the western end of wall ***231*** appeared to form the foundation of a 4' (1.21m) wide, square-section chimney, similar to that shown in the nineteenth-century engraving (Plate 6), and placed immediately inside the external wall ***251*** (Fig 8; Plates 39 and 40). It is also likely that, as in the extant example at Pilkington's No 9 Tank House in St Helens, (Krupa and Heawood 2002), the flue from the switch gear was placed well above floor level, suggesting that the remains of both the chimney flue (***231***) and chimney (***256***) represented only the foundational levels of each.

*Plate 39: Curving possible chimney flue **231**, north-west of the Siemens furnace*

*Plate 40: Possible chimney foundation, **256***

3.4.23 The southern side of air flue ***221*** was overlain by a machine-made, red brick wall, ***257*** (Fig 8), built in three-stretcher English Garden Wall bond, using a grey sooty mortar (Plate 41). This had a return at its eastern end, and appeared to have formed the outer wall of the tank furnace. It had 7'5" (2.30m) wide, rebated double relieving arches in both the north and east faces (Plates 41 and 42), and presumably continued around the southern and western side of the furnace, with similar arches to each face, those on the east/west alignment almost certainly forming a central access 'cave', given the probable positioning of the gas and air flues.

3.4.24 Removal of flue ***219*** and part of the tank structure ***230*** during the final stages of the excavation revealed that the arch of the northern side of the furnace was blocked, presumably during construction, by the substantial refractory blocks forming the base of the furnace (Plate 43).

Plate 41: External wall of Siemens furnace, ***257***

*Plate 42: Relieving arch in north wall of **257***

*Plate 43: Bottom block of tank furnace behind relieving arch in north wall of **257***

3.4.25 At the eastern edge of Area 2, the eastern wall of flue ***226***, associated with the earliest furnace (Fig 8), was removed subsequently to form an access passage to the west of a secondary structure. Although this was only partially revealed within the excavation area (Fig 7; Plate 44), its outer wall (***258***) appeared almost identical to furnace wall ***257***, being of similar brick construction and with a central relieving arch in its exposed western face (Plate 45). This was blocked, flush with the inner arch (Plate 45), possibly representing the back wall of the 'cave', which appeared to have only been accessed from the eastern side of the furnace. Seven courses above the crown of the arch, a series of eight sockets within the wall face almost certainly represent beam slots for a roof across the newly-widened passageway ***226*** (Fig 8), presumably housing slender steel beams below a concrete slab floor.

*Plate 44: Furnace **258**, in eastern section of Area 2*

*Plate 45: West wall of furnace **258**, with central arched aperture and joist sockets above*

3.4.26 The remainder of the structure, which formed a second Siemens-type refractory furnace, was only partly exposed in plan, as it lay beyond the excavation area (Fig 7), but this revealed a narrower central section of the south wall in the position of the arch to the west. It also revealed that the wall was only externally faced for a thickness of 1½-bricks in red brick, with piers of yellow refractory brick (Plate 44) placed in the south-western and south-eastern corners. Above the upper extant course of the south-western corner of the wall, four fragments of 2" (0.05m) thick refractory tile survived, indicating probable blowing floor level (Plate 44).

3.4.27 *Gas producer:* to the south-west of furnace ***258***, a further structure was inserted into the remodelled flue of the original furnace. This completely blocked the flue, demonstrating its disuse as a flue at this time, the northern part being re-used as an access passageway between the sub-floor levels of the western two regenerative furnaces. The structure was only partially revealed within the section of the trench (Figs 7 and 8; Plate 46), but comprised a vertical 4 x 3' (1.21 x 0.91m) chamber (***227***) with two flues above its southern side (Plate 46). The chamber was also braced with vertical steel I-section stanchions, with transverse and lateral tie rods between, incorporated into the construction of the refractory brick-lined walls (Plate 46). The inner faces of the chamber were covered in a fine tar-like residue, which thickened towards the base, whilst the bottom was filled with fine clinker (Plate 47). The evidence strongly suggests that this represented a single gas producer, the tar being highly indicative of a coal and water-fired producer, which generated a carbon monoxide / carbon dioxide mixed gas of the highest possible caloric value for optimal use within the furnace (Hermansen 1929). The front wall, which had almost entirely collapsed, probably housed an incline grate, possibly indicating why it had collapsed, either under the weight of the wrought iron bars, or having been demolished to salvage the wrought iron. A pan of sheet iron would have been placed below this grate, within the ash pit, providing the water vapour to induce the optimal reaction.

3.4.28 The gas produced rose into the central rear flue, which was also burnt and slightly sooted (Plate 46), and was placed on a concrete base, carried on steel beams across the earlier passage/flue ***226***. Whilst this appears to have been placed on the 'wrong' side of the producer, away from the two furnaces to the north-west and north-east (Fig 7), this was a typical arrangement, having also been observed at Powell & Rickets Glass Works in Bristol (OA North 2009), and allowed access to the front of the producers from the cave and other subterranean passages associated with the furnace. The short length of the gas flue from the producer, and an apparent rear wall on its southern side, suggest that the flue rose vertically, probably into an iron sheet flue, which could feed flues leading to the switch room. It is unclear whether a single gas producer of this size could have supplied two furnaces, although they appear to have been of relatively small size in comparison to those excavated at larger glass works in St Helens and Bristol (Krupa and Heawood 2002; OA North 2008; OA North 2009). It is likely that at least one further producer lay to the east, supplying the eastern furnaces, and it remains unclear whether this gas producer was retained to supply the later Pyrex furnaces.

*Plate 46: Gas producer **227**, in south-eastern section of Area 2*

*Plate 47: Interior of gas producer **258**, with tarring of side walls and ash deposit in base*

3.4.29 ***Phase 3 – the Pyrex furnace:*** the majority of the remains in the southern part of Area B related to the third, and final tank furnace (***217***), installed for the production of Pyrex glass following the securing of the British license for its manufacture by the firm, by this time trading as James A Jobling & Co, in 1921. Almost the entire Siemens-type furnace was removed, although the tank bottom and regenerative flues beneath its eastern end appear to have been capped with concrete to form a new floor level for the later furnace, which was offset slightly to the west (Fig 8). A new room was created around the furnace, with its floor placed at approximately the level of the bottom of the tank of the earlier Siemens furnace, with associated walls of both red brick and concrete shuttering inserted (Fig 8). The tank itself was a continuous borosilicate, end-port, recuperative furnace. It was placed on columns that rose from a deep cellar level, removing the western part of the earlier furnace, and rising through the floor of the plant room (Plate 48), carrying the tank at a height of 1.4m above the extant concrete floor of the plant room (***201***). This is clearly depicted in Wolfgang Trier's long-section through a borosilicate glass furnace (Plate 49), although that depicted has three side regenerators, rather than the single end-port recuperator of the Jobling's furnace. The 13 brick piers supporting the tank survived to varying degrees (Fig 8; Plate 48), and comprised two-brick, square, 18" (0.46m), refractory brick columns placed on a three-course tiered base. The western nine piers formed a 16' by 15'6" (4.87 x 4.72m) rectangle, which formed the 'melt end' of the furnace, with the four remaining piers forming the rounded 'working end' of the furnace, (Fig 8). A tank for borosilicate glass needs a weir between melting and refining sections of the melting end, with a throat to the working end, which was heated separately, as a result of the high melting end temperatures (Trier, 1989, 13).

Plate 48: Columns supporting the tank of the Pyrex furnace

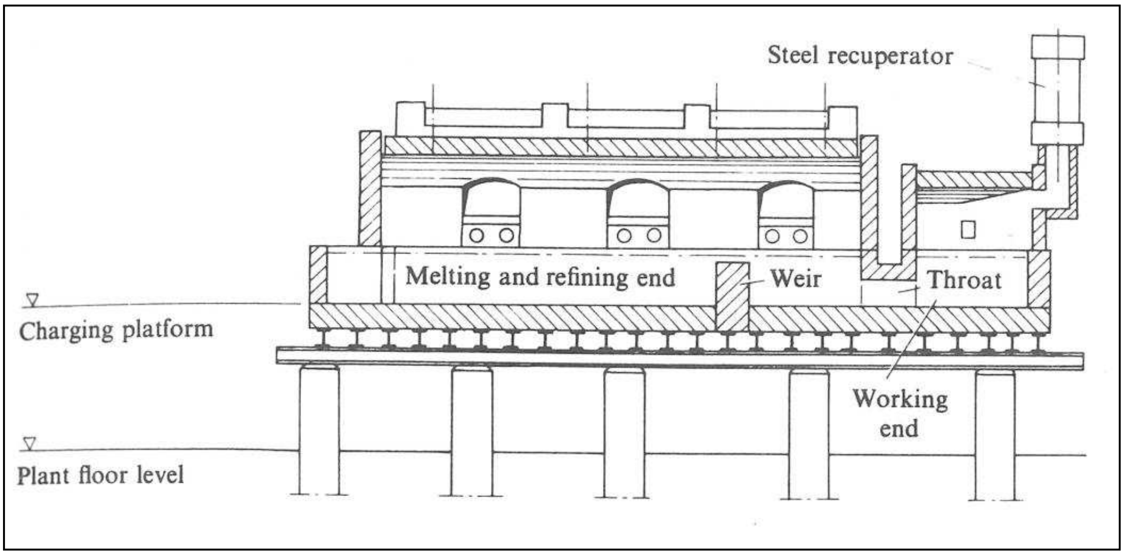

Plate 49: Long-section through a typical borosilicate tank furnace with three vertical regenerators (Trier 1989)

*Plate 50: Glass metal **217**, above refractory tile floor **216***

3.4.30 Tanks with throats could be built shorter than those without, as the refining zone need extend into the conditioning zone in order to achieve the temperature reduction needed for working. Considerations of energy loss also favour square melting areas, and both appear to have been features of the Jobling’s furnace. More recently improved techniques of thermal insulation, however, have made this less important (Trier 1989, 14f), suggesting that the furnace was constructed relatively early within the period of Pyrex manufacture on site.

3.4.31 The piers, and the furnace outline they defined, overlay an 8” (0.21m) thick floor of heavily burnt and oxidised refractory tile, ***216*** (Plate 39). For the majority of the melt end of the furnace, this was bounded by two to three courses of refractory brick (Plate 50), although in parts of the southern side of the furnace, this was overlain by up to seven courses of unbonded red brick (Plate 50). This formed a boundary wall to a large flow of glass metal, ***217***, which covered most of floor ***216*** below the melt end of the furnace (Fig 8; Plates 48 and 50). This appeared to represent the standard procedure for emptying the tank above, although it presumably held less metal when emptied for maintenance, than it did after its final firing. The depth of such furnaces typically varies from 700-900mm for a working end, and 1.10 to 1.30m for the melting end of a furnace producing clear container (Trier 1989, 14).

3.4.32 The furnace was butted on its western side by a vertical recuperator (***232***), measuring 11 x 9’5” (3.35 x 2.90m), comprising four vertically-set chambers of refractory brick construction within an outer skin of red brick, and bound by vertical iron stanchions and rails (Fig 8; Plate 51). The interior of the structure was divided into four chambers by transverse walls of refractory brick. The two eastern chambers, nearest the furnace, were 4’^{2} (1.21m), whereas the rear two were slightly narrower, at 3’ (0.91m) on the east/west axis (Fig 8). These rear two chambers were also empty to the water table, which was situated approximately 1m below floor ***201***. The front chambers, however, retained vertically-set, square-section ceramic pipes, on a 5 x 5 grid, each having its internal corners rounded, to aid the flow of air (Plate 52).

*Plate 51: Recuperative stack, **232**, on west side of Pyrex furnace*

Plate 52: Detail of recuperator tubes

3.4.33 This represents an alternate method to that developed by the Siemens brothers, for re-using exhaust gas within a furnace. The principal of the recuperator is simpler than the regenerative furnace, whereby cold air *en route* to the furnace passes adjacent to conductive tubes of hot exhaust air flowing towards a chimney, with heat being passed between the two. This simple process requires no switching mechanisms, with the intake air being constantly heated by the exhaust, but once gas replaced coal or wood as the primary fuel, this could not be heated within such a system. The high temperatures over 1500°, frequently reached in large tank furnaces are also not viable with recuperative furnaces, as the heat exchange between exhaust and intake air is not so efficient in a recuperator as it is within a regenerator. Given their relative simplicity, the earliest recuperators predated Siemen's regenerative furnace, comprising cast-iron pipes (Hermansen 1929, 177). However these were susceptible to leakage, and many subsequent attempts to increase the reliability and efficiency of recuperators ended in failure. In the early twentieth century, Hermansen introduced a recuperator, made of refractory material, and less prone to leakage, offering an alternative to the Siemens-type furnace. The Hermansen-type recuperator blocks have channels in their outer section, allowing the intake air to flow between the pipes, which carry the exhaust.

3.4.34 Only the air was preheated in the Jobling's recuperator, the vertical gas flues both being empty, and devoid of accretions from the exhaust, that was observed in the eastern, air recupertors. Access ports into the recuperator tubes were observed in the southern face of the external wall (Plate 51), with an area of rebuilding below, suggesting the replacement of a leaking tube.

3.4.35 The base of the recuperator was not identified during the excavation, and was possibly placed considerably below the limit of excavation. Trier's cross-section through a borosilicate furnace (Plate 53) shows a considerable depth to the chamber, and although a regenerative stack is depicted, its more efficient heat exchange would suggest that a recuperator was not likely to be any shorter. Steps from the south-western corner of concrete floor ***201*** (Fig 8), would have afforded access to the recuperator base, and the cellar level of the furnace, but they were quickly submerged below the water table.

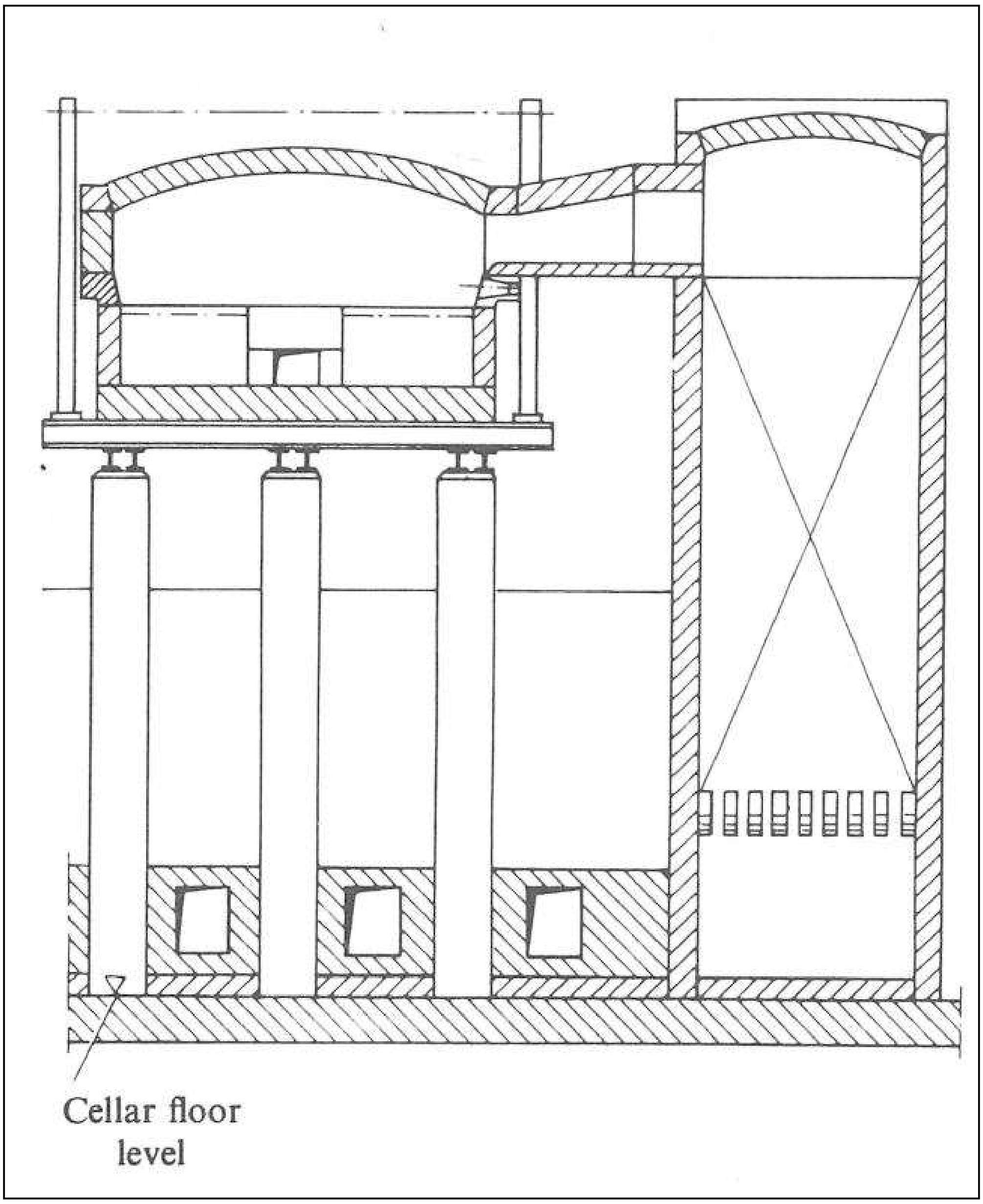

Plate 53: Cross section through a borosilicate furnace, with regenerative stack (Trier 1989)

3.4.36 Excavation in the south-western corner of Area 2 revealed the remains of an octagonal-shaped chimney (***213***), which was almost certainly associated with the borosilicate furnace (Fig 8; Plate 53). A flue (***212***) entered chimney ***213*** on its southern side, taking a U-shaped route from the recuperator (***232***), and incorporated a square-shaped access manhole, set into the crown of the flue a short distance to the south of chimney ***213***. (Fig 8; Plate 54) This may have housed a damper, intended to control the flow rate of exhaust entering the chimney. A similar access, placed immediately to the rear of recuperator ***232***, presumably regulated the exhaust flow from the furnace.

*Plate 54: Chimney **213** and flue **212**, looking north-west, with flue **214** to the rear*

3.4.37 The chimney was first depicted on the Ordnance Survey plan of 1941 (Fig 4), suggesting a construction date between 1919 and 1941. This period coincides with the commencement of Pyrex production in the 1920s, suggesting that furnace ***217*** represented an early, or possible original borosilicate furnace within the complex. An aerial photograph of the complex taken in 1937 (Plate 15) clearly shows the chimney, but also shows a large expansion of the complex on its northern side, also depicted on the Ordnance Survey plan of 1941. Whilst this may have suggested that the expansion was undertaken to accommodate the new Pyrex production facility, the archaeological evidence suggests that primary production was undertaken by new furnaces that replaced earlier examples.

3.4.38 The chimney also served buildings placed on its northern side (Fig 7). This appears to have replaced an earlier chimney shown on the late nineteenth-century engraving (Plate 6). Whilst the stratigraphic evidence shows the flue from the ancillary structures (***214***) was erected after the chimney, butting its external face, unlike that from recuperator ***232***, it does butt an existing bull-nosed aperture in the wall of the stack (Plate 55), suggesting that the northern flue was included within the design of the chimney, but formed a slightly secondary phase of construction, once the primary role of the chimney as an exhaust to a new borosilicate furnace, had been completed. The two flues were divided within the chimney base by a central partition wall, which was seemingly intended to allow separately controlled exhaust from each flue (Plate 56).

*Plate 55: Butt joint between flue **214** and chimney **213***

*Plate 56: Dividing wall within base of chimney **213***

3.4.39 Flue ***214***, entering the northern side of the chimney, may have been connected to a pair of boilers housed in Room ***236***. This room had certainly been a hot working area, incorporating refractory brick floors, and the remains of several flue dampers and refractory brick-built walls reminiscent of the layout of a Lancashire-type boiler (Plate 57). The brick floors to the north also appeared typical of an annealing house, comprising several layers of unbonded brick, some of which appeared heat-damaged. Several rectangular structures with refractory brick linings appeared to represent small heaters, designed to control the temperature within the annealing house. This area was heavily remodelled, presumably as annealing technology and mechanisation increased, and also as the product transformed from flint glass to Pyrex production.

*Plate 57: View of western part of Area 2: flue **214** enters from the left, serving an area with refractory brick floors that probably represented the housing for a Lancashire-type boiler*

3.4.40 The northern part of the eastern range was devoid of original features, and probably represented warehousing for raw materials, workshops and preparation areas. It was, however, remodelled subsequently into a production area, with several large flues and concrete bases cutting the original walls (Fig 7). The largest of these was a north-west/south-east-aligned flue, ***206***, which rose from the north-west, and fed into a shallower north/south aligned flue, ***260*** (Plate 48). Two access hatches were placed within flue ***206*** (Plate 58); that on the western side presumably affording access into the flue, with a second hatch adjacent to its junction with flue ***260*** presumably forming a damper housing. Flue ***260*** had a brick scar for a probable iron sheet butterfly valve, placed to the north of the inlet from flue ***206*** (Plate 59). A third flue, ***261***, appeared to mirror ***206*** to the west, entering the central flue in a similar position, and was aligned at a steeper angle beneath a later concrete base (Fig 7). This flue was closed with an iron sheet, placed immediately behind an iron lintel, and apparently representing the corroded remains of a butterfly valve (Plate 50). In the north-eastern corner of Area 2, a further square refractory brick hatch lay above flue ***261***, which was exposed *c* 1.5m lower (Plate 61).

*Plate 58: View of northern part of Area 2: flues **206** (left) and **261** (right) fed into a smaller flue, **260** (centre) which served chimney **203**. Regenerator **225** clearly cut flue **260***

*Plate 59: Chimney **203**, with flues **206**, **260**, and **261** to rear*

*Plate 60: Probable butterfly valve extant within flue **261***

*Plate 61: Deep flue **261**, with access hatch*

3.4.41 The three merged flues fed into a circular structure, ***203***, constructed of a 2½-brick thickness of red brick, lined with a single skin of refractory brick (Plates 58 and 59). This was interpreted previously as a small circular furnace, but actually represented a chimney, serving the three flues.

3.4.42 The central flue (***260***) was truncated at its northern end, apparently being cut by a twin-chamber rectangular structure (***225***) of full-brick thickness construction in refractory brick (Plates 58 and 62), bearing 'BURNAXE' and 'DOUGLAS D' stamps (*Appendix 3*). It was externally faced on its southern and eastern sides with a skin of red brick (Plate 62), and was shuttered with concrete and metal sheeting to the north. This appeared to represent a pair of vertical flues into a furnace placed on the adjacent base. Whilst no evidence for checker brick or recuperative tile was observed *in-situ*, the rubble infill potentially obscured such features lower within the chamber, and retained several square-section refectory bricks, typical of regenerative checkers (Plate 62). The size of the chambers differed, with that on the western side being narrower, representing the gas intake to the furnace (Plate 58). Flue ***225*** appeared to have been associated with an adjacent substantial concrete base, forming the north-western corner of an approximately 7.5m² structure, which presumably represented the base for a small regenerative furnace (Fig 7). This butted chimney ***203*** at its south-western corner (Fig 7), but any use of the chimney by the feature on the base, which presumably represented some form of heating plant or furnace, took place above the level of the surviving remains. However, the survival of a deposit of colourless glass waste within the base of the chimney (Plate 59), suggests that it may have been redundant by this time.

*Plate 62: Regenerator **225** during demolition*

3.4.43 Two further flues were identified beyond the northern boundary of Area 2, during groundworks by the site remediation contractors. Both were placed significantly deeper than those within Area 2 (Plate 63), with the shallower, eastern flue (***262***) being *c* 4m below the foundational level of the external wall of the original glass works (***249***). It comprised a 4' (1.21m) wide, 6' (1.83m) high horizontal flue, comprising a full-brick thickness of refractory brick, below a shallow segmental crown (Plate 64), and with a refractory brick floor of two courses. The feature, which was only examined in section, and was infilled with scrap metal, clearly dated to the expansion of the complex on its northern side, and demonstrates the depth of flues utilised for supplying the furnaces which had vertically set regenerators or recuperators.

*Plate 63: Flues **262** (left) and **263** (right) in section to north of Area 2*

3.4.44 The second flue (***263***) was placed slightly deeper, but was smaller than that to the east, measuring only 3' (0.91m) wide, and 2'6" (0.76m) high. It was of similar construction to flue ***262***, but with an external skin of red brick to either wall, and with a slightly cambered floor (Plate 65). The flue survived below Area 2, widening and increasing in height behind the aperture revealed in section, and being only silted to about 0.1m depth (Plates 65 and 66), and was blocked with collapsed brickwork at its southern end, where a vertical shaft (Plate 66) almost certainly led into regenerator ***225***, demonstrating the depth of such structures could be in excess of 5m.

*Plate 64: Detail of flue **262***

*Plate 65: Detail of flue **263***

*Plate 66: Interior of flue **263**, with vertical opening above brick blocking at rear*

3.5 AREA 3

3.5.1 Area 3 measured approximately 250m^2, and comprised an east/west-aligned trench (Figs 2 and 10). The eastern end of the trench was excavated more fully during this phase of work, as the remains of a further regenerative furnace were established beneath the rubble generated from the initial mechanical excavation within this part of the area.

3.5.2 The main length of Area 3 contained a small flue and two parallel walls. The southern brick wall had visible returns at either end, forming a structure Room ***304***) of 27ft (8.23m) in length (Fig 10). Its coursing was irregular, and included several refractory bricks, apparently randomly placed within its construction. As the feature was only established in the southern section of the trench, its width or purpose was not determined, although its position relative to the late nineteenth-century Ordnance Survey mapping suggests that it may represent the northern wall of a further furnace (Figs 2 and 3).

3.5.3 Flue ***302*** was located to the east of this structure (Fig 10), further suggesting its relation to a furnace. It was made of refractory bricks stamped 'NHC' and capped with square flags of refractory material (Plate 67). Sample *103* was taken from an ashen deposit within the flue. Within the excavation it had been truncated by the manhole of a modern drain, constructed of frogged bricks bearing a 'LUMLEY' (*Appendix 3*).

*Plate 67: Detail of Flue **302***

3.5.4 The north wall (***303***) formed the section of the excavated trench (Fig 10), and was built of wire-cut brick, in three-stretcher English Garden Wall bond, set on an irregular sandstone foundation plinth (Plate 68), which itself included some reused brick. A gap in the wall at its western end was infilled with clay and cinder deposits (Plate 69), whilst, at its eastern exposed end, the wall had been erected on a bed of cinders (Sample *104*; Plate 70). The wall was aligned with an internal wall within Area 2 (Wall ***245***; Figs 2-4), suggesting that it ran the entire length of this range of the glassworks, and again appeared to represent a boundary along the northern side of the furnaces.

*Plate 68: The fabric of wall **303**, showing the sandstone plinth*

*Plate 69: Aperture at the western end of wall **303**, with clinker infill*

*Plate 70: Clinker infill below the sandstone footings at the eastern end of wall **303***

3.5.5 At the eastern end of Area 3, the trench was widened to reveal a concrete chamber, ***301*** (Fig 10), surviving to an exposed height of approximately 4m (Plate 71). The chamber contained a rectangular vertically-set regenerative furnace, ***305*** (Plate 72). Rubble was removed from around the furnace and the remains were then cleaned by hand.

*Plate 71: Regenerative furnace **305** within a concrete chamber*

*Plate 72: Detail of regenerative furnace **305***

3.5.6 The outer sides of ***305*** were made of red brick bearing a 'CELL-O-BRICK' stamp (*Appendix 3*), laid in three-stretcher English Garden Wall bond, with refractory brick headers. The interior was built entirely of refractory tiles, many stamped 'DOUGLAS-D'. The lining of each of the four internal chambers, and the lattice within, were constructed of edge-set refractory blocks (Plate 72) measuring 15 x 6 x 3in (0.38 x 0.15 x 0.08m), some of which bore the additional stamp '5' (Plate 73). The lattice was supported by segmental arches from the north to south wall of each chamber, supported at the sides by angled springers set into the side walls. Further detail lay below the water table, but it would appear that the arches clearly related to flues supplying the furnace. The western two chambers were heavily vitrified towards their bases, with a whitish to pale greenish deposit found between the dividing wall and the lattice (Sample *118*). Fragments of white Pyrex glass were recovered from the fill of the chambers, one bearing the word 'Cornings'.

3.5.7 Hermansen was undertaking his research at a time broadly contemporary with the introduction of borosilicate glass furnaces for producing Pyrex at Joblings. He noted that the refractory checkers, generally 300x150x75mm, should be piled at intervals equal to the thickness of the brick (Hermansen 1929, 166), *ie* at a spacing of 75mm apart, producing an even checker pattern. Towards the end of the twentieth century, thinner brick were being utilised, as those thicker than 65mm were inefficient, as with reversal periods of not more than 30 minutes, the core of the brick hardly plays a part in heat exchange (Trier 1989, 41). Trier also quantified brick length as between 230 and 375mm, and height varying between 100 and 150mm, with tolerances of only +- 0.5mm to ensure stability of the stack (*ibid*). For heat economy reasons the spacing between the bricks should be as short as possible, as not only does it allow for more checkers within a given volume, but also for a given amount of checker bricks it produces a maximum velocity and thus greater sweeping of heat (Hermansen 1929, 166). However, in practice, larger distances were required, as the narrow spaces became infilled; not by carbon in the gas chambers, as this is burnt away on account of the surplus air in the waste gas, but by particles of the charge, such as sand, soda, and lime (*ibid*). It was, therefore generally recommended that spacings of 125mm were used (Dralle 1911).

3.5.8 By the early twentieth century, it was already understood that horizontal regenerators were not ideal, as the horizontal movement of air does not produce an even distribution of the current. (Hermansen 1929, 166). Hot flue gases natural pass down through the checkers, and cold currents upwards, so horizontal regenerators had open flues below the checker stack, to allow movement on a vertical plane through the stack, rather than horizontally. However, the lowest radiation loss occurs when the four regenerative chambers are built together as a square (*op cit*, 170), and thus vertically set regenerators, with well-insulated side walls to further prevent heat loss were introduced. Although regenerator ***232*** looks relatively small when compared with the large horizontal regenerators excavated in St Helens and Bristol (Krupa and Heawood 2002; OA North 2009), they were often deeply-set into the basement of the buildings in which they were housed (Plate 73). Thus, a similar surface area for heat exchange could be created within a vertical regenerator, for a much smaller footprint, and with a more efficient flow.

*Plate 73: Regenerative blocks within furnace **305**, some bearing an inverted '5' stamp (right)*

3.5.9 The whole structure was braced by horizontal steels, supported by four vertically set, I-section steel joists. Two were placed on the west side of the furnace, with the other two set slightly wider in the middle of the north and south sides (Fig 10).

3.5.10 At the base of furnace ***305***, steel doors placed on the outside of the north and south walls formed dampers, allowing control of the gas flow, and to allow inspection into the refractory chambers. They were set within rails, and were operated by sliding vertically (Plate 74). There was also a removable block observed in the south exterior wall of the south-east chamber, and as this was placed within the highest surviving part of the furnace, it is possible that such a feature may have been present on all sides (Plate 75).

*Plate 74: Sliding steel doors on the north face of furnace **305***

*Plate 75: Removable block in the upper south wall of regenerative furnace **305***

4. ANALYSIS OF THE GLASS-WORKING MATERIALS

4.1 INTRODUCTION

4.1.1 The archaeological excavations undertaken on the site of Jobling Glass at Lisburn Terrace, Sunderland recovered material evidence for the manufacture of a range of glass products. This material comprises a range of finished glass artefacts and characteristic waste (especially threads). While recent archaeological work has begun to shed light on nineteenth-century glass production (*eg* Percival Vickers, Manchester and Lodge Road, Birmingham), relatively little is known of twentieth-century manufacturing processes.

4.2 HISTORICAL AND TECHNICAL BACKGROUND

4.2.1 The production of press-moulded glass in Britain began in the Midlands and probably used essentially the same glass recipe (potash, lead oxide and sand) that had been used in the blown lead glass sector (Dungworth and Brain 2009; 2013). The later nineteenth century saw production of much press-moulded glass in England shift to the North East. It has also been suggested (Latimore 1979, 32) that at least some of the success of the north-east press-moulded glass industry rested on its use of 'semi-lead glass', which contained less lead and a proportion of sodium and barium (cf. Angus-Butterworth 1948, 36). Latimore has also suggested that while American and European manufacturers succeeded in using soda-lime-silica glass (presumably of a similar composition to that used for window glass and, from the later nineteenth century, increasingly for bottle glass), in England this recipe was deemed insufficiently durable for press moulding. The recent analysis of debris from a nineteenth-century glass house in Manchester suggests that a great variety of glass recipes were used, including ones with less lead and more sodium (Willmott *et al.* 2012). The Manchester evidence suggests that the traditional lead crystal recipe (Dungworth and Brain 2009; 2013) was increasingly restricted to free-blown vessels (Willmott *et al*. 2012). Much of the press-moulded glass produced in Manchester was essentially a soda-lime-silica glass, although this glass usually also contained small amounts of lead.

4.2.2 Greener died in 1882 and the firm was bought in 1886 by James Augustus Jobling (Baker 1983, 7). The company was renamed Greener & Co and, although some restructuring seems to have occurred, the range of products remained largely the same. The main emphasis was on press-moulded colourless and coloured domestic glass: the colours included translucent blue, green, brown and yellow, as well as jade-coloured glass, and the range of forms included bowls, jars, vases, candlesticks, dressing table sets, flower rings and posy bowls (Latimore 1979, 74–87). The firm appears to have followed the general trends of fashion in domestic glass and reduced output of coloured glass at the end of the nineteenth century in favour of colourless glass (Latimore 1979, 86). Fashion changed again after the First World War and the firm (known as Jobling's from 1921) began to produce an opalescent pressed glass called Opalique which imitated Lalique (Notley 2000, 37).

4.2.3 While the early post-war period saw Jobling's produce a wide range of decorative domestic glass, their output was increasing dominated by Pyrex. Pyrex (a borosilicate glass) had been patented by the American company Corning Glass just before the First World War. Pyrex was capable of withstanding very rapid changes in temperature which made it ideal for laboratory ware. It was soon realised that it could be used for casserole dishes and the like which could be taken directly from the oven to the dining table (Evans 1983, 22). Corning had tried to interest many British manufacturers in their new glass but it was Ernest Jobling Purser who saw its potential. The manufacture of Pyrex proved to be highly successful and a 60-ton tank furnace was constructed in 1927 with automated presses (Baker 1983, 8). Jobling introduced a series of decorated designs from the early 1930s (Hibberd 2007) which facilitated the production of dinner sets to match the ovenware. Flameware (initially introduced in 1938) was designed to be used in the oven and on top of the stove. Ernest Jobling Purser retired in 1949, and the company went through a series of complex changes of ownership which ultimately led to the company being acquired by the Corning Glass Works in 1954. The 1950s saw the development of an opaque white Pyrex (Opalware, later called Caterware or Tableware) which was even tougher and more resistant to changes in temperature.

4.2.4 Opalware was used extensively for the production of dinners sets and these were increasingly produced with screen-printed enamel patterns (Hibberd 2007; Mauzy 2002). In the 1950s Corning developed a new material (called Pyroceram in the UK) which was initially produced as a glassy material that could be cast to shape but was then heat treated to take on some properties of very tough ceramics.

4.2.5 The technical aspects of both early Pyrex production and later developments are incompletely understood. Pyrex was initially a borosilicate glass and later specifications (e.g. PYREX 7740) indicate a silicate glass with 13wt% boron oxide (B_2O_3), 4wt% soda (Na_2O) and 2.3wt% alumina (Al_2O_3). While it is often assumed that all Pyrex glass is a borosilicate, this is not always true. Borosilicate glasses have a very low rate of thermal expansion which allows them to be taken from an oven straight to a table without cracking. The same resistance to thermal shocking can also be achieved by tempering glass. Methods of glass tempering were developed during the twentieth century which allowed the substitution of the rather expensive borosilicate glass with soda-lime-silica glass. Both Flameware and Opalware achieved their heat resistance through tempering rather than through the use of a borosilicate glass. Shaw and Evans (1983, 16) suggest that Flameware was an aluminosilicate glass (cf Baker 1983, 10) but they describe Opalware as having a 'complex composition consisting of about 60% silica combined with many other constituents' (Shaw and Evans 1983, 17). The glass-ceramic materials such as Pyroceram produced from the 1950s were often lithium-aluminium-silicate (spodumene) glasses but a range of other elements were introduced (e.g. magnesium, zinc, titanium and fluorine). The heat treatment of these glasses could lead to devitrification (crystallisation) or to microphase separation. In the latter case two immiscible glasses form and separate but the separation is usually at the 1 micron scale.

4.3 CATEGORIES OF MATERIALS RECOVERED

4.3.1 The material recovered comprises a range of finished glass artefacts and glassworking waste, as well as other categories such as clinker and possible raw materials. The types of waste and the range of finished glass artefacts suggest that most of the recovered material relates to the manufacture of utilitarian ware of the twentieth century. There are no clear examples of nineteenth-century glass.

4.3.2 All of the material submitted for assessment has been examined visually following standard procedures (Paynter and Dungworth 2011). All of the glass artefacts and waste has been sorted into categories (cf Dungworth and Cromwell 2006; Paynter and Dungworth 2011) based on colour and form. It is clear that a small proportion of the finished glass recovered from the Lisburn Terrace site was not produced there. The clearest cases are the bottles with maker's marks identifying another producer.

4.3.3 The visual examination of the glass and glass waste was supplemented in a few cases by qualitative chemical analysis. This was achieved using a X-Ray Fluorescence spectrometer (EDAX Eagle II) but no attempt was made to quantify the results. The XRF was used to both identify the major glass types, such as soda-lime-silicate and borosilicate, as well as the use of some elements to colour (or decolourise) the glass. In several cases the analysed glass or glass waste appeared to contain only silicon — these samples are almost certainly borosilicates.

4.3.4 ***Raw Material:*** a substantial (18.7kg) sample was taken of a white to pale green crystalline but rather friable material. The material is soluble in water and XRF failed to detect any significant X-ray peaks. This is boron oxide used in the manufacture of Pyrex.

4.3.5 ***Colourless glass:*** most of the material examined (35kg) comprised colourless glass working waste and artefacts probably made at the Lisburn Terrace site. The limited range of artefact types and the recurrence of identical forms suggests that these represent items produced at this site. A few of the forms are repeated in coloured glass.

4.3.6 The forms of finished glass identified include oval casserole dishes of a type first introduced in the 1920s (Plate A1). This form continued to be popular remained in production throughout the 20th century. One example has a Pyrex log which bears a ligatured JP monogram (Plate A2); this may refer to Jobling Purser. The best known UK Pyrex logo was the crown introduced in 1953 (Evans 1983, 34) and the chronology of earlier logos is poorly known.

Plate 76: Oval dish (sample #05)

Plate 77: Pyrex logo (note the ligatured JP above and below the word Pyrex

4.3.7 The remaining colourless glass is dominated by small jugs or tankards (cylindrical, octagonal and fluted), a wide variety of bowls and ash trays (Plate A). Some bowls bear the legend "BRITISH MAKE" suggesting they were made for export to the USA between the World Wars. The simple nature of the form and decoration of most of these vessels suggests they were manufactured after the First World War. The assemblage includes several large domed objects of uncertain function (Plate A4).

Plate 78: Ash tray (sample #18)

Plate 79: Large conical/bell-shaped objects (samples #19–20)

4.3.8 ***Coloured glass:*** coloured glass vessels and working waste (13.0kg) were present in a wide variety of colours, including several shades of green, red, blue, opaque white, orange, and black. Most of the coloured glass (8.3kg) comprised large fragments of unstratified blue and green tank metal. Green glass was relatively abundant and the most commonly identified form was the ash tray (Plate A5). Many colours were represented by a relatively small number of rather small fragments (e.g. only 0.2kg of red glass) and some uncertainty remains as to whether all of the coloured glass was actually produced by Joblings. The opaque white vessels and waste appear to be made examples of Tableware or Caterware (Figure 6).

Plate 80: Ash trays (sample #22)

Plate 81: Opalware or Caterware cups (samples #23 and #24)

4.3.9 16.8kg of crucible and tank furnace bricks were examined. Several fragments have adhering glass (blue and colourless) while another has a friable vitrified surface suggesting that it is a fragment of the roof (crown) of the furnace and that the vitrification has occurred through the action of volatile alkali (sodium).

4.3.10 9.5kg of devitrified glass waste were examined. This material was probably produced (accidentally) during the manufacture of glass at Lisburn Terrace but it may have undergone a variety of reactions which will have altered its chemical composition (e.g. glass-ceramic interaction, Dungworth 2008). 3.1kg of clinker and other black vitreous materials were examined. These are likely to represent material which formed during the combustion of coal and may be related to the operation of a glass-melting furnace, however, most glass-melting furnaces from the late 19th century onwards have been heated using gaseous fuels. By the middle of the 20th century (if not earlier) the furnaces at Joblings were fuelled by creosote/pitch. One fragment of black slag also contains minor amounts of zinc and nickel and is unlikely to be a waste from the glass industry.

4.3.11 2.4kg of finished glass has been identified as not having been made at Lisburn Terrace. This includes window glass, milk bottles and green glass bottles bearing maker's marks on the bases.

4.4 SCIENTIFIC ANALYSIS

4.4.1 The visual examination of the glass (in combination with limited qualitative EDXRF analysis) indicated some of the range of glass types that were manufactured by Joblings. This included some borosilicate Pyrex, some Opalware and soda-lime-silica glass. Further details on the nature of the glass were investigated through the quantitative chemical analysis of selected samples (Table 1). The selected samples were prepared using standard metallographic procedures: all samples were embedded in epoxy resin and ground and polished to a 1-micron finish. Polished samples were examined using optical and scanning electron microscopes to determine the nature of any surface treatments as well as any corrosion. Chemical composition was determined using a bench-top energy dispersive x-ray fluorescence (EDXRF) spectrometer and an energy dispersive x-ray detector attached to the scanning electron microscope (SEM-EDS). The former technique provides better sensitivity for a range of minor elements (*eg* arsenic and strontium), while the latter technique provides better sensitivity for light elements. It was anticipated that some of the samples would contain boron and while considerable effort was expended trying to directly measure the boron content of all samples, this was ultimately unsuccessful. Nevertheless it is possible to indirectly assess the possible boron content of these samples. The analysis of a range of glass standard reference materials suggests that the difference between 100wt% and the total of all detected elements is the boron oxide content. The analysed samples have been divided into a number of categories based on their glass composition.

LAB #	CONTEXT	SAMPLE	DESCRIPTION
LISB#01	***203***		Colourless waste (dribble)
LISB#02	***209***		Colourless beaker with fluted walls
LISB#03	***203***		Colourless vessel (circular)
LISB#04	***203***		Colourless vessel (circular, mould number 168-B)
LISB#05	***207***		Colourless vessel (oval, casserole dish)
LISB#06	***207***		Colourless vessel (oval, casserole dish)
LISB#07	***209***		Colourless press-moulded vessel (failed, waste)
LISB#08	***209***		Colourless press-moulded vessel (base)
LISB#09	***210***		Colourless press-moulded vessel
LISB#10	***209***	112	Colourless waste (thread)
LISB#11	***209***	112	Colourless waste (thread)
LISB#12	***211***		Blue waste
LISB#13	***301***		Ceramic with adhering glass
LISB#14	***301***		Blue glass adhering crucible (#15)
LISB#15	***301***		Crucible with adhering blue glass (#14)
LISB#16	***220***		Colourless press-moulded vessel (dish)
LISB#17	***220***		Colourless waste (droplet)
LISB#18	***224***		Colourless press-moulded vessel (ash tray)
LISB#19	***225***		Colourless cone-shaped object (large)
LISB#20	***225***		Colourless cone-shaped object (large)
LISB#21	***225***		Colourless waste (thread)
LISB#22	***231***		Green press-moulded vessel (ash tray)
LISB#23	***301***		Opaque white cup (base glass) + blue decoration
LISB#24	***301***		Opaque white cup
LISB#25	***301***		Opaque white waste (dribble)
LISB#26	***302***		Colourless waste (thread)
LISB#27	***302***		Colourless waste (thread)
LISB#28	***201***	107	Colourless press-moulded vessel
LISB#29	***201***	107	Colourless press-moulded vessel
LISB#30	***201***	107	Colourless waste (lump)
LISB#31	***201***	107	Colourless waste (lump)
LISB#32	***201***	107	Colourless waste (thread)
LISB#33	***201***	107	Colourless waste (thread)
LISB#34	***201***	107	Colourless waste (thread)
LISB#35	***201***	107	Colourless waste (thread)
LISB#36	***201***	107	Colourless waste (thread)

Lab #	Context	Sample	Description
LISB#37	***203***	108	Colourless vessel
LISB#38	***203***	108	Colourless vessel
LISB#39	***203***	108	Colourless vessel
LISB#40	***203***	108	Colourless vessel
LISB#41	***203***	108	Colourless waste (lump)
LISB#42	***203***	108	Colourless waste (lump)
LISB#43	***203***	108	Colourless waste (lump)
LISB#44	***203***	108	Colourless waste (lump)
LISB#45	***203***	108	Colourless waste (thread)
LISB#46	***203***	108	Colourless waste (thread)
LISB#47	***203***	108	Colourless waste (thread)
LISB#48	***203***	108	Colourless waste (thread)
LISB#50	***301***		Devitrified waste?

Table 1: Details of materials sampled for analysis

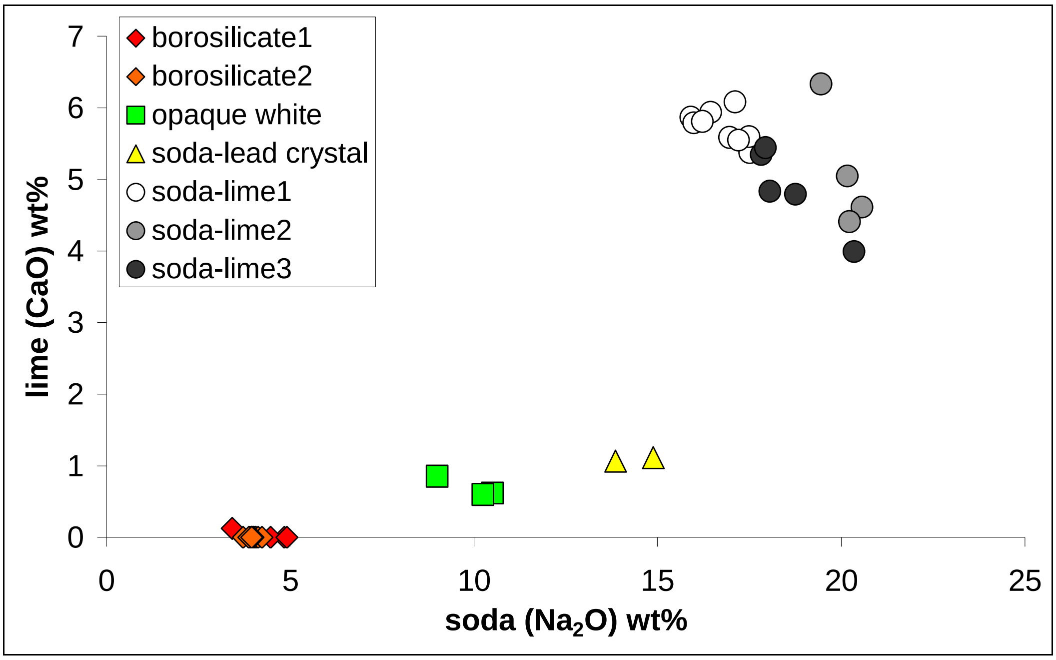

Plate 82: Soda and lime content of the analysed glass and glass-working waste

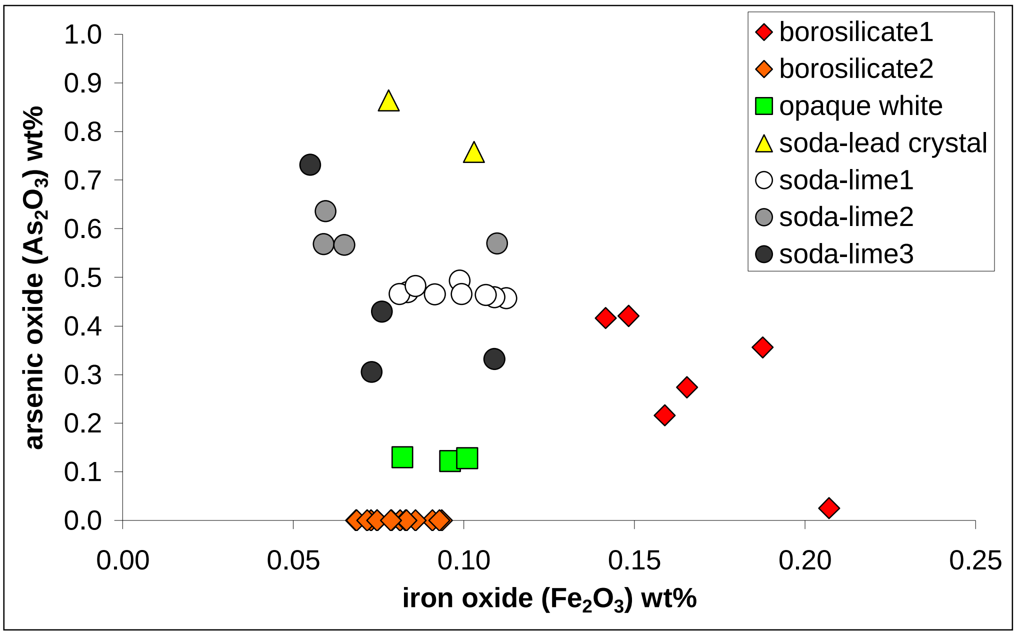

Plate 83: Iron oxide and arsenic oxide content of the analysed glass and glass-working waste

4.4.2 ***Borosilicate1 (1, 3, 4–6, 17):*** six samples contain high levels of silica (c. 80wt%), small amounts of soda (c. 4wt%) and alumina (c. 2wt%), and analysed totals which are both sufficiently and consistently low to suggest that they contain boron (10–15wt% of the oxide). The apparent composition of this glass (Table 2) corresponds closely to Pyrex 7740, developed in the early 20th century and made at Joblings under license from Corning.

	B_2O_3	Na_2O	Al_2O_3	SiO_2	Fe_2O_3	As_2O_3	ZrO_2
Mean	~12	4.2	2.0	77.5	0.17	0.28	<0.01
sd		0.6	0.3	1.8	0.02	0.15	

Table 2: Average composition of the borosilicate 1glasses

4.4.3 The borosilicate 1a glass samples are also characterised by very low levels of other elements. In most cases no other elements were detected. The glass contains small amounts of iron although these are the highest levels of iron among all of the colourless glass samples analysed. The glass consistently contains small amounts of arsenic which was presumably added deliberately to refine the glass (and possibly to reduce the colouring effect of the iron present). The vessel fragments that could be identified included the classic Pyrex oval casserole dish (Plates A1 and A2). The form of the logo on the Pyrex oval dish shows that this was manufactured prior to 1953.

4.4.4 ***Borosilicate 2 (19, 20, 21, 37–48):*** in total, 15 samples have a composition which is similar to borosilicate2 but with less iron, no arsenic but some zirconium (Table 3). The borosilicate2 glass includes fragments of production waste (threads, etc) and a limited variety of vessel forms. Some of the vessel fragments were so small that it was difficult to propose what sort of vessel they were made from.

4.4.5 The only substantially complete objects were large cone or bell-shaped objects of uncertain function (Figure 4). The low levels of iron in borosilicate2 compared to borosilicate1 suggest that this might be a slightly later recipe. The presence of the zirconium is not easily explained. Some zirconium (c. 0.01wt% ZrO_2) is present in most sands and glass, but the levels of this element in the borosilicate2 glass are much higher normal. It is difficult to see why zirconium might be deliberately added to a glass. Small amounts of zirconium undoubtedly erode from furnace walls and the 20th century saw the development of zirconium-containing refractories; however, most twentieth-century glass contains negligible amounts of this element.

	B_2O_3	Na_2O	Al_2O_3	SiO_2	Fe_2O_3	As_2O_3	ZrO_2
Mean	~12	4.0	2.2	79.3	0.08	<0.02	0.17
sd		0.1	0.1	0.8	0.01		0.19

Table 3: Average composition of the borosilicate 2 glass

4.4.6 ***Soda-lime Glasses:*** a total of 21 samples contain moderate amounts of silica (*c* 70–73wt%), significant proportions of soda (*c* 16–20wt%) and minor amounts of lime (*c* 4.5–6wt%). The analysed total for these glasses (*c* 96–98wt%) suggests that little or no boron is present in these samples. The composition of these glass samples conforms to soda-lime-silica glasses widely used throughout the twentieth century. The soda-lime-silicate glasses have been divided into three sub-groups (soda-lime1, soda-lime2 and soda-lime3) based on very slight differences in their chemical composition.

4.4.7 *Soda-lime1 (samples 28–36):* soda-lime1 glass is represented by nine samples of which seven are working waste and two are press-moulded vessels.

	B_2O_3	Na_2O	Al_2O_3	SiO_2	SO_3	CaO	Fe_2O_3	As_2O_3	BaO
Mean	nil	16.8	0.2	73.9	0.2	5.7	0.10	0.47	<0.2
sd		0.6		1.0		0.2	0.01	0.01	

Table 4: Average composition of the soda-lime1 glasses

4.4.8 *Soda-lime2 (9, 18, 26 and 27):* soda-lime2 glass is represented by four samples, of which two are working waste and two are press-moulded vessels (one of which is an ash tray). The glass is distinguishable from the other soda-lime-silica glasses by the presence of manganese (presumably added to reduce the colouring effect of the iron) and the high levels of arsenic.

	B_2O_3	Na_2O	Al_2O_3	SiO_2	K_2O	CaO	MnO	Fe_2O_3	As_2O_3	BaO	PbO
Mean	nil	20.1	0.1	70.3	<0.1	5.1	0.15	0.07	0.59	<0.2	0.4
sd		0.5	0.1	0.4		0.9	0.02	0.02	0.03		0.6

Table 5: Average composition of the soda-lime2 glasses

4.4.9 *Soda-lime3 (2, 7, 13 and 22):* soda-lime3 glass is represented by 5 samples of which 2 are working waste (glass adhering to a crucible and a failed vessel) and 3 are press-moulded vessels (one of which is a green ash tray). The relatively high average iron content of this group is the result of the inclusion of sample #22. This sample is green and contains elevated levels of iron and copper to achieve this colour.

	B_2O_3	Na_2O	Al_2O_3	SiO_2	K_2O	CaO	MnO	Fe_2O_3	As_2O_3	BaO	PbO
Mean	nil	18.7	0.1	70.6	<0.1	4.7	0.17	0.21	0.5	0.7	0.5
sd		1.1		2.2		0.6	0.03	0.30	0.2	0.5	0.4

Table 6: Average composition of the soda-lime3 glasses

4.4.10 ***Opalware (23–25):*** the samples of opaque white glass proved to have just as complicated a chemical composition as suggested by Shaw and Evans (1983, 17). The glass has a silica base (and slightly more than that suggested by Shaw and Evans) which has been fluxed with soda (the analysed total is sufficiently high to suggest that boron was not a part of the batch. The glass contains fluorine and the proportions of fluorine and other elements suggest that it was added as AlF_3 (rather than as cryolite, Na_3AlF_6). The fluorine was probably added due to its tendency to promote microphase separation (Figures 9 and 10) which had allowed the production of opaque and opalescent glass since the beginning of the 20th century. The glass also contains significant proportions of strontium which would have helped the glass to devitrify (crystallise) during cooling.

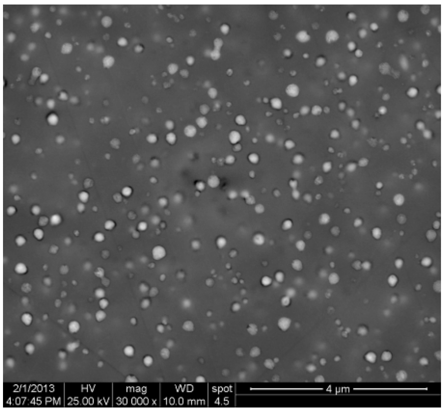

Plate 84: SEM image of sample #25 showing microphase separation

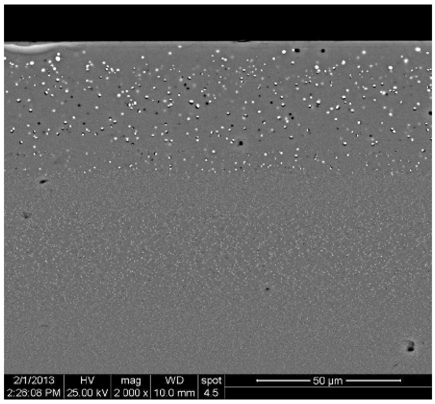

Plate 85: SEM image of sample 24 showing microphase separation. Note different size of particles at the surface

	B_2O_3	**F**	**Na_2O**	**Al_2O_3**	**SiO_2**	**K_2O**	**CaO**	**Fe_2O_3**	**As_2O_3**	**SrO**
Mean	nil	6.3	9.9	7.3	70.0	1.2	0.7	0.09	0.13	3.4
sd		0.7	0.8	0.1	2.3	0.2	0.1	0.01	0.01	0.2

Table 7: Average composition of the Opalware glass samples

4.4.11 ***Soda-lead crystal (10 and 11):*** two samples of glass-working waste contain soda and lead with only very low levels of other elements (Table 8). This glass is a soda-lead crystal; rather than the more conventional potash-lead crystal. Soda-lead crystal glass was used in Manchester in the nineteenth century (Willmott *et al* 2012).

	B_2O_3	Na_2O	Al_2O_3	SiO_2	P_2O_5	Cl	K_2O	CaO	Fe_2O_3	As_2O_3	Sb_2O_3	PbO
Mean	Nil?	14.4	0.3	52.7	0.4	1.8	0.2	1.1	0.09	0.8	0.7	20.7
sd		0.7	0.1	1.6	0.1	0.1	0.1	0.1	0.02	0.1	0.1	0.5

Table 8: Average composition of the soda-lead crystal glass samples

4.4.12 ***Ungrouped samples:*** the remaining seven samples have compositions which do not match any of the groups described above. This includes two samples of refractory (one crucible [#15] containing blue glass [#14] and one fragment of tank wall [#13c], or possibly crown, with adhering glass [#13g]). The two refractories are broadly similar to each other: the oxides of aluminium and silicon account for over 90wt% of the material with a range of minor oxides. The composition of this admittedly small sample of refractories appears to be rather conservative compared to some of the developments in glassmaking refractories discussed in contemporary literature. The zirconium content of the refractories was unexceptional. Two samples of blue glass are both soda-lime-silica glasses; however, these do not share precisely the same chemical composition as any of the other soda-lime-silica glasses discussed above. The two blue glasses were coloured in quite different ways. One (#12) was coloured with a combination of iron and copper while the second (#14) was coloured with cobalt. A third ungrouped soda-lime-silica glass has an exceptionally high soda content.

4.4.13 ***Additional analyses:*** the SS110 from context 301 was identified as a potential raw material during the assessment. It comprised an off-white, water-soluble crystalline material. A combination of EDXRF, SEM-EDS and XRD analysis confirmed that this was sodium sulphate (sodium saltcake), the most commonly employed flux in the twentieth-century glass industry.

4.5 DISCUSSION

4.5.1 The material evidence from the Lisburn Terrace glassworks of James A Jobling provides insights into the manufacture of glass during the twentieth century. The material was recovered from a variety of contexts; however, these were rarely well dated. There was limited archaeological stratigraphy and few associated artefacts which could provide information on the date of deposition (or manufacture). In a few cases, some dating information could be derived from a typological study of the glass artefacts manufactured. A small number of vessels had manufacturer's marks which established that they were Pyrex (Figure 2) and that they had been produced before 1953. Similarly the Opalware vessels (Figure 6) must have been produced some time after the early 1950s.

4.5.2 A little over 40% of all the analysed material is a borosilicate glass. This appears to conform to Corning 7740 and is likely to be the glass that was licensed to Jobling in 1921. The range of samples analysed does not unfortunately provide enough information to indicate when (if ever) the works switched to the production of glass ovenware based on tempered soda-lime-silica glass rather than annealed borosilicate glass. The analysis of this glass has revealed aspects of the borosilicate which were not expected. There are clearly two different recipes in use: one with higher iron and detectable amounts of arsenic and one with lower iron and no detectable arsenic. It is not clear whether these were both in use at the same time. It is possible that one recipe superseded the other, in which case it is plausible that the low iron and arsenic recipe would be the later. Curiously the latter glass also contains appreciable amounts of zirconium, but the source of the zirconium and the intention (if any) behind its incorporation in the glass are unclear.

4.5.3 Soda-lime-silica glass was the second most abundant glass type represented in the analysed samples. Soda-lime-silica glasses have been used in most branches of the twentieth-century glass industry including flat glass (Dungworth 2011) and containers (Dungworth 2012). One of the major advantages of this type of glass over the great variety of glass recipes used before the beginning of the 20th century was that it gave a glass with particular properties that were suited to forming on a large scale using machines. The mechanisation of the bottle industry led to the adoption of soda-lime-silica glass as this could (with relative ease) be made sufficiently fluid to accurately fill moulds. A relatively high soda content ensured the glass would be sufficiently fluid during forming (Turner 1926). The flat glass sector tended to prefer a glass with a slightly lower soda content and a higher calcium content due to differences in the forming techniques used, such as continuous drawing of sheets of hot glass. From the 1930s onwards a proportion of calcium has been replaced by magnesium to prevent devitrification of flat glass during forming. The Jobling soda-lime-silica glass contains more soda and less lime than either contemporary window glass or bottle glass. It is likely that the recipe was developed to match the nature of production.

4.5.4 In general a high soda content would ensure a fluid glass which would quickly and accurately fill a mould. The low lime content would encourage the glass to become stiff quickly as it cooled which would allow moulds to be emptied quickly and so speed up production. The higher soda content and lower lime content, compared to contemporary bottle glass, may reflect the fact that Jobling produced relatively thin-walled and open forms which would lose heat quickly.

	Na_2O	MgO	Al_2O_3	SiO_2	CaO	Fe_2O_3
Jobling	18.0	<0.1	0.2	72.1	5.4	0.12
Bottles	16.8	0.5	1.0	74.0	9.0	0.13
Windows (<1930)	12.9	0.1	1.2	71.9	12.9	0.21
Windows (1930–60)	13.9	2.8	0.9	72.2	9.7	0.13
Windows (1960>)	13.3	3.8	1.3	72.2	8.3	0.12

Table 8: Table 9: Average composition of twentieth-century soda-lime-silica glass, including Jobling press-moulded glass, window glass (Dungworth 2011) and bottle glass (Dungworth 2012)

4.5.5 The material analysed included a small proportion of Opalware which proved to have a complex chemical composition using raw materials which were rarely if ever used in other branches of the glass industry. The examples from Lisburn Terrace are silicate glasses fluxed with soda, aluminium fluoride and strontium. The soda would help to reduce the melting temperature. The aluminium fluoride might encourage microphase separation which could contribute to an opalescent quality. The action of the strontium is less clear although strontium and barium have been cited as helping to produce spontaneous glass-ceramics without the need for heat treatments. There is a need for further research into the manufacture of Opalware.

5. OTHER FINDS

5.1 INTRODUCTION

5.1.1 The artefactual assemblage recovered during the course of the investigation comprised finds from various material categories, including glass vessels, industrial residues (glass production waste and cullet), glass-melting crucibles, post-medieval pottery, clay tobacco pipes, ceramic building material, ironwork and copper alloy. The overall finds assemblage was substantial in size, but was dominated by glass. A summary of the other classes of artefact is provided in the following sections.

5.2 POST-MEDIEVAL POTTERY

5.2.1 In total, 12 sherds of pottery, all dating to the late nineteenth or early twentieth century, were recovered from the excavation (Plate 86). Most of the pottery was recovered from spoil, and is thus unstratified, but a single fragment of late nineteenth-century stoneware came from Area 2, and part of the base of a cast statuette representing a crouching lion, or perhaps sphinx, in a brown-glazed coarse cream fabric, was from ***204*** in Area 2 (Plate 87). The base of the piece was stamped 'W&LAB 1017', presumably a reference to the maker.

5.2.2 The unstratified pottery is largely undiagnostic late nineteenth- or early twentieth-century fabrics, the poor quality of the glaze suggesting that some could be wasters. The presence of a pottery kiln in the close vicinity is reinforced by the presence of a fragmentary ring saggar, and a ceramic 'stilt' (Plates 88 - 90), used to separate flatwares in the kiln during firing.

Plate 86: Fragments of pottery recovered from the excavation

Plate 87: Fragments of a cast ceramic statuette

Plate 88: Fragments of a ring saggar recovered from the excavation

Plate 89: Ceramic stilt from the excavation

Plate 90: Ceramic stilt from the excavation

5.3 CLAY TOBACCO PIPE

5.3.1 The excavations produced three fragments of clay tobacco pipe. These derived from a single late nineteenth- or early twentieth-century bowl, stamped DUBLIN (Plate 91), which was found in Area 2.

Plate 91: Stamped clay tobacco bowl

5.4 CERAMIC BUILDING MATERIAL

5.4.1 A sample of bricks was collected as single examples of each type of manufacturer's stamp recovered from the excavation. In total, 18 complete or near complete examples were recovered. All of the sampled bricks were examined visually, and a gazetteer of the manufacturers' stamps is presented in *Appendix 3*.

5.4.2 The range of bricks types included hand-made and machine-pressed common red bricks, engineering bricks, and refractory bricks and specialist blocks produced from fire clays. Most of the sampled bricks fall with a date range spanning the later nineteenth to mid-twentieth century, with a few examples of late twentieth-century material.

5.5 COPPER ALLOY

5.5.1 A single copper-alloy object was recovered from the excavation. The object probably derived from a large cast ?brass pipe junction, from deposit ***207*** in the central part of Area 2, presumably on-site plant.

5.6 IRONWORK

5.6.1 In total, 14 fragments of ironwork came from the excavation (Plate 92). All of the objects were recovered from the fill of ***204*** in Area 2 and appear to be structural, coming from the building or its fittings, with the exception of a bucket handle.

Plate 92: The iron objects recovered from the excavation

6. CURATION AND CONSERVATION

6.1 RECIPIENT MUSEUM

6.1.1 Tyne & Wear Museums and Archives has been nominated as having the capacity to co-ordinate the deposition of the finds and the paper and electronic archive. Paper and digital copies of issued reports will be deposited with the museum.

Tyne & Wear Museums and Archives Discovery Museum, Blandford Square, Newcastle upon Tyne, Tyne and Wear NE1 4JA
Tel: (0191) 232 6789

6.2 CONSERVATION

6.2.1 No specific conservation needs are required.

6.3 STORAGE

6.3.1 The complete project archive, which will include written records, plans, black and white and colour photographs, digital plans and photographs, artefacts, ecofacts and sieved residues, will be prepared following the guidelines set out in *Environmental standards for the permanent storage of excavated material from archaeological sites* (UKIC 1984, Conservation Guidelines 3) and *Guidelines for the preparation of excavation archives for long-term storage* (Walker 1990), prior to deposition. The digital data will be temporarily stored on the server at OA North, which is backed up on a daily basis. For long-term storage of the digital data, CDs will be used, the content including the reports, plans, scanned images and digital photographs. Each CD will be fully indexed and accompanied by the relevant metadata for provenance. The digital record should ideally be duplicated as a paper record for long-term archiving, including comprehensive printouts of photographs and survey plots, labelled and summarised.

6.3.2 All dry and stable finds will be packed according to the Museum's specifications, in either acid-free cardboard boxes, or in airtight plastic boxes for unstable material. Each box will have a list of its contents and will in general contain only one type of material, such as pottery or bone.

6.4 PACKAGING

6.4.1 The assemblage is currently well-packaged and will require no further packaging. Box lists derived from the site database have been compiled and will be updated when the identification of objects is complete. The paper records will be presented in either ring binders or in acid-free storage, fully indexed, and with the contents labelled.

6.5 DISSEMINATION

6.5.1 The complete results obtained from the archaeological investigation associated with the development at Lisburn Terrace are incorporated in this final excavation report, which includes the findings from the detailed analysis of each material category. In addition to St Modwen, copies of this final archive report will be forwarded to Tyne & Wear Museum Services, Sunderland Council Planning Department and Conservation Officer, the Tyne & Wear Historic Environment Record, and Sunderland library.

6.5.2 Given the regional, or even national, significance of the results, an agreement has been made to publish the site in order to disseminate the findings to a national audience. It is anticipated that the results will be published as a journal article in *Industrial Archaeology Review*.

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APPENDIX 1: LIST OF GLASS MATERIALS EXAMINED

Box	Comment	Context	Sample	Description	Weight
1	Fill of	***204***		Pale green moulded bottles. All identified as for drinks suppliers based on the Tyne or in Sunderland. Includes a maker's mark "B & Co Ltd"	1041
1	Fill of	***204***		Colourless jugs or tankards (including some handles). Cylindrical, octagonal and fluted. Base diameters 50-80mm.	659
1	Fill of	***204***		Fragments of 5 colourless truncated spheres (base dia = 38mm, h = 12mm). One has casting sprue attached.	103
1	Fill of	***204***		Window glass	36
1	Fill of	***204***		Colourless press moulded glass	50
1	Fill of	***204***		Cylindrical vessel?	81
1	Fill of	***204***		Blue waste lump	37
1	Within	***210***		Colourless bottles, jugs or tankards. Cylindrical. Base diameters 50–60mm.	103
1	Within	***210***		Colourless press moulded bowls	141
1	Within	***210***		Colourless small fragments	97
1	Gap between	***204/205***		Very pale green bottle neck with applied rim, finished with tool	20
1	Gap between	***204/205***		Colourless hexagonal vessel fragments. Walls slope outward. Very thick bases	115
1	Gap between	***204/205***		Pale green hexagonal vessel fragments. Walls slope outward. Thick bases	70
1		***209***	112	Colourless threads and dribbles	10
1		***209***	112	Pale blue fragment	1
1		***211***	113	Clinker	700
1		***211***	113	Fragment of pale blue glass	3

Box	Comment	Context	Sample	Description	Weight
1	Within	***211***		Fragment of pale blue glass	22
1	Fill of	***209***		Colourless press moulded bowls	30
1	Fill of	***209***		Colourless handles	71
1	Fill of	***209***		Vessels: cylindrical, octagonal and fluted	337
1	Fill of	***209***		Colourless waste	106
1		***207***		Colourless oval casserole	1434
1		***207***		Colourless press moulded bowl	179
1	Within	***203***		Very pale pink press moulded vessel	160
1	Within	***203***		Colourless milk bottles	429
1	Within	***203***		Colourless oval casserole	213
1	Within	***203***		Colourless vessel (tankards?)	431
1	Within	***203***		Very pale green vessel (tankards)	346
1	Within	***203***		Colourless waste	17
1	Within	***203***		Colourless miscellaneous vessel (labware?) fragments	282
1		***209***	112	Pale blue fragment	16
1		***209***	112	Dense, iron-rich, black slag	58
1		***209***	112	Green glass waste	5
1		***209***	112	Colourless waste	192
1			102	Colourless waste	417
2		***301***		Tank furnace brick with pale green glass adhering (actually colourless - only pl gr at interface with ceramic)	6573
2		***301***		Crucible with blue glass adhering	4282
2		***301***		Tank furnace brick with thin friable layer of colourless/white glass. Probably crown fragment with attack/vitrification by volatile alkali	5644
3		***225***		Fragments of colourless glass from large conical and hemispherical objects	4125
3		***225***		Colourless waste	5

Box	Comment	Context	Sample	Description	Weight
3		***227***		Large fragments of very pale green tank metal	695
3		***227***		Dark green glass fragment - heavily weathered	57
3		***227***		Red signal glass	106
3		***227***		Red glass waste	90
3		***227***		Colourless vessel (tankards?)	131
3		***227***		Orange glass fragment	23
3		***220***		Colourless press-moulded bowls	320
3		***220***		Colourless waste	292
3		***220***		Pale green devtrified waste	125
3		***223***		Colourless milk bottle	310
3		***231***		Colourless bowl fragments	42
3		***231***		Green ash trays - 46mm high, 85mm across, hexagonal in plan, fluted sides, dished top and bottom	1004
3		***224***		Colourless ash trays	456
3		***224***		Pale green press-moulded bowl	38
3	Between	***221+222***		Base of green bottle (moulded)	277
4	Inside flue		103	Colourless threads and dribbles	143
4	Inside flue		103	Colourless press-moulded vessels	60
4	Inside flue		103	Black vitreous waste	260
4		***301***		Opaque white cup fragments with blue transfer ? Decoration	236
4		***301***		Opaque white dribble	5
4		***us***		Mix of colourless and coloured glass. Some vessel (inc bottle and press-moulded vessel) and some waste	1260
4		***302***	105	Furnace wall	349
4		***302***	105	Colourless thread	5
4		***302***	105	Clinker? (very dense)	1374

Box	Comment	Context	Sample	Description	Weight
4		***us***		Black glass bowl with flat base and horizontal fluting on walls (MNI = 3)	203
4		***us***		Colourless jar	66
4		***us***		Colourless bottle neck	65
4		***us***		Dark green bottle base	141
4		***us***		Red press-moulded bowl	16
4		***us***		Opaque green bowl	26
4		***us***		Pale green press-moulded bowl	34
4		***us***		Pale green bottle base	25
4		***us***		Opaline moulded figurative object	115
4		***us***		Colourless press-moulded bowls with scalloped or vertically fluted walls. Inside of former moulded with "BRITISH MAKE"	956
4		***us***		Pale green waste	15
4		***243***		Blue press-moulded plaque? "1919RYD"?	101
4		***243***		Colourless bowls and flask	958
4		***243***		Colourless waste	41
4		***243***		Pale amber press-moulded bowl	69
4		***301***		Pale green devitrified waste	64
4		***503***	104	Clinker	693
4		***503***	104	Colourless thread and droplets	17
4		***us***		Pale blue and pale green tank metal	8265
SS		***201***	107	Colourless waste and press-moulded vessel fragments with vertical fluting	13376
SS		***203***	110	White to pale green friable material (sodium sulphate).	18761
SS		***301***	118	White to pale green devitrified glass waste	9313
SS		***203***	108	Colourless waste and press-moulded vessel fragments	8917

APPENDIX 2: COMPOSITION OF ANALYSED SAMPLES

Part 1

Lab #	B_2O_3	F	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	PbO
LISB#01	15	<1	4.8	<0.1	1.5	74.6	<0.2	<0.2	<0.1	0.1	<0.1	<0.1
LISB#02	<5	<1	18.1	<0.1	0.1	72.1	<0.2	<0.2	0.1	<0.1	4.8	0.2
LISB#03	11	<1	4.5	<0.1	2.0	78.9	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#04	13	<1	4.9	<0.1	2.2	76.2	<0.2	<0.2	<0.1	0.1	<0.1	<0.1
LISB#05	12	<1	3.9	<0.1	2.1	78.5	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#06	12	<1	4.0	<0.1	2.1	77.8	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#07	<5	<1	20.4	<0.1	<0.1	68.2	<0.2	<0.2	0.2	<0.1	4.0	0.2
LISB#08	<5	<1	25.0	<0.1	0.1	66.5	<0.2	<0.2	0.2	<0.1	3.8	<0.1
LISB#09	<5	<1	19.4	<0.1	0.1	70.7	<0.2	<0.2	0.1	<0.1	6.3	<0.1
LISB#10	<5	<1	14.9	<0.1	0.3	53.8	0.4	0.2	1.9	0.2	1.1	21.1
LISB#11	<5	<1	13.9	<0.1	0.3	51.5	0.4	0.3	1.8	0.2	1.1	20.3
LISB#12	<5	<1	16.9	<0.1	0.4	66.9	<0.2	<0.2	0.2	0.1	3.4	2.8
LISB#13c	<5	<1	0.8	0.3	24.0	69.8	<0.2	<0.2	0.1	0.2	0.2	<0.1
LISB#13g	<5	<1	18.8	<0.1	0.1	72.8	<0.2	<0.2	0.2	0.2	4.8	0.1
LISB#14	<5	<1	16.9	<0.1	1.3	65.9	<0.2	<0.2	0.3	<0.1	3.8	10.1
LISB#15	<5	<1	0.3	0.3	19.6	63.8	<0.2	<0.2	<0.1	0.5	0.2	<0.1
LISB#16	<5	<1	17.9	<0.1	0.7	68.9	<0.2	<0.2	0.2	0.3	5.4	1.0
LISB#17	12	<1	3.4	<0.1	2.1	79.0	<0.2	<0.2	<0.1	0.3	0.1	<0.1
LISB#18	<5	<1	20.2	<0.1	0.1	69.7	<0.2	<0.2	0.2	0.2	5.0	1.3
LISB#19	11	<1	4.0	<0.1	2.3	79.3	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#20	11	<1	4.0	<0.1	2.3	79.3	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#21	12	<1	4.0	<0.1	2.2	79.2	<0.2	<0.2	0.1	<0.1	<0.1	<0.1
LISB#22	<5	<1	17.8	<0.1	0.3	69.4	<0.2	<0.2	0.1	<0.1	5.3	0.8
LISB#23b	<5	5.7	9.0	<0.1	7.4	72.6	<0.2	<0.2	<0.1	1.5	0.9	<0.1

Lab #	B_2O_3	F	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	PbO
LISB#23s	<5	<1	2.2	<0.1	3.4	27.7	<0.2	<0.2	<0.1	<0.1	<0.1	47.9
LISB#24	<5	7.2	10.5	<0.1	7.3	68.7	<0.2	<0.2	<0.1	1.1	0.6	<0.1
LISB#25	<5	6.2	10.2	<0.1	7.3	68.5	<0.2	<0.2	<0.1	1.0	0.6	<0.1
LISB#26	<5	<1	20.6	<0.1	<0.1	70.5	<0.2	<0.2	0.2	<0.1	4.6	0.2
LISB#27	<5	<1	20.2	<0.1	0.2	70.4	<0.2	<0.2	0.1	<0.1	4.4	0.3
LISB#28	<5	<1	17.5	<0.1	0.2	74.0	<0.2	0.2	0.1	<0.1	5.4	<0.1
LISB#29	<5	<1	17.5	<0.1	0.1	74.5	<0.2	0.2	0.1	<0.1	5.6	<0.1
LISB#30	<5	<1	16.4	<0.1	0.2	73.8	<0.2	0.2	<0.1	<0.1	5.9	<0.1
LISB#31	<5	<1	15.9	<0.1	0.2	74.2	<0.2	0.2	0.1	<0.1	5.9	<0.1
LISB#32	<5	<1	16.0	<0.1	0.2	73.2	<0.2	0.2	0.2	<0.1	5.8	<0.1
LISB#33	<5	<1	16.2	<0.1	0.2	72.9	<0.2	0.2	<0.1	<0.1	5.8	<0.1
LISB#34	<5	<1	17.0	<0.1	0.2	72.9	<0.2	0.2	0.1	<0.1	5.6	<0.1
LISB#35	<5	<1	17.2	<0.1	0.2	73.2	<0.2	0.2	0.1	<0.1	5.6	<0.1
LISB#36	<5	<1	17.1	<0.1	0.2	76.2	<0.2	0.2	0.1	<0.1	6.1	<0.1
LISB#37	11	<1	4.1	<0.1	2.3	79.6	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#38	11	<1	3.9	<0.1	2.3	79.7	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#39	12	<1	4.0	<0.1	2.2	79.1	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#40	12	<1	4.0	<0.1	2.2	78.8	<0.2	<0.2	0.1	<0.1	<0.1	<0.1
LISB#41	12	<1	4.1	<0.1	2.2	78.0	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#42	10	<1	4.1	<0.1	2.2	80.4	<0.2	<0.2	0.1	<0.1	<0.1	<0.1
LISB#43	11	<1	4.2	<0.1	2.2	79.9	<0.2	<0.2	0.1	<0.1	<0.1	<0.1
LISB#44	11	<1	4.0	<0.1	2.2	79.9	<0.2	<0.2	0.1	<0.1	<0.1	<0.1
LISB#45	11	<1	3.9	<0.1	2.2	79.9	<0.2	<0.2	0.1	<0.1	<0.1	<0.1
LISB#46	10	<1	3.7	<0.1	2.6	80.6	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#47	14	<1	3.9	<0.1	2.1	77.4	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
LISB#48	12	<1	4.0	<0.1	2.2	78.8	<0.2	<0.2	0.1	<0.1	<0.1	<0.1
LISB#50	<5	<1	1.9	0.2	0.9	90.6	<0.2	<0.2	<0.1	1.2	2.0	<0.1

Part 2

Lab #	TiO_2	Cr_2O_3	MnO	FeO	CoO	CuO	ZnO	As_2O_3	SrO	ZrO_2	CdO	Sb_2O_3	BaO
LISB#01	<0.1	<0.1	<0.02	0.16	<0.02	<0.02	<0.02	0.22	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#02	<0.1	<0.1	0.20	0.08	<0.02	<0.02	<0.02	0.43	0.03	<0.01	<0.2	<0.2	0.5
LISB#03	<0.1	<0.1	0.02	0.19	<0.02	<0.02	<0.02	0.36	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#04	<0.1	<0.1	<0.02	0.17	<0.02	<0.02	<0.02	0.27	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#05	<0.1	<0.1	<0.02	0.15	<0.02	<0.02	<0.02	0.42	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#06	<0.1	<0.1	<0.02	0.14	<0.02	<0.02	<0.02	0.42	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#07	<0.1	<0.1	0.20	0.07	<0.02	<0.02	<0.02	0.31	0.03	<0.01	<0.2	<0.2	0.6
LISB#08	<0.1	<0.1	0.16	0.07	<0.02	<0.02	<0.02	0.33	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#09	<0.1	<0.1	0.17	0.06	<0.02	<0.02	<0.02	0.57	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#10	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	0.86	<0.01	<0.01	<0.2	0.7	<0.2
LISB#11	<0.1	<0.1	<0.02	0.10	<0.02	<0.02	<0.02	0.76	<0.01	<0.01	<0.2	0.6	<0.2
LISB#12	<0.1	<0.1	0.07	0.90	<0.02	0.84	0.08	0.34	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#13c	1.4	<0.1	0.05	2.09	<0.02	<0.02	<0.02	<0.02	<0.01	0.05	<0.2	<0.2	<0.2
LISB#13g	<0.1	<0.1	0.16	0.11	<0.02	<0.02	<0.02	0.33	0.02	<0.01	<0.2	<0.2	0.7
LISB#14	0.1	<0.1	0.10	0.61	0.20	0.09	<0.02	0.41	<0.01	<0.01	<0.2	<0.2	0.5
LISB#15	1.1	<0.1	<0.02	1.46	<0.02	<0.02	<0.02	<0.02	<0.01	0.05	<0.2	<0.2	<0.2
LISB#16	<0.1	<0.1	0.16	0.06	<0.02	<0.02	<0.02	0.73	0.01	<0.01	<0.2	<0.2	1.5
LISB#17	<0.1	<0.1	0.02	0.21	<0.02	<0.02	<0.02	0.03	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#18	<0.1	<0.1	0.15	0.06	<0.02	<0.02	<0.02	0.64	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#19	<0.1	<0.1	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	<0.01	0.08	<0.2	<0.2	<0.2
LISB#20	<0.1	<0.1	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	<0.01	0.08	<0.2	<0.2	<0.2
LISB#21	<0.1	<0.1	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	<0.01	0.13	<0.2	<0.2	<0.2
LISB#22	<0.1	<0.1	0.13	0.76	<0.02	0.30	<0.02	0.74	<0.01	<0.01	<0.2	<0.2	0.3
LISB#23b	<0.1	<0.1	0.02	0.10	<0.02	<0.02	0.04	0.12	3.6	<0.01	<0.2	<0.2	<0.2
LISB#23s	3.4	1.0	<0.02	0.24	2.20	<0.02	<0.02	<0.02	<0.01	5.2	1.6	<0.2	<0.2
LISB#24	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	0.13	3.4	<0.01	<0.2	<0.2	<0.2
LISB#25	<0.1	<0.1	0.02	0.10	<0.02	<0.02	0.06	0.13	3.2	<0.01	<0.2	<0.2	<0.2
LISB#26	<0.1	<0.1	0.14	0.06	<0.02	<0.02	<0.02	0.57	<0.01	<0.01	<0.2	<0.2	<0.2

Lab #	TiO_2	Cr_2O_3	MnO	FeO	CoO	CuO	ZnO	As_2O_3	SrO	ZrO_2	CdO	Sb_2O_3	BaO
LISB#27	<0.1	<0.1	0.13	0.11	<0.02	<0.02	<0.02	0.57	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#28	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	0.47	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#29	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	0.47	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#30	<0.1	<0.1	<0.02	0.09	<0.02	<0.02	<0.02	0.47	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#31	<0.1	<0.1	<0.02	0.11	<0.02	<0.02	<0.02	0.46	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#32	<0.1	<0.1	<0.02	0.09	<0.02	<0.02	<0.02	0.48	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#33	<0.1	<0.1	<0.02	0.10	<0.02	<0.02	<0.02	0.49	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#34	<0.1	<0.1	<0.02	0.11	<0.02	<0.02	<0.02	0.46	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#35	<0.1	<0.1	<0.02	0.11	<0.02	<0.02	<0.02	0.46	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#36	<0.1	<0.1	<0.02	0.10	<0.02	<0.02	<0.02	0.47	<0.01	<0.01	<0.2	<0.2	<0.2
LISB#37	<0.1	<0.1	<0.02	0.09	<0.02	<0.02	<0.02	<0.02	<0.01	0.15	<0.2	<0.2	<0.2
LISB#38	<0.1	<0.1	<0.02	0.09	<0.02	<0.02	<0.02	<0.02	<0.01	0.09	<0.2	<0.2	<0.2
LISB#39	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	<0.02	<0.01	0.17	<0.2	<0.2	<0.2
LISB#40	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	<0.02	<0.01	0.16	<0.2	<0.2	<0.2
LISB#41	<0.1	<0.1	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	<0.01	0.08	<0.2	<0.2	<0.2
LISB#42	<0.1	<0.1	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	<0.01	0.08	<0.2	<0.2	<0.2
LISB#43	<0.1	<0.1	<0.02	0.09	<0.02	<0.02	<0.02	<0.02	<0.01	0.13	<0.2	<0.2	<0.2
LISB#44	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	<0.02	<0.01	0.16	<0.2	<0.2	<0.2
LISB#45	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	<0.02	<0.01	0.09	<0.2	<0.2	<0.2
LISB#46	<0.1	<0.1	<0.02	0.09	<0.02	<0.02	<0.02	<0.02	<0.01	0.84	<0.2	<0.2	<0.2
LISB#47	<0.1	<0.1	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	<0.01	0.11	<0.2	<0.2	<0.2
LISB#48	<0.1	<0.1	<0.02	0.08	<0.02	<0.02	<0.02	<0.02	<0.01	0.14	<0.2	<0.2	<0.2
LISB#50	0.2	<0.1	0.03	0.31	<0.02	<0.02	<0.02	<0.02	<0.01	0.19	<0.2	<0.2	<0.2

APPENDIX 3: GAZETTEER OF SAMPLED BRICK

The following information has been compiled largely from a published account of the brickworks in the North East (Davison 1986), coupled with entries in nineteenth- and twentieth-century trade directories, and contemporary newspaper articles.

A3.1 STAMPED MACHINE-PRESSED RED AND ENGINEERING BRICKS

1 BACKWORTH: Backworth Colliery Brickworks was opened in 1877 by H Foster & Co, with production concentrated initially on firebricks. Standard bricks were produced between the 1930s and 1945, although firebricks were the principal product manufactured thereafter. General Refractories Ltd took over the works in 1955, and continued to produce bricks until 1967, when the works was finally closed.

2 LONDONDERRY: Brickworks established at Seaham Colliery. Mechanised brick production began in 1856, and continued to post-1950.

3 LBC: The London Brick Company was founded at Fletton, near Peterborough, by John Hill in 1889. The London Brick Company is referred to in trade directories for 1896 and 1898 (Kelly 1896, 702; Kelly 1898, 75), although it was not incorporated as a company until 1900. Hill ran into financial difficulties, and a receiver was appointed to run the company in 1912. Hill died in 1915 but, after the receiver was discharged in 1919, Hill's son continued to run the brick-making business. In 1923, the London Brick Company merged with BJ Forder.

4 P B Co LTD: The Potteries Brick Company, based in Hanley, was a sales merchanting company for a group of brick manufacturers in the Staffordshire Potteries area. The company did not have its own brick works, but had arrangements with the respective producers for them to press their wares with the P B Co stamp. The company was in operation by the end of the nineteenth century (but are not listed in trade directories for 1896), and continued in business until 1966 (*London Gazette*, 28 January 1966).

5 COOK (END STAMP): J Cook & Sons of Washington Station

6 ? (END STAMP) – J Swinburne of Birtley or J F Swinburne of East Tanfield

7 PENSHAW BRICKWORKS: Based at Fence Houses in County Durham, the Penshaw Quarries & Brick Works was in production from 1897 to 1925. The Ordnance Survey map of 1896 shows Cross Rigg Quarry on the site, whilst the edition of 1920 depicts a large brickworks situated in the quarry, connected with railway lines. The proprietors of the firm were J & W Lowry (Kelly 1914, 612). The brickworks is absent from the Ordnance Survey map of 1939, suggesting that the kilns and ancillary buildings had been demolished by that date.

8 ___LLINE: The partial stamp of an unidentified brick manufacturer.

9 USWORTH: Usworth bricks were manufactured at Usworth Colliery, near Washington in County Durham. It is uncertain when brick-making commenced at the colliery, although a John Hall is referred to as a brick maker at the colliery on 1852 (*London Gazette*, 25 June 1852). However, there are no brick manufacturers listed in a trade directory for 1855 (Slater 1855). Usworth Bricks Ltd went into liquidation in 1973 (*London Gazette*, 12 November 1973).

10 WASHINGTON: Washington Brickworks 1890s-1950. In 1900, the Washington Brickworks Company Ltd announced their intention to wind up their business (*London Gazette*, 20 November 1900).

11 IRIS PELAW: The Pelaw Terra-Cotta Works was established by Jones and Maxwell in 1895, and occupied a site a short distance to the west of Monkton Coke Works in South Tyneside. By 1911, this was reputed to be the largest manufactory of first-class engineering bricks in north-east England. The Iris brickworks formed part of the Pelaw group, and was situated at Heaton on the opposite bank of the River Tyne. The Pelaw brickworks closed in 1968.

12 LUMLEY: The Lumley Brick Company was based at Fence Houses in County Durham, and was established in the nineteenth century. In 1891, the partnership between Thomas Gilchrist, George Wragge and JR Gilchirst was dissolved, but the Lumley Brick Company continued in business under the direction of Thomas Gilchrist (*London Gazette*, 6 October 1891). The company was finally dissolved in 1951 (*London Gazette*, 2 February 1951).

13 LOWRY: This may have been manufactured by George Edward Lowry and Walter Lowry, who joined in partnership as the New Herrington Brick & Tile Company in 1892. The brickworks was located near Houghton-le-Spring in County Durham.

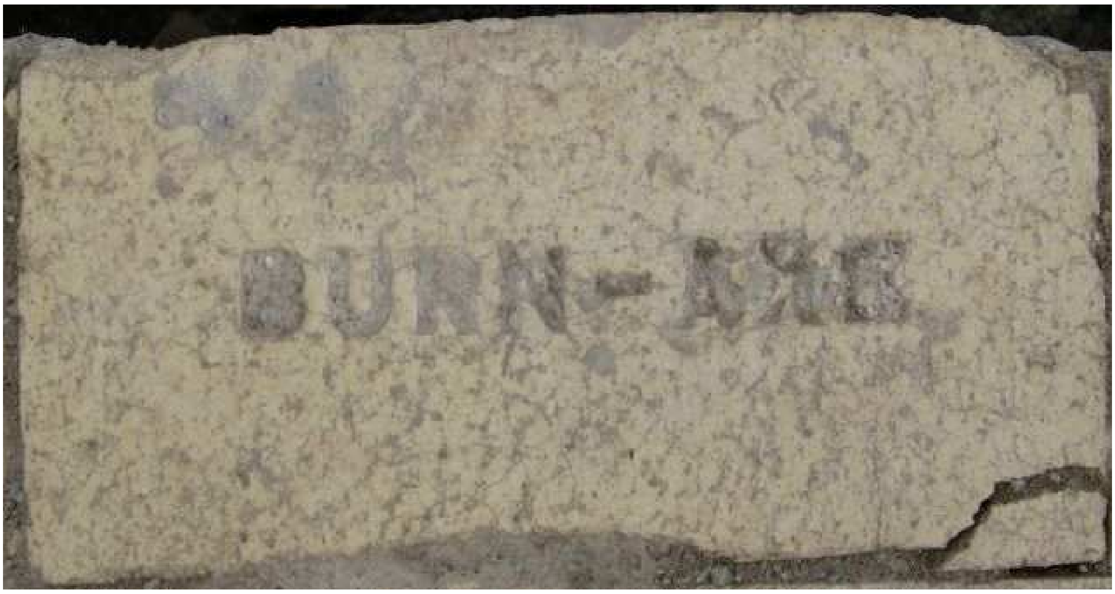
14 CELL-O-BRICK: Modern brick.

A3.2 STAMPED REFRACTORY BRICKS

1 EST STOURBRIDGE: Probably manufactured by Messrs GH Snowball & Co at their brickworks situated between Swalwell and Derwenthaugh in Gateshead. This large works, which developed an extensive export market, was in production from 1854 to 1935.

2 BURN / BURN 25 / BURN-AXE / BURNAXE / FURN-AXE / HARDAXE - These were produced by the Burn Fireclay Co at the Stobswood Brickworks near Morpeth, which commenced production in the 1860s using surface clay. However, the modern fire-brickmaking enterprise began in 1923, when Stobswood Coal Company began making bricks at Stobswood Colliery using clay extracted from two coal seams in the colliery. The partnership between the Stobswood Coal Company and the Burn Fireclay Company, owned by John Henry Burn and Frank Hawthorn Burn respectively, was dissolved by mutual consent in January 1934 (*London Gazette*, 19 January 1934). Thereafter, the Burn Fireclay Company was established in its own right, and remained in production for the manufacture of firebricks for lining kilns and in chemical equipment until 1999. Bricks manufactured during the company's latter period of operation were stamped with the 'AXE' trademark


BURN 25



3 COWEN – Brick making commenced in Blaydon Burn in *c* 1730, although fireclay was being excavated from the burn some 70 years earlier and taken to Paradise on the north side of the Tyne for manufacturing bricks. Anthony Forster began his brick-making business at Blaydon Burn in the early nineteenth century, and was soon joined in partnership by his brother in law Joseph Cowen. The firm made fire bricks, and also specialised in manufacturing industrial gas retorts. Cowen eventually bought out Anthony Forster, and expanded the business, trading under the name of Joseph Cowen & Co from *c* 1823. The brickworks remained in production until the 1960s, when the supply of suitable clay diminished. Joseph Cowen was also associated with the Lily Brickworks at Rowlands Gill.

4 LILY: Lily Brickworks was associated with the Lilley drift coal mine at Rowlands Gill, which was opened by Joseph Cowen in 1877. Coal was mined from the Brockwell seam which had good coking qualities, and a bank of coking ovens was built. However, the large quantities of clay being extracted from the coal seams meant that it was financially more rewarding to convert the coking ovens into brick kilns. The colliery closed in 1957, although the brickworks continued in production until 1977, utilising clay from Blaydon.

5 DOUGLAS-D: Probably manufactured by the Douglas Firebrick Co Ltd of Dalry, Ayrshire. The works was in operation by 1917, and remained in production until 1945.

6 E & M: E & M Firebrick Works, Low Benwell, originally at Blaydon Burn in the 1830s, taken over by WC Carr in 1850. Bricks were still being hand-moulded in 1894, although machine-pressed regenerator stove bricks were in production by 1912

7 F & L: Ferens & Love owned Cornsay Colliery at Hamsteels in County Durham, and established a large brickworks adjacent to the colliery in the nineteenth century to capitalise on the rich resource of fireclay present in the coal seams. The firm is listed as coal owners and fire brick manufacturers in a trade directory for 1890 (Kelly 1890, 104). The company went into voluntary liquidation in 1937 (*London Gazette*, 14 September 1937), although it seems that they had ceased manufacturing firebricks by that date; the firm is listed solely as colliery owners and retort manufacturers in a trade directory for 1914 (Kelly 1914). The company was re-established in 1937, and continued trading until 1975 (*London Gazette*, 17 June 1975).

8 FOSTER: A product of the Hotspur Brickworks in Backworth, near Newcastle upon Tyne, which was opened in 1877 by H Foster & Co. Initially, the firm produced firebricks, although housebricks were also produced between the early 1930s and 1945. The works was taken over in 1955 by General Refractories Ltd, and closed in 1967.

9 GEM:

10 LAMBTON: Lambton Firebrick and Sanitary Pipe Works at Burnmoor, Fence Houses is listed in trade directories for Durham. The works produced high-quality fireclay goods for the Lambton collieries between 1894 and 1960. The works comprised four Newcastle kilns, seven circular downdraught kilns, and an 18-chamber Belgian-type continuous kiln.

11 LUCAS: A Lucas, Dunston 1841-1938, probably same as Lucas Brothers Ltd

12 NETTLE: probably a product of the Manuel Brickworks in Linlithgow, Scotland, which was operated as part of the Stein Group and became the largest firebrick works in Europe. The Nettle bricks were named after a clay seam with a high alumina content. The first Nettle bricks were produced in 1930.

13 NHC: Possibly the stamp of the North Hetton Coal Company, owners of Moorsley Colliery, where an extensive firebrick works was in production in the early 1890s (Kelly 1890; Whellan 1894).

14 P B Co LTD: The Potteries Brick Company was a sales merchanting company for a group of brick manufacturers in the Staffordshire Potteries area. The company did not have its own brick works, but had arrangements with the respective producers for them to press their wares with the P B Co stamp. The company was in operation by the end of the nineteenth century (but are not listed in trade directories for 1896), and continued in business until 1966 (*London Gazette*, 28 January 1966).

ILLUSTRATIONS

LIST OF FIGURES

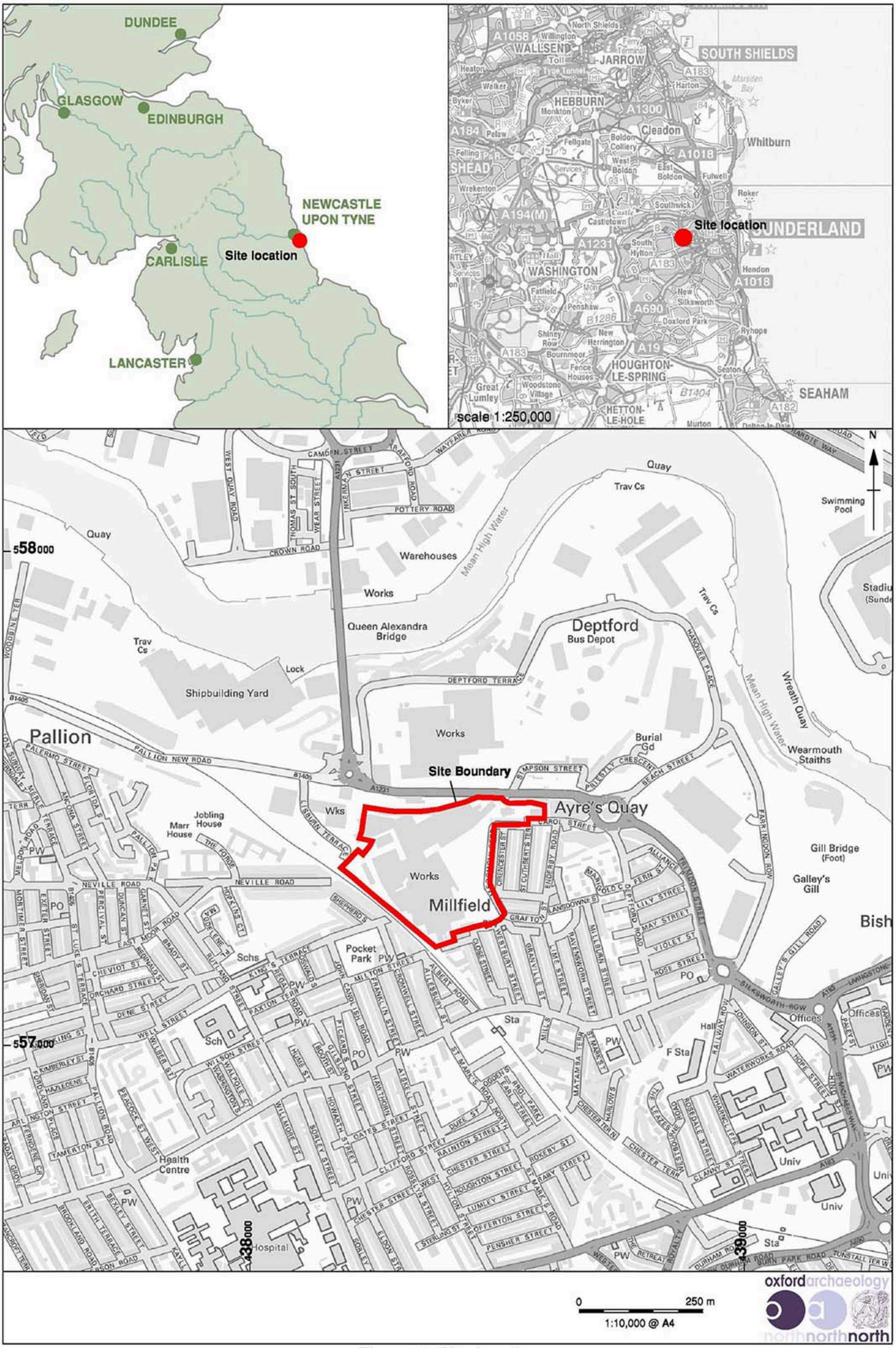


Figure 1: Site location

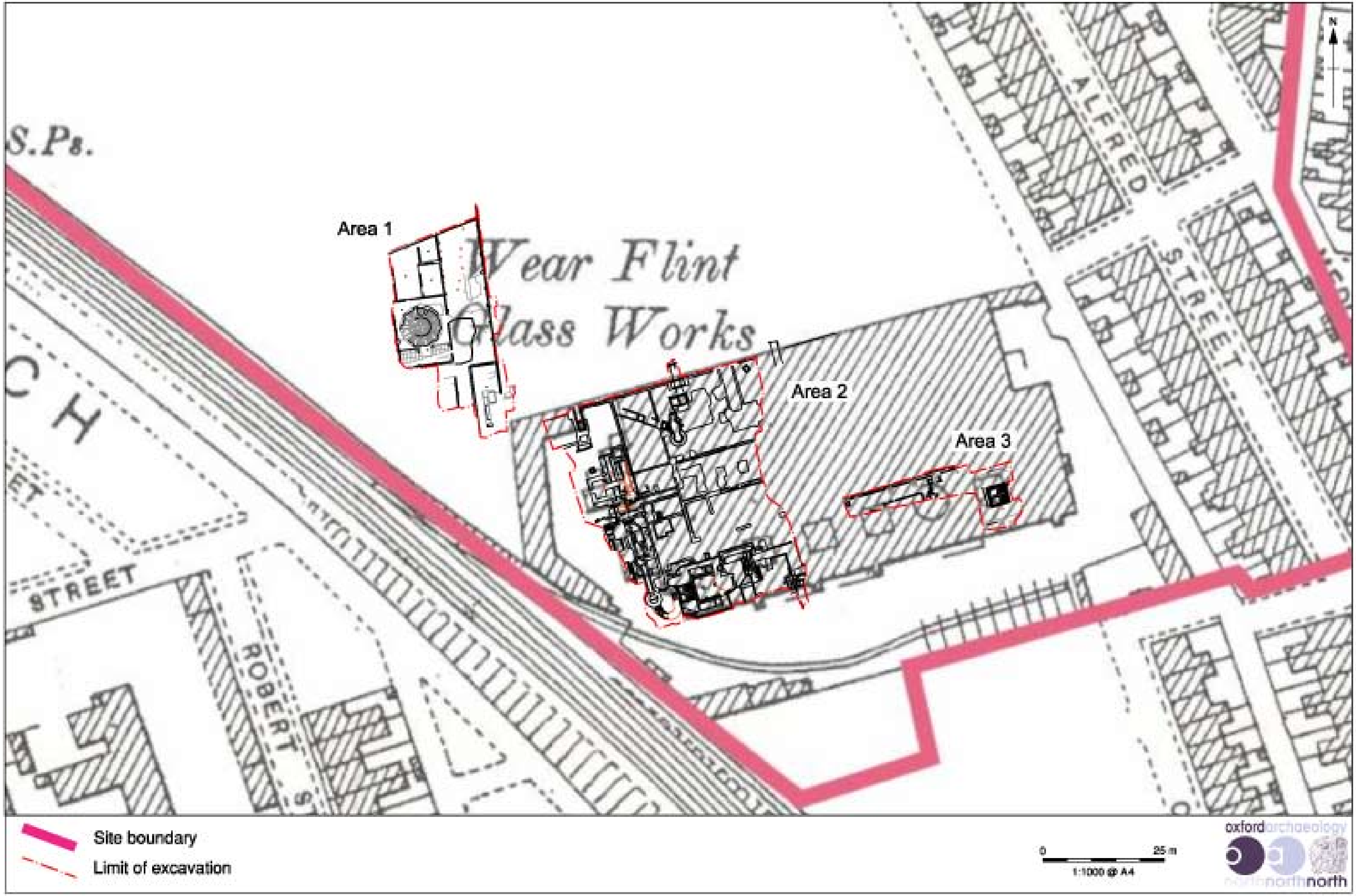


Figure 2: Excavation areas superimposed on the Ordnance Survey map of 1897

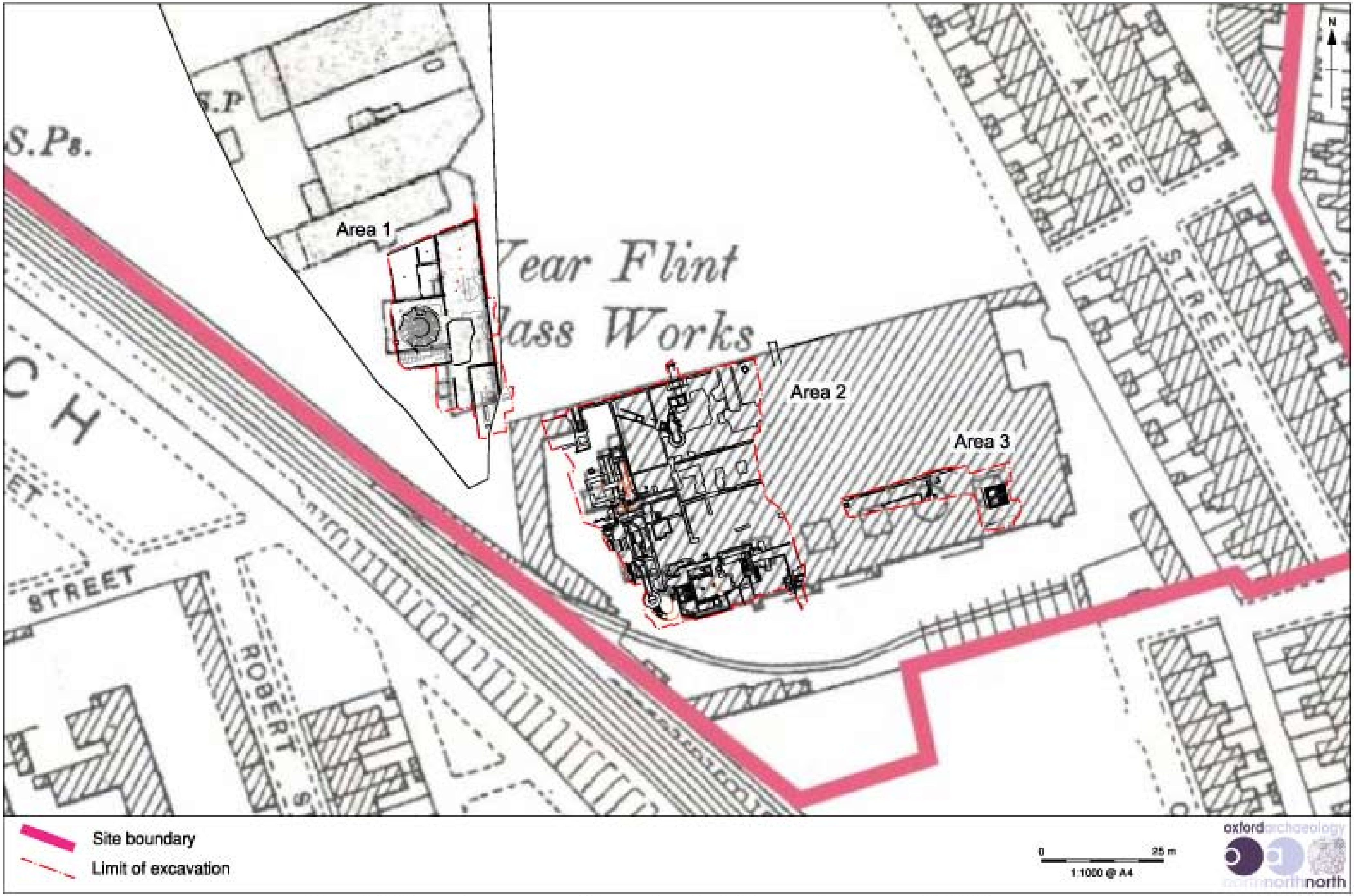


Figure 3: Excavation areas superimposed on the Ordnance Survey map of 1919

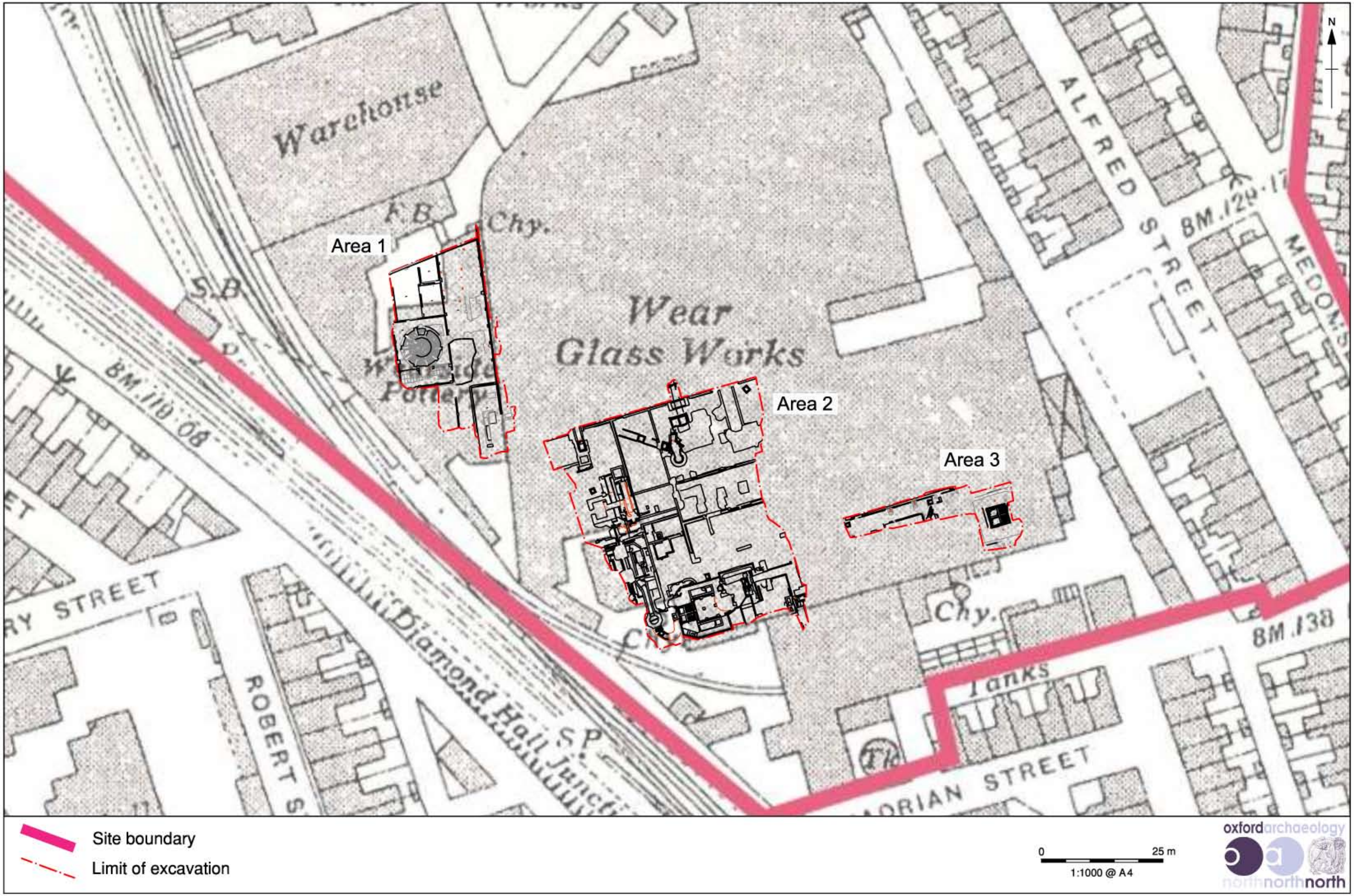
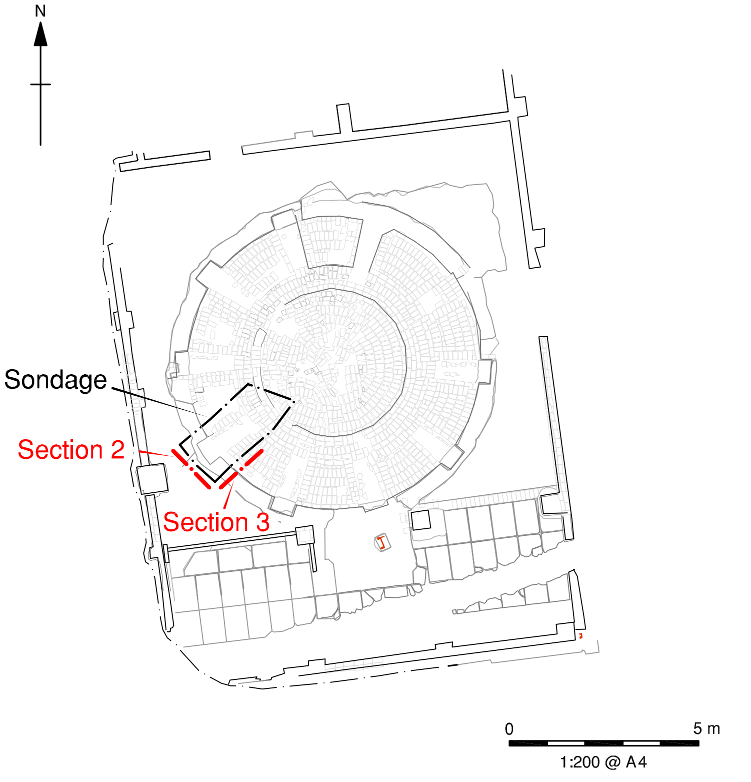
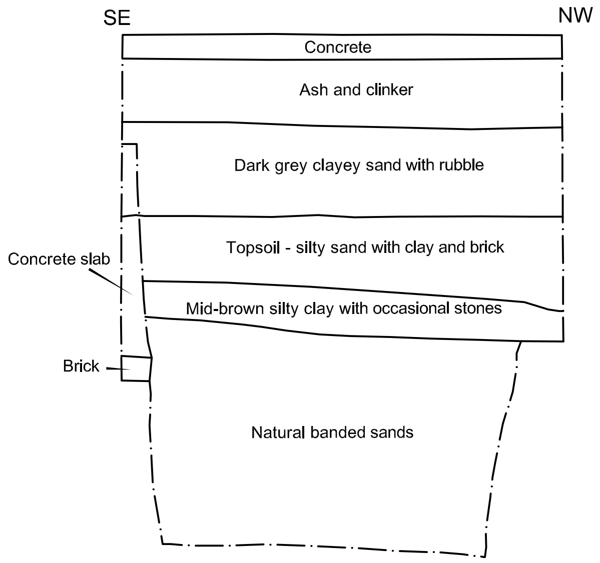


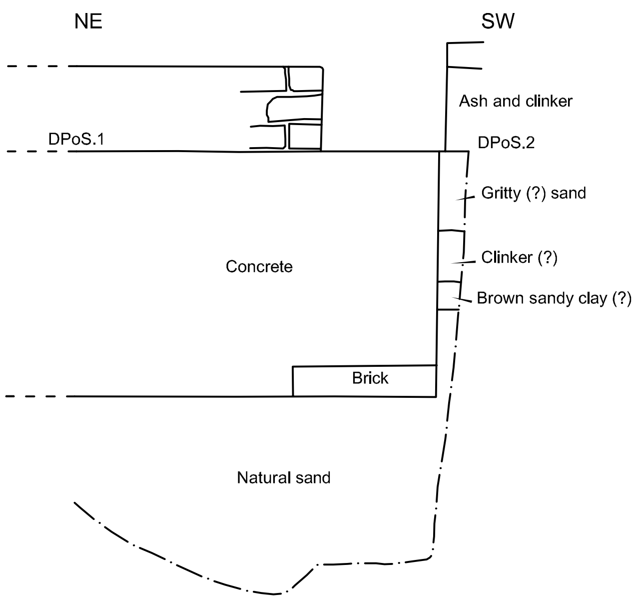
Figure 4: Excavation areas superimposed on the Ordnance Survey map of 1941

Figure 5: Plan of Area 1





Section 2 - north-east-facing



Section 3 - north-west-facing

Limit of excavation

layer

0 5 m
1:25 @ A4

oxfordarchaeology north

Figure 6: Sections excavated through kiln base ***105***

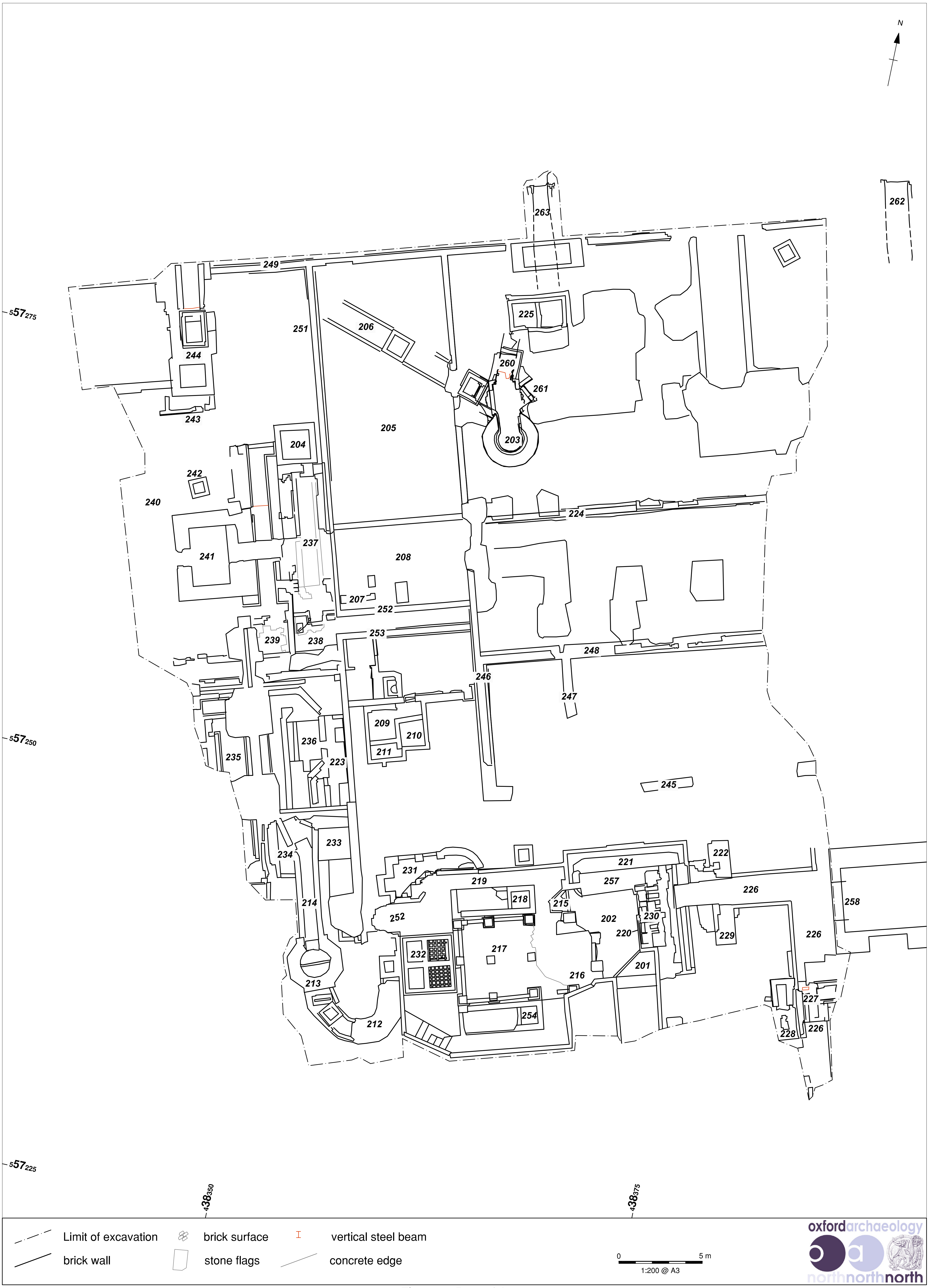


Figure 7: Plan of Area 2

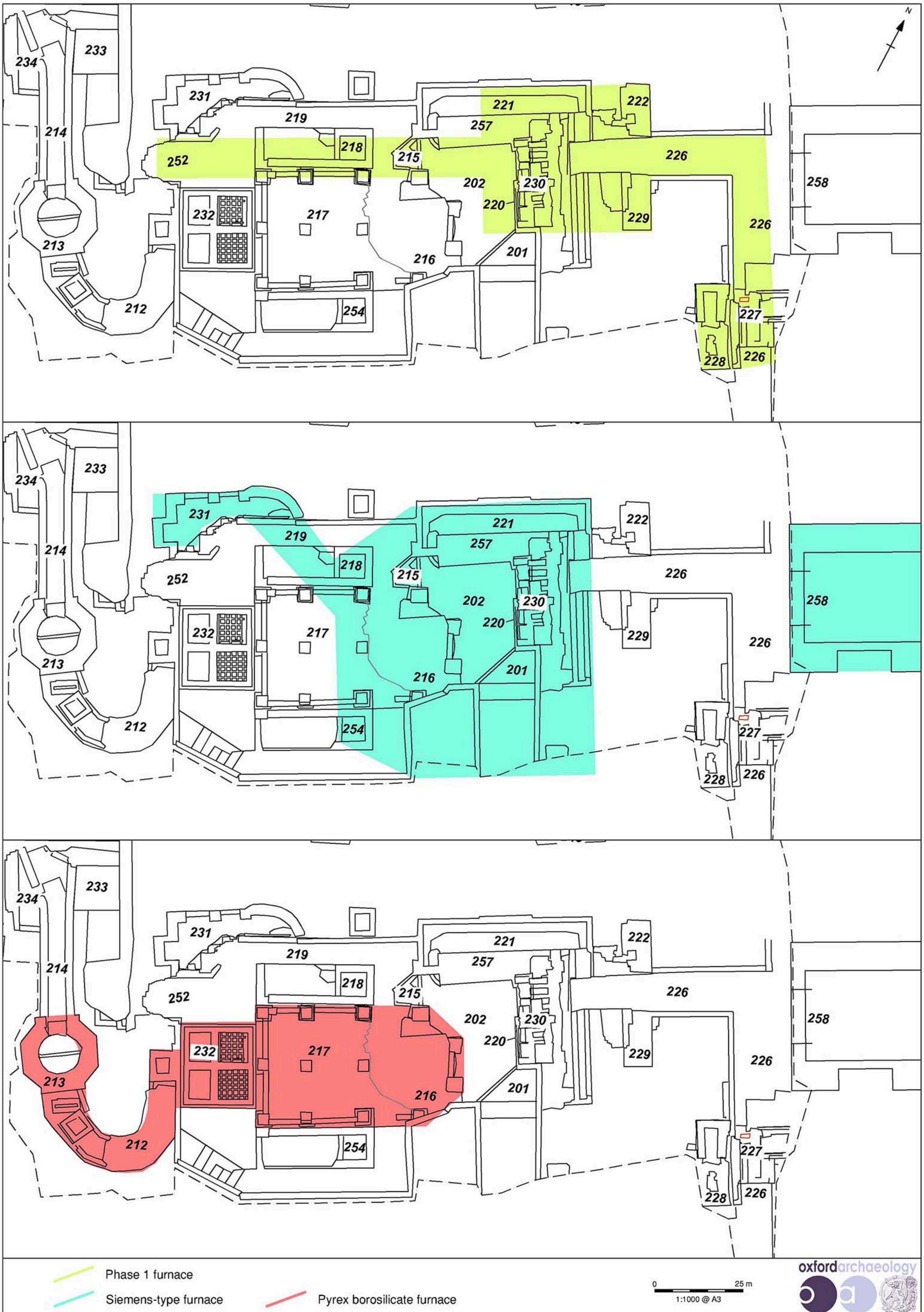


Figure 8: Furnace phase plan

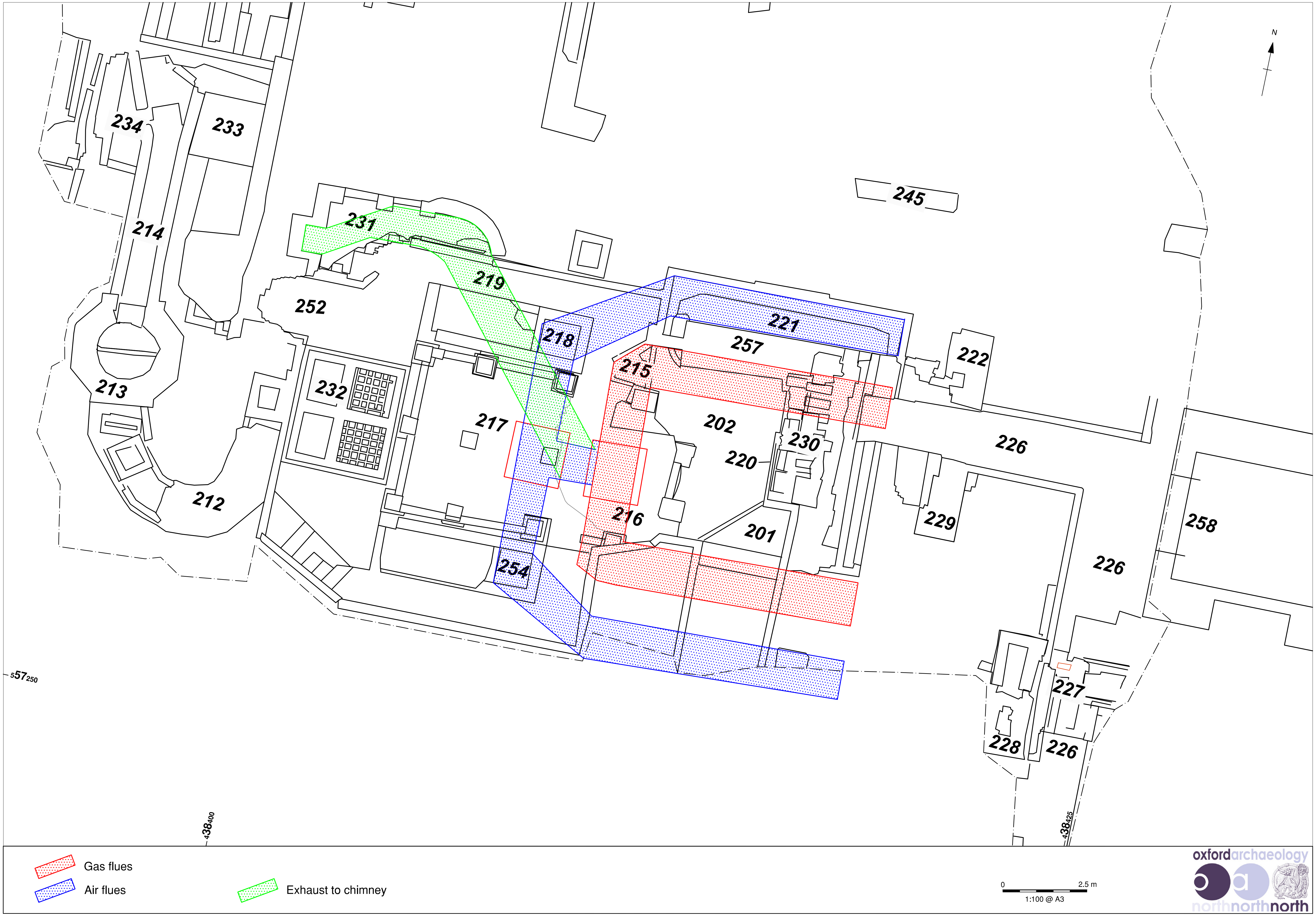
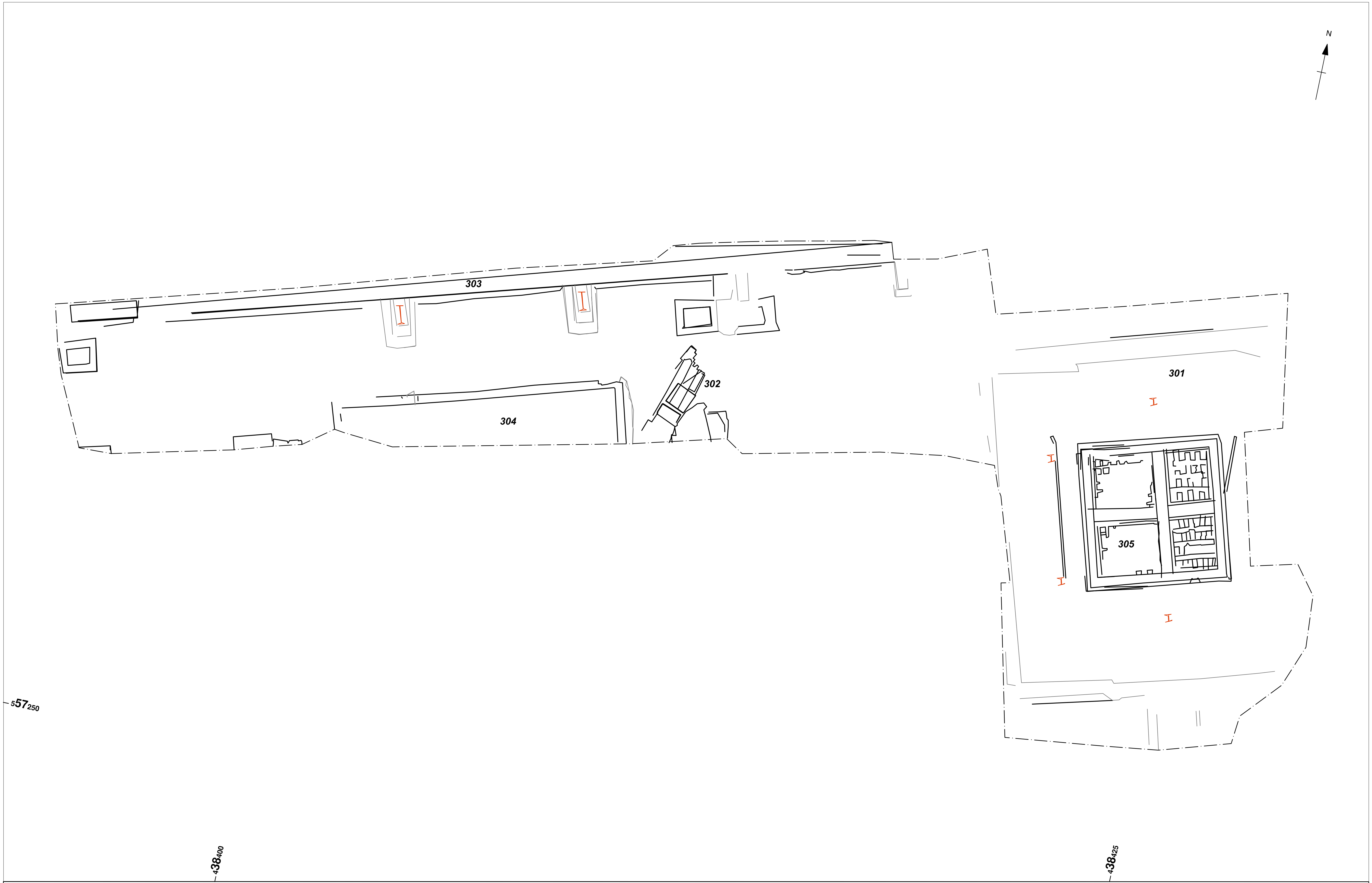


Figure 9: Probable flues associated with Siemens-type furnace



Limit of excavation | brick surface | vertical steel beam
brick wall | stone flags | concrete edge

0 2.5 m
1:100 @ A3

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northnorthnorth

Figure 10: Plan of Area 3