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**To cite this article:** Hugh Willmott, Kate Welham & Camilla Bertini (18 Jun 2026): Glassworking at Barking Abbey: the characterization of an Anglo-Saxon industry, *Archaeological Journal*, DOI: 10.1080/00665983.2026.2679356

**To link to this article:** <https://doi.org/10.1080/00665983.2026.2679356>



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## Glassworking at Barking Abbey: the characterization of an Anglo-Saxon industry

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### ABSTRACT


Excavations conducted between 1985 and 1990 at the site of Barking Abbey yielded extensive evidence of the earliest Anglo-Saxon monastery, founded in the seventh century and subsequently sacked by the Vikings in AD 870. One of the most noteworthy finds was the base of a glass furnace, along with pits containing glass-melting crucibles and working waste. This paper presents the first comprehensive analysis of this material. The circular furnace was constructed from clay-bonded Roman tiles and employed both forced air at the base and apertures in its superstructure to regulate its operating temperature. A recalibration of the original archaeomagnetic dates shows that the furnace was operating between c. AD 730–845 and belongs to the earliest phase of monastic occupation of the site. Crucible and waste finds demonstrate that glasses were being remelted to produce decorative glass vessels and complex millefiori canes for use in high-quality metalwork. Consequently, the evidence for glassworking presented here represents the most important assemblage found to date from this period in Britain. It provides unique insight into craftworking in a Middle Saxon monastery and reshapes our understanding of the industry nationally.

### Introduction

In AD 666, the double monastery at *In Berecingm* (Barking) was founded by Erkenwald, later Bishop of London, and ruled by its first abbess, his sister Ethelburga (Sherley-Price 1968, 216). The abbey prospered for the next two centuries before, according to tradition, it was sacked by the Vikings and its inhabitants slaughtered in AD 870. The site lay abandoned for a century before being re-founded in the 960s as part of St Dunstan's programme of monastic revival. Religious life continued unbroken at the site for nearly 600 years until its dissolution in November 1539. At that point, it had become one of the wealthiest female houses in the country, with an annual income of c. £862 (Knowles and Hadcock 1951, 210).

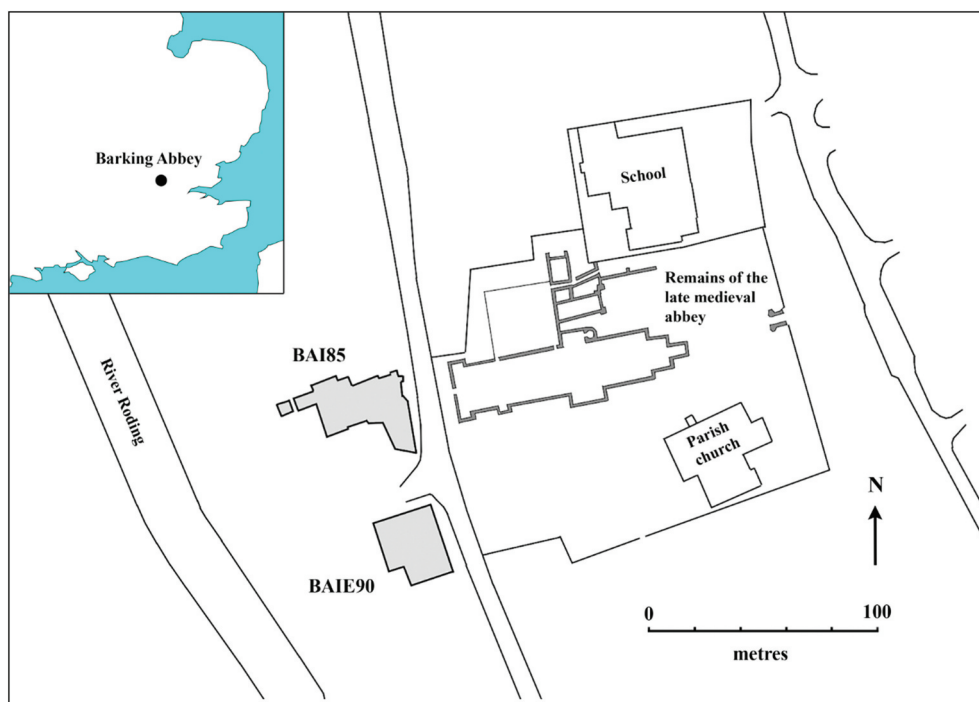
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with contributions by Ann Wilkinson, Cathy Batt and Dan Carter.

 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/00665983.2026.2679356>

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**Figure 1.** Location of the trenches at Barking Abbey in 1985 (BAI85) and 1990 (BAIE90).

Excavations undertaken by the Passmore Edwards Museum in 1985 (site code BAI85) and 1990 (site code BAIE90) in the area immediately to the west of the later Medieval abbey ruins produced extensive evidence for archaeological occupation dating back to the seventh century (Figure 1). One of the most significant features discovered was the base of a glass furnace, along with the largest assemblage of glassworking material retrieved from an Early Medieval context in England. The nature of glassworking activity at Barking has been the subject of limited discussion (e.g. Bayley 2000; Heyworth 1992, 170; Willmott and Welham 2015), but until now no comprehensive analysis or publication has been undertaken, aside from a summary article in *Current Archaeology* (MacGowan 1996). Given the scarcity of evidence for glassworking in Early Medieval England, this has proved a significant lacuna in understanding this important, yet ephemeral, industry. Occasional finds of crucibles and working waste have been published from several ecclesiastical sites including Jarrow, Whitby and Kirkdale (Mills and Cramp 2006; Paynter, Jennings and Price 2014), the emporia at Southampton and Ipswich (unpublished SOTLS:2011.8.167; Broadley 2025), and later urban centres such as York, Gloucester and Lincoln (Bayley 2008; Mainman 1990, 469–472; Vince 1979, 172–176). However, to date, the only other comparable site with evidence for glassworking furnaces is Glastonbury (Willmott and Welham 2015), and these were far more poorly preserved, and the associated glassworking assemblage was limited.

One reason for this academic oversight was the relative inaccessibility of the finds and archive. Shortly after the excavations were completed, the Passmore Edwards Museum closed, and the archive was transferred to the Newham Heritage Service. In

2003, the archive underwent a post-excavation assessment as part of a wider project design undertaken by the Museum of London Archaeology Service to publish 10 interventions near the abbey. However, funding for this was not forthcoming (Sloane, Malcolm and Malt 2003). Following this, the finds and some copies of the paper archive were deposited in the Valence House Museum. However, certain key elements of the documentary and photographic archive have become dispersed in the intervening years. Between 2019 and 2025, Museum of London Archaeology, supported by local volunteers and funded by a Heritage Lottery Fund grant, undertook a post-excavation assessment of archives to make them more accessible and enable future research. This assessment did not include the evidence for glassworking from BAIE90, as this was already underway due to the authors' research presented in this paper. However, MOLA did undertake a review of the ceramics from the site, which has been invaluable in helping phase some of the deposits containing glassworking debris. Finally, it is worth noting that between 2015 and 2018, the area encompassing BAI85 and BAIE90 underwent further archaeological investigations by Thames Valley Archaeology Services (TVAS) as part of the redevelopment of the Abbey Road Retail Site (Pine et al. 2025). Although this did not add new evidence for the furnace previously encountered, features found in adjacent, previously unexcavated areas may be related to glassworking activity.

## The excavations

In 1985, the redevelopment of a retail warehouse on the opposite side of Abbey Road from the west front of the later Medieval monastic church resulted in the excavation of an irregular trench measuring approximately 30 × 40 m (Figure 1). Key Early Medieval features encountered included two ranges of timber buildings, one running west-east in orientation and abutting the second, which ran north-south (MacGowan n.d., 3; MacGowan 1996, 174–175).

Dendrochronological analysis suggested that these were constructed from timbers felled between the sixth and late eighth centuries. Two timber-lined wells, dated to the early ninth century, were also found, along with timbers from a possible clack mill constructed shortly after AD 705. A north-south running building range overlaid several pits containing a range of high-status finds, some with ecclesiastical connections. These included three styli, several manicuring sets, fragments of gold thread and extensive evidence of weaving activity in the form of loom weights, spindle whorls, pin beaters and combs (MacGowan 1996, 175). One of the largest collections of Middle Saxon vessel glass, comprising 167 fragments and deposited in the first quarter of the eighth century, was also recovered from this area (Willmott forthcoming). However, there is no indication that this material was related to glassworking; thus, its presence is likely coincidental. Of more relevance to this current study, several pit contexts (2733 and 3738) contained a few large fragments of the superstructure from a glass furnace as well as a Roman tile coated with a deposit of blue/green glass, interpreted by Vera Evison (1991, 93) as part of a 'tank' for melting glass.

In 1985, several two-metre-wide evaluation trenches were excavated to the south of the main intervention. One encountered the top of a complex of pits containing clear evidence of glassworking activity in the form of waste glass. Unfortunately, the finds

and records from this evaluation cannot be located today. However, in 1990, this area became the focus of redevelopment, and a more extensive trench measuring  $25 \times 30$  m was fully excavated (Figure 1). Although heavily truncated by later activity, Early Medieval features were encountered across the trench. On the northern section edge, a large hearth was formed from reused Roman tiles set on edge; although its function is unclear, it appears more domestic than industrial (Figure 2). In the southern area of the trench, portions of a west-east-running pathway were found, partially overlying an earlier pit, while in the middle of the trench, a single west-east-running beam slot from a possible building was encountered. However, of greater significance was an irregular

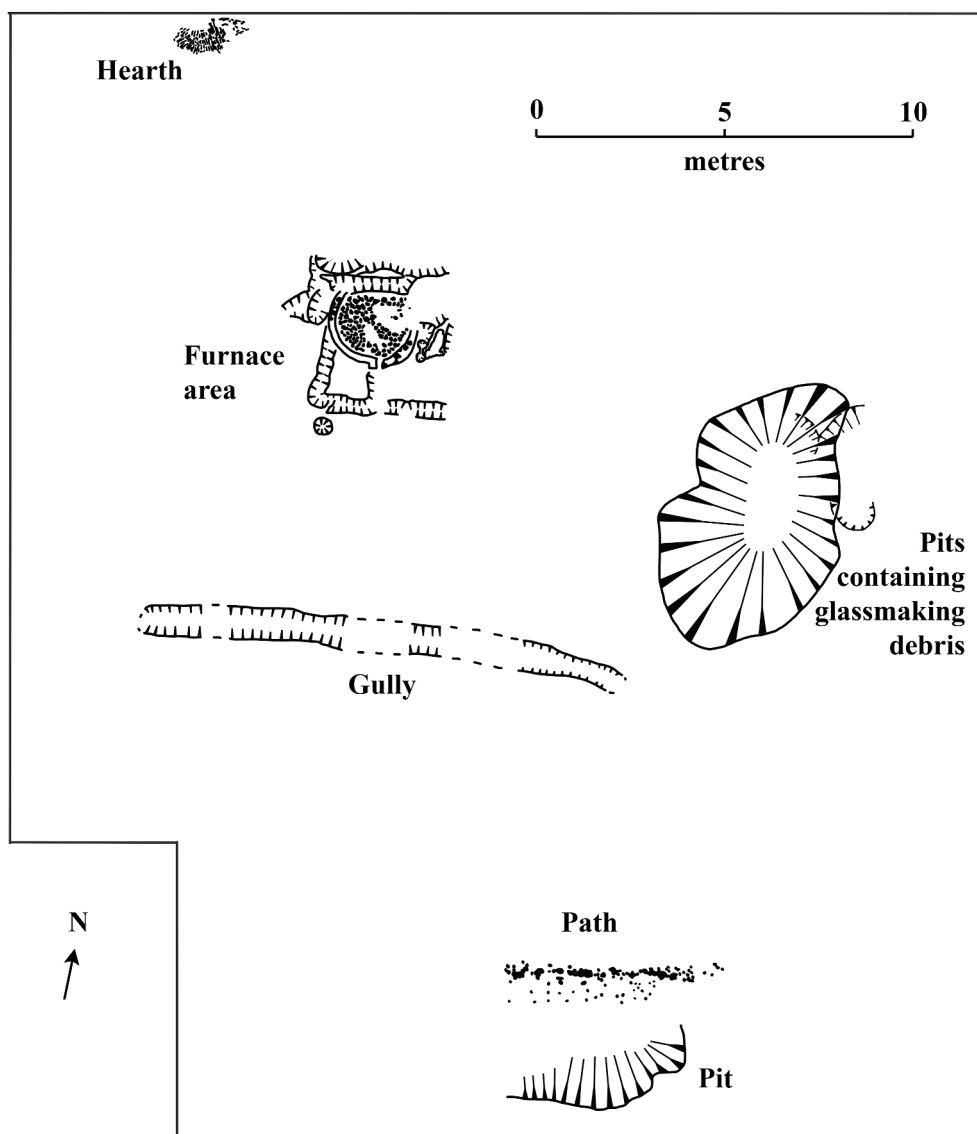


Figure 2. Principal features located in 1990 (BAIE90).

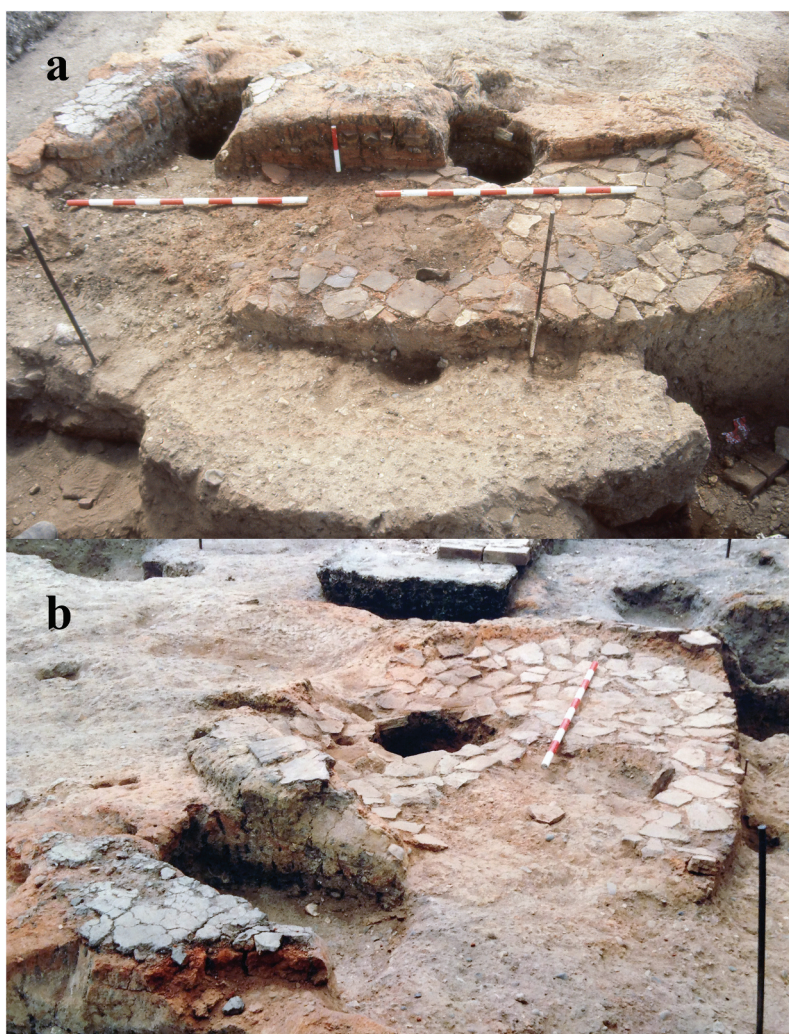
area of intense burning to the north, which, on excavation, proved to be a well-preserved glass furnace. Five metres to the southeast of this, and disturbed by later activity, were a series of intercutting pits corresponding with those first observed five years earlier, two of which [805] and [880] contained fragments of furnace super-structure, crucibles and glass waste.

Between 2015 and 2018, Thames Valley Archaeology Services undertook a further programme of interventions in the area surrounding the glassmaking activity. In evaluation trench 5, located just to the south of BAI85, a furnace (80) lined with Roman tile was encountered. Although this was not securely dated, the excavator suggested there was circumstantial evidence that it was Saxon in date and possibly used to work glass (Hull 2015, 15). Open-area excavations in 2018 uncovered two highly fired structures constructed from Roman building materials in the area directly north of the BAIE90. The first (5035), associated ash dump and heavily truncated, clearly had been subject to extensive burning; this was noted by the excavator as possibly resembling the 1990 glass furnace (Pine et al. 2025, 24). A second structure (1327) was of near identical shape, size and construction to the BAIE90 glass furnace (32, pl. 19). However, no evidence for glassworking was encountered in association with either of these features, and soil sampling that might have provided more indicative evidence was not undertaken. Consequently, any interpretation of their function must remain speculative.

### The BAIE90 furnace

The furnace area was first identified as an extensively burnt feature, roughly 5 m square. Adjacent to this and immediately to the east was a smaller patch of highly vitrified natural clay. Upon excavation of the more extensive burnt feature, it became clear that this was formed from several layers of demolition and debris that overlaid and extended beyond the footprint of a furnace lying beneath (MacGowen, n.d., 7) (Figure 3). The cause of the vitrified area to the east was less clear; initially interpreted as the base of a second furnace, it is more likely to represent a secondary structure or working area. However, its relationship to the principal furnace was lost due to later disturbances that truncated it stratigraphically.

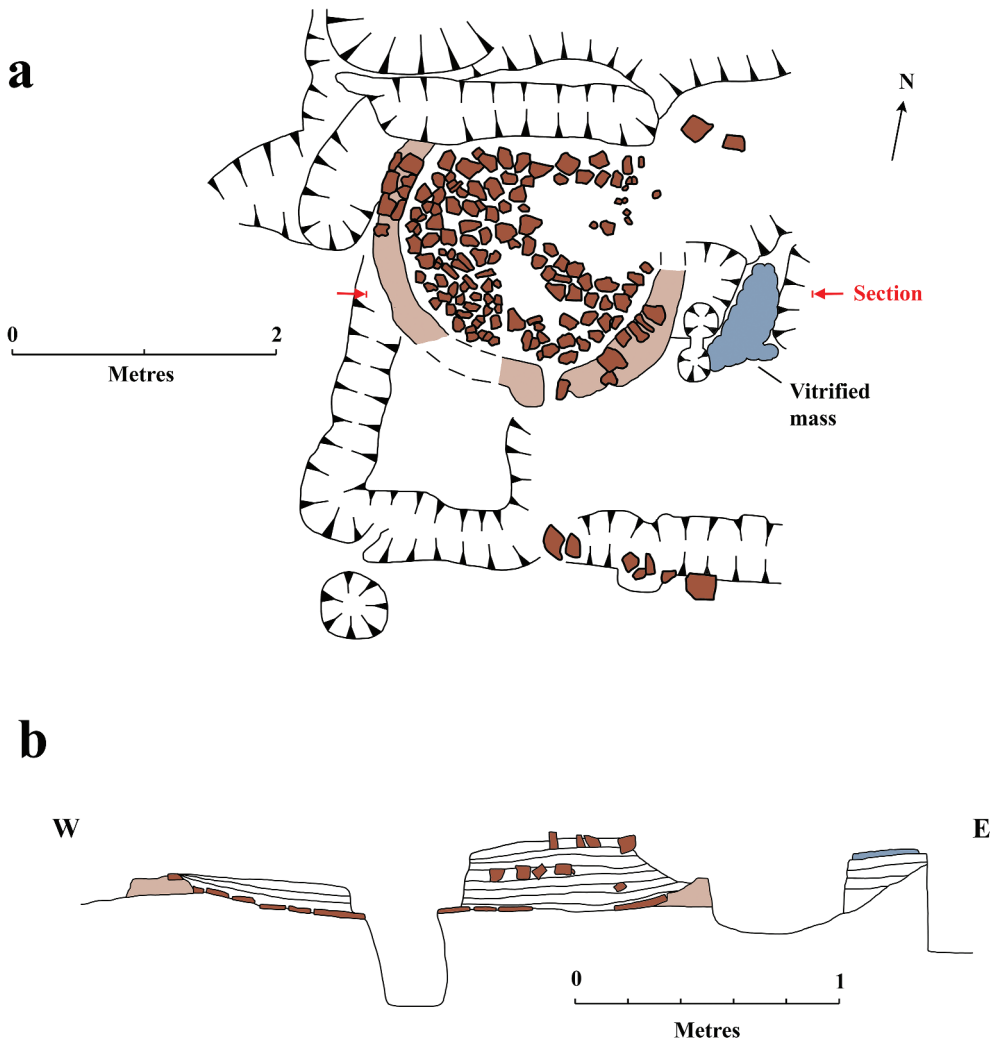
The furnace and overlying layers of demolition material were cut by four later Saxon beam slots, forming a square (Figure 4). Although almost directly overlying the furnace, they post-dated it, so any relationship seems coincidental. The surviving base of the furnace, which was circular and approximately 2.5 metres in diameter, was remarkably well preserved and enabled a detailed reconstruction. Save for where later pits had cut through, the floor was covered entirely with reused Roman tiles set into the natural clay hollow below, which had been hardened by baking, creating a solid surface. On the southern and western sides, the base of the furnace wall survived to a height of around 20 cm and was 20–30 cm wide, again formed from vitrified natural clay set with Roman tile. Later truncations had removed the north and eastern portions of the furnace wall. However, a small 20 cm-wide V-shaped opening was identified on the southern side. Although this might have functioned as a stoke hole for the raking out of ash, its odd V-shaped profile suggests otherwise. Instead, there is evidence to suggest that this



**Figure 3.** The glass furnace: (a) partially excavated, looking south; (b) fully excavated, looking west. The associated vitrified area is visible in both pictures, immediately to the east of the main furnace.

opening was intended to allow the insertion of a tuyère to force air into the furnace (discussed further below).

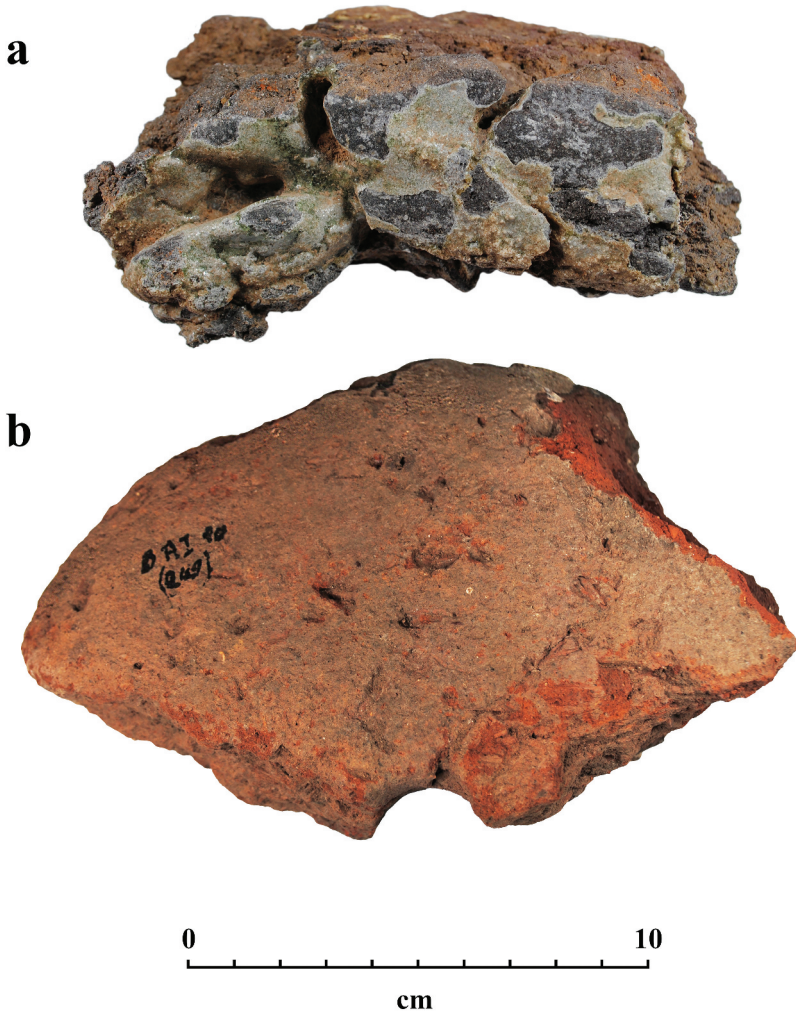
Significant quantities of furnace superstructure were found within the layers sealing the furnace floor. This material also occurred in the associated pits to the southeast. Together, they enable at least a partial reconstruction of the furnace. Quantities of highly fired daub, often with vitrified surfaces, and vitrified Roman tile suggest that they were used to construct the upper stages of the furnace, the tile providing support and rigidity to the clay matrix. The fragment of Roman tile with droplets of glass adhering, identified by Evison (1991, 93) as a ‘tank’ to melt raw materials, is more likely to have been part of an internal shelf or ‘siege’ upon which the crucibles would have rested. A similar tile fragment from the 1990



**Figure 4.** The furnace and vitrified area: (a) plan; (b) section.

excavations appears to retain elements of the crucible base, which had partly fused to it.

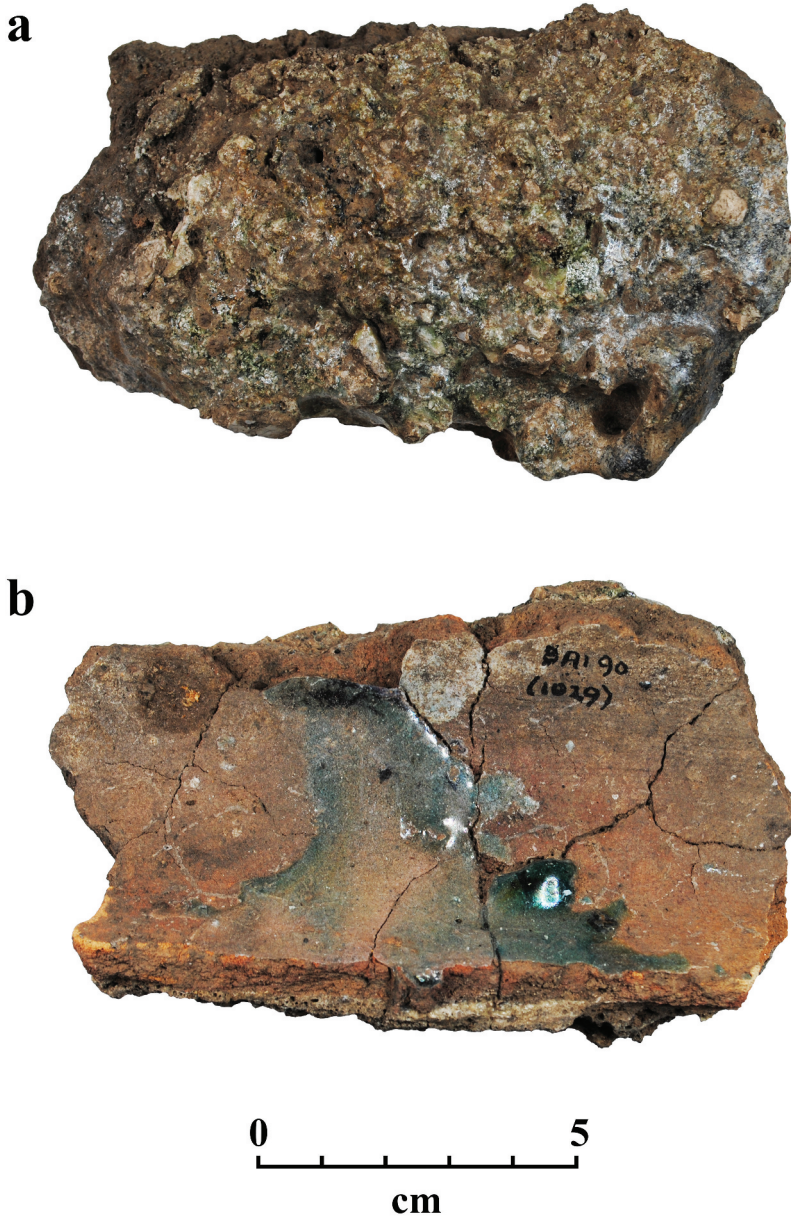
Other diagnostic elements relating to the furnace structure can be identified. The largest of these is a fired clay ring, sub-rectangular in section. Although it has undergone extensive heat distortion, making precise reconstruction difficult, it has an outer diameter of approximately 35 cm and an inner diameter of around 20 cm (Figure 5). Only highly vitrified on one edge, rather than placed entirely within the furnace, it must have formed part of the wall and most likely functioned as a working aperture or vent. Significantly, this ring corresponds in size and thus function to a second object, a circular clay disc 20 cm in diameter. Slightly elliptical in cross-section, it has a central hole 2 cm in diameter and is highly vitrified on one surface (Figure 5). This disc served as the cover for a working



**Figure 5.** Furnace superstructure: (a) clay aperture; (b) clay cover.

aperture; the central hole allowed it to be removed and replaced with an iron tool. Similar ‘glory hole’ covers, or *boccarella*, have been found at the ninth-century AD glass workshop of San Vincenzo al Volturno in Molise, Italy (Charleston 1978, 15). Here, two clay discs with central perforations were uncovered, one within the ash fill of a pit and the other present in a demolition layer above a rectangular glass furnace constructed from tiles bonded with clay (Hodges, Leppard and Mitchell 2011, 144).

Perhaps the most unexpected finds were several fragments of a fired clay tuyère, the largest of which enabled partial reconstruction (Figure 6). This piece is conical in shape, with a gradually tapering internal diameter. The outer surface is highly vitrified due to prolonged exposure to furnace heat, while the interior remains largely unaffected. Significantly, the inner surface retains distinct fabric impressions, suggesting



**Figure 6.** Tuyère: (a) external vitrified surface; (b) interior with fabric impressions (below).

the tuyère was made by moulding clay around a cloth-covered former or directly onto the bellows' nozzle. This practice has been observed in the production of 'ceramic brazing shrouds' for Early Medieval metalworking, such as ceramic fragments with fabric impressions found associated with non-ferrous working at Cathedral Hill, Armagh (Kerr et al. 2015, 45). The inner surface also retains dribbles of blue/green glass that presumably dripped onto the tuyère after it was removed from the furnace.

Although glassworking has been identified at several Anglo-Saxon sites (discussed below), only at Glastonbury have comparable furnace structures been discovered. Between 1955 and 1957, Radford excavated the remains of five glass furnaces, located beneath the cloistral ranges of the post-Conquest abbey (Willmott and Welham 2015). Later Saxon activity and the construction of post-conquest buildings severely disturbed the furnaces, removing almost all evidence of their structural remains; however, two (Furnaces 1 and 3) were sufficiently complete to allow a tentative reconstruction.

The Glastonbury furnaces were slightly smaller than that found at Barking, and both were somewhat elliptical in shape: Furnace 1 measuring  $1.8 \times 1.2$  m and Furnace 3 measuring  $2.0 \times 1.4$  m externally. The best-preserved furnace, Furnace 1, had a stokehole 22 cm wide and was flanked by two stones to create a solid opening at its western vertex. The walls were approximately 13–15 cm thick, and the slightly concave floor was lined with reused Roman tiles (Willmott and Welham 2015, 222–223). Furnace 3 had a similar-sized stokehole on its longer southern side and a highly burnt, concave floor that did not appear to have been tile-lined. However, given that this furnace was more heavily disturbed, these features might have been removed at a later date (Willmott and Welham 2015, 225–226).

A further similarity between the Barking and Glastonbury furnaces can be seen in the fragments of superstructure found. At Glastonbury, numerous highly fired clay daub fragments were recovered, often with vitrified inner surfaces, and many of these contained wattle impressions, as at Barking. Also at Glastonbury, the presence of highly fired and reused Roman tile demonstrated that these had been incorporated into the superstructures. Finally, at least two fragments of curved clay aperture were recovered from Glastonbury. Although these were not as highly vitrified as the Barking example, they must have originated from the upper portion of the furnace.

The preserved furnace plan and the surviving elements of the superstructure at Barking enable a tentative reconstruction to be suggested that closely mirrors one previously proposed by the authors at Glastonbury (Willmott and Welham 2015, 231–232). The Glastonbury reconstruction drew heavily from the experimental work of David Taylor and Mark Hill (2008), who have successfully built and operated Roman-style circular ‘pot furnaces’. Although based on archaeological evidence from the Classical world, their size and form are remarkably consistent with those of their Early Medieval counterparts, and experimental firing shows that these structures could sustain a temperature of 1050°C (Taylor and Hill 2008, 255). The Barking furnace had a tiled floor and walls constructed from clay and tile, which, in likelihood, rose to the level of the ‘siege’. The upper portion of the furnace, containing the venting apertures and the gathering hole through which the glassworker accessed the crucible, was seemingly made from daub strengthened with wattling.

Incorporating a tuyère, and thus using forced air, in the glass furnace at Barking is a unique find on an Early Medieval glassworking site in England. It is usually assumed that tuyères and bellows were associated with metalworking (e.g. Tylecote 1981). However, there is no reason they might not have been employed in other industries when increased airflow was required. Indeed, tuyères have been identified at other glassworking sites, although they date to different periods. For example, an unspecified quantity of tuyères was found amongst the glassworking debris at Kopia, India, dating

from the second century BC to the second century AD. Here, they were thought to be associated with the manufacture of beads and bangles (Kanungo et al. 2010, 905). Excavations of the fourteenth-century Wealden glasshouse at Blunden's Wood, Surrey, revealed that a subsidiary furnace had a tuyère opening leading directly into its central firebox (Wood 1965, 59). Likewise, a mudbrick structure attached to a tank-style furnace at Mishlab, al-Raqqa, Syria, which likely dates to between the late eighth – early ninth century AD, had holes for the insertion of up to three separate tuyères, although it is not clear whether they would have been in use simultaneously (Khalil and Henderson 2011, 240–241). Consequently, the evidence for the use of forced air in the furnace at Barking is entirely consistent with early glassworking practices.

### Dating of the furnace

During the Passmore Edwards Museum's excavations, 32 samples were collected for archaeomagnetic dating from two locations directly associated with the furnace. Those taken from the base of the furnace floor had a calibrated date of AD  $920 \pm 50$  years at 95% confidence, whilst those from the vitrified surface next to it produced a date of AD  $925 \pm 60$  years at 95% confidence (Clark 1990a, 1990b). These date ranges were problematic, as they fell squarely into the period between the documented sacking of the first monastery in AD 870 and its refoundation in the 960s, a conundrum noted by the excavator (MacGowan 1996, 178).

As part of this study, the original data were recalibrated by Ann Wilkinson and Cathy Batt at the University of Bradford, resulting in revised date ranges (Supplementary Appendix 1). The samples from the furnace floor can now be dated to AD  $777 \pm 68$  years, and the vitrified surface adjoining it to AD  $785 \pm 95$  years, both at a 95% confidence level. Combined, these provide an overlapping range of AD 730–845, and now place the operation of the glassworking phase firmly within the earlier phase of monastic occupation. This recalibration is further corroborated by the recent re-evaluation of the ceramics by MOLA. Significantly, pit (805) contained two sherds within its fills in direct association with considerable quantities of glassworking material: a chaff-tempered ware of late sixth to mid-eighth century date in context (249) and a North French black burnished ware of c. AD 650–750/800 in context (974) (Lyn Blackmore, pers. comm., September 10, 2025).

The revised dating of the Barking furnace is not only important in helping to place it more accurately within its site-specific context, but it also adds to an emerging pattern suggesting that there was a flourish in monastic glassworking in England during the late seventh and eighth centuries, which seems to have ended by the early ninth century with the Viking incursions. The documented arrival of Continental glassmakers at the monastery at Wearmouth and Wilfrid's church at York in the 670s is well known (Cramp 1975, 93), while a late seventh-century date for the glass furnaces at Glastonbury has recently been established beyond doubt (Willmott and Welham 2015, 233). Eighth-century glassworking waste has been found at Whitby Abbey, and a single fragment of twisted coloured rod from Kirkdale Minster is likely to be of a similar date, based on its chemical composition (Jennings 2005; Paynter 2009; Paynter, Jennings and Price 2014). Consequently, this new date for operations at

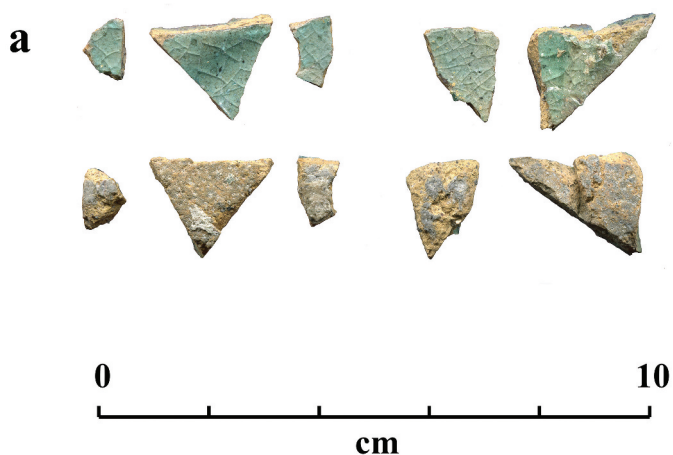
Barking is entirely consistent with an emerging pattern of activity across England between the late seventh and eighth centuries.

## Crucibles

Almost all the crucibles and glassworking waste were recovered from within two pits, [805] and [880], excavated in 1990 and located 5 m southeast of the furnace. However, a few fragments were also recovered from scattered contexts around the trench. Crucibles are among the most diagnostic finds associated with glassworking; their presence indicates that glass was intentionally melted or even produced on-site. In total, 39 fragments of glassworking crucibles were recovered, belonging to two distinct types: upright jars and shallow dishes.

Jar crucibles are a well-recognized Early Medieval type ([Figure 7\(a\)](#)). The small size of the surviving sherds from Barking makes their precise reconstruction difficult, but they conform to more complete examples from elsewhere. They were made from highly refined light or buff refractory clay, all of which contained internal blue/green glass residues. Portable X-ray fluorescence (pXRF) analysis has confirmed the presence of a range of metallic elements (e.g. antimony, arsenic, copper, lead and tin) known to be associated with Early Medieval glass compositions ([Freestone 2015](#)) (see [Supplementary Appendix 2](#)). Morphologically, they are identical to 29 fragments of jar crucible from Glastonbury ([Willmott and Welham 2015](#), 224), a single rim found at Jarrow ([Mills and Cramp 2006](#), 470) and an unpublished base from Southampton (Southampton Museums and Archives SOTLS:2011.8.167). Although the dimensions of the Barking jar crucibles are impossible to reconstruct, the Jarrow example had a rim diameter of around 120 mm, whilst a rim from Glastonbury was 162 mm wide, and the vessel had an estimated height of 180 mm. Consequently, the Barking crucibles were likely of similar proportions ([Figure 8\(a\)](#)).

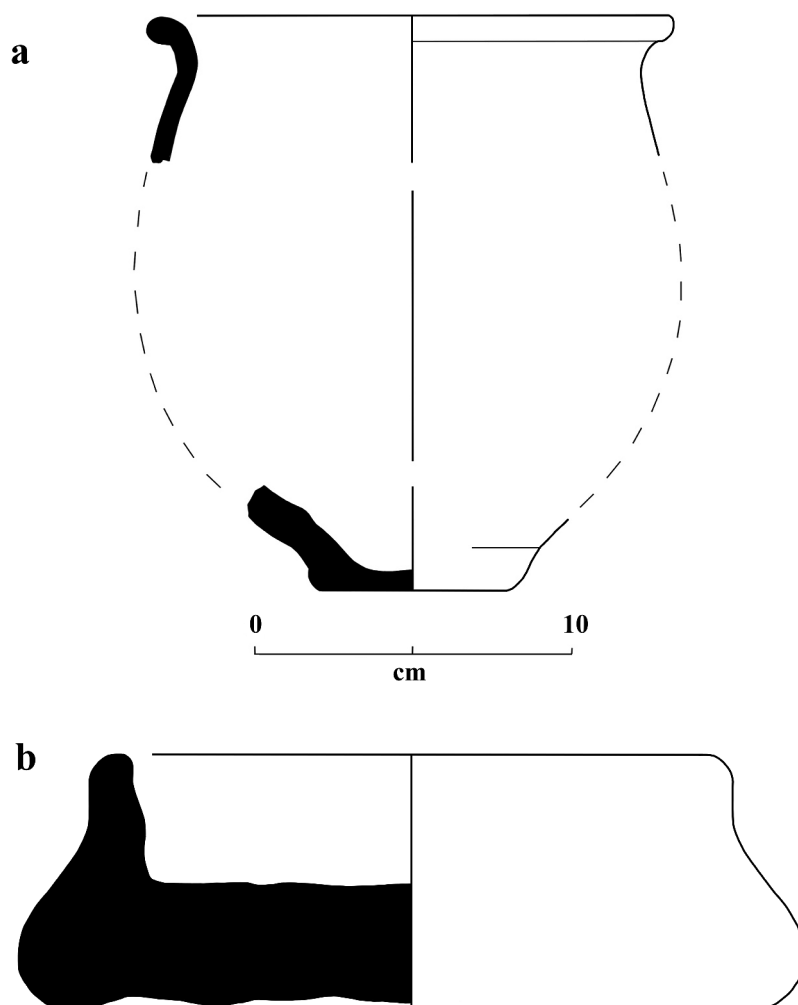
The close similarity between these fragments of jar crucible from different sites raises several intriguing possibilities. Their fabrics, as well as their form, are all alike and entirely different from their respective local ceramic traditions. Furthermore, they could not be more geographically spread, coming from County Durham, Essex and Hampshire, regions within three different Anglo-Saxon kingdoms until the ninth century. This level of uniformity thus hints at a potential common design, if not origin; one that is, in all probability, continental European. The record of glassmakers from Gaul arriving at both Wearmouth and York in the last quarter of the seventh century has already been discussed (see [Cramp 2006](#), 56–57), and in addition to their expertise, they almost certainly brought equipment essential to their trade. Whether these included crucibles remains unknown, but the appearance of the same type of crucible at three documented monastic sites may not be coincidental. However, despite this apparent hint of an overseas origin, petrographic analysis of the Barking jar crucibles suggests that they were made from highly refined, wheel-turned, iron-poor London Clay ([Supplementary Appendix 3](#)). Nonetheless, the quality of their manufacture is in stark contrast to that of most other ceramics on the site, dating to the earliest phase of the monastery; as wheel-turned wares became common at Barking only from the ninth century onwards ([Rednap 1991](#), 356–357). Consequently, whilst produced locally, the



**Figure 7.** Crucibles from barking: (a) jar fragments; (b) rim and base from a dish.

jar crucibles were made using imported expertise, presumably by the glassworkers who used them.

In addition to the jar crucibles, fragments of very different shallow dish-shaped crucibles were recovered (Figure 7(b)). The most complete had a rim diameter of around 200 mm and a height of 80 mm (Figure 8(b)), and almost all came from the same pit contexts (995) (1029), which also contained the majority of the glassworking waste. These were irregular and thick-bodied, made from a coarse, handmade, organic-



**Figure 8.** Crucible profiles: (a) reconstructed jar based on fragments found at Glastonbury; (b) complete cross-section of a dish from Barking.

tempered fabric with calcareous glauconitic sandy inclusions, probably derived from the southern bank of the Thames in the Barking area (see Supplementary Appendix 3). The coarse local ceramic was severely degraded and highly friable due to prolonged exposure to high temperatures. This deterioration occurred uniformly throughout the crucible, suggesting they were placed within the furnace rather than being heated from below on a hearth. These dish crucibles did not contain thick glass deposits, like the jar crucibles, but slight traces of glass did survive in small patches on almost all examples.

The function of the Barking dish crucibles is unclear. Morphological parallels can be seen at a range of Early Medieval glassworking sites e.g. at Buckden (Rye and Bayley 1996), Jarrow (Mills and Cramp 2006, 470) and tenth-century locations such as

Gloucester (Bayley 1979, 201–204), Flaxengate, Lincoln (Bayley 2000, 140; 2008) and York (Bayley and Doonan 1999; Mainman 1990, 469–472; Tweddle 1986, 226–227). However, these sites have been predominantly associated with the manufacture of lead-based products, such as litharge, which was used to glaze ceramics or to produce lead glasses (Mills and Cramp 2006, 471–473; Tite 2006, 478). The Barking lead levels (see Supplementary Appendices 2 and 4) are insufficient to corroborate this type of activity. While the possibility that these crucibles might relate to a metalworking process cannot be discounted entirely, the crucible finds from Hare Court, on the periphery of Lundenwic, may provide the most useful comparator for Barking. Three fragments from one or two separate dish-shaped crucibles were found in association with eighth–ninth century vessel glass (Butler 2005, 61). Produced from a coarse, sandy fabric with blue-green glassy residues, one rim suggests a similar vessel diameter of c. 200 mm (Butler 2005, 54–55, 61, fig. 65). Analysis indicates these were used for melting soda-lime-silicate glass with minor traces of lead, tin and copper (Butler 2005, 61).

The dish crucibles at Barking are complex to interpret. Where comparative forms of these crucibles are reported, except for Hare Court, they are generally related to the use or possible production of opacifiers for high-lead glasses (predominantly opaque yellow). The lead content of the glass means that lower temperatures are required to soften or melt it, and such glasses were used to produce small items, including beads and rods, as well as glass for enamelling. However, no direct evidence exists at Barking for high-lead glasses attached to any crucible fragments recovered. What is intriguing is that there is evidence of objects produced from opaque white glasses, including moils, pulls and rod waste ends (see Supplementary Appendix 4). Could the dish-shaped crucibles be part of a multi-stage process, and were the small quantities of low-lead silica-lime glass about to be mixed with something else? The elevated tin levels found in residues on one dish crucible (SF659b) could indicate the inclusion of an opacified glass, as tin oxide is known to have been used in opaque white glass at this time (Paynter, Jennings and Price 2014, 39) (see Supplementary Appendix 2).

In contrast, the shallow dish crucibles from Gloucester, Lincoln and York have all been suggested for the production of beads and possibly other small items (Bayley 2000, 139–140). Such forming activities required lower temperatures; for this purpose, poorer-quality crucibles made from local clays may have sufficed. Whilst there is no evidence for bead manufacture at Barking, the production of glass rods was taking place on site (see below) and would similarly require a lower melting temperature.

## Glassworking waste

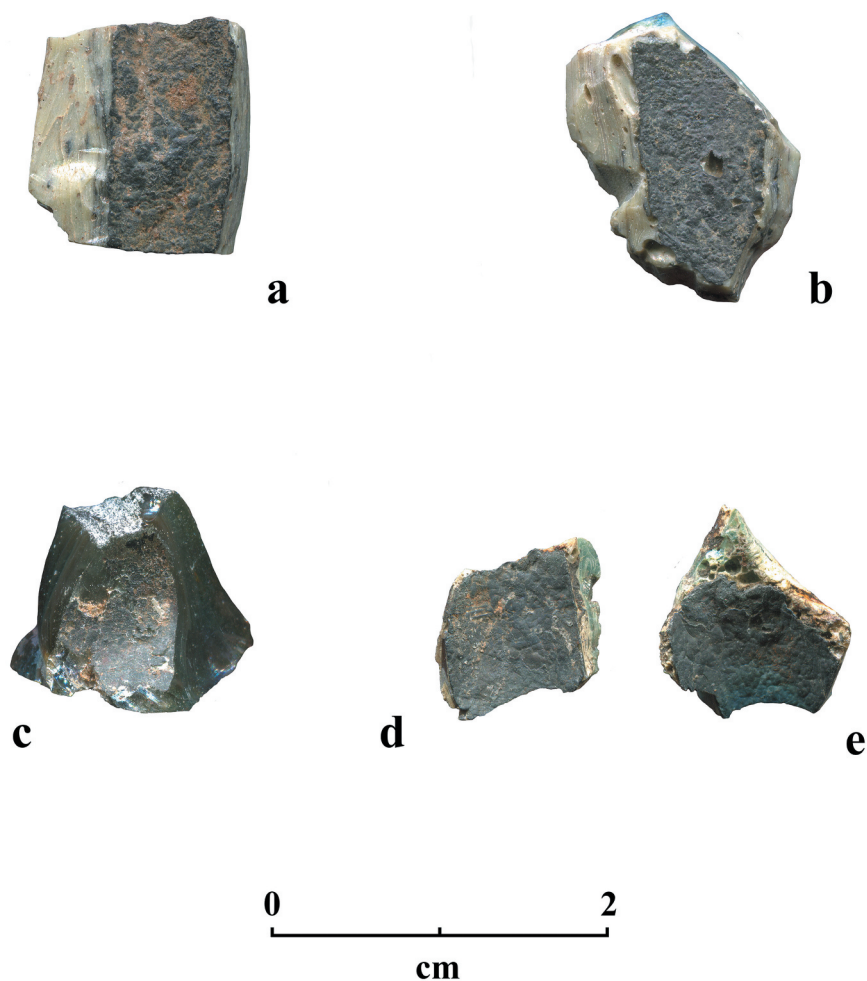
Small lumps and fine glass threads were the most numerous elements of glassworking waste recovered (Figure 9). These could have derived from all aspects of vessel and object manufacture, but, in particular, the threads resulted from the blowing of vessels and the application of decorative trailing. Otherwise, they are relatively undiagnostic, but these lumps and threads illustrate the range of glasses being worked. Blue/green glass was the most common, but dark green/black (hereafter referred to as black), turquoise, amber, opaque yellow and opaque white are also present. All these colours are typical for Early Medieval glassworking, with blue/green being the predominant base colour used for vessel glass, whilst others were usually used for decorative



**Figure 9.** Fine glass threads from glass blowing.

elements. Parallels can be drawn with the assemblage from Glastonbury, where blue/green was the most common colour, and turquoise, amber/brown and opaque white occurred in smaller quantities, presumably as they too were restricted to decorative elements (Evison 2000, 189–190; Willmott and Welham 2015, 230).

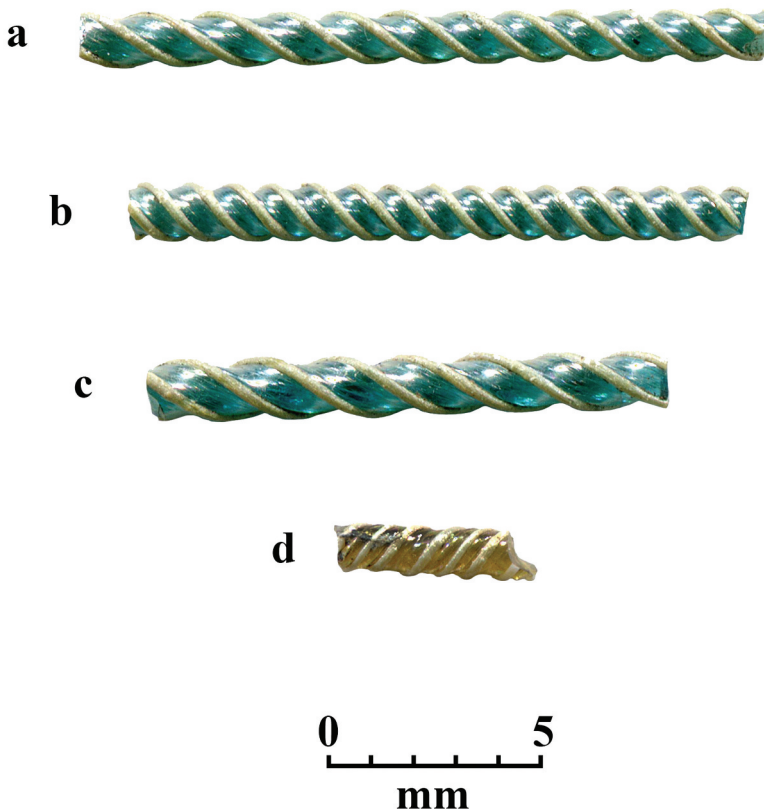
At Barking, 19 fragments of finished Early Medieval vessel glass were recovered from across the trench excavated in 1990. Vessel glass might ordinarily be expected to occur on a Saxon site of the status of Barking and, indeed, was found in large quantities in the 1985 trench to the north. Given this, some can be discounted as having no connection to the glassworking activity at the site. Nonetheless, 13 fragments were found within the fills of pits [805] and [880] and were directly associated with glassworking waste, warranting brief consideration. These fragments are tiny; the most significant measures just  $19 \times 9$  mm. All are fine body fragments and thus



**Figure 10.** Moils: (a–b) opaque white; (c) black; (d–e) blue/green.

relatively undiagnostic, but are likely from globular beakers or palm/funnel cups, which were the most common contemporary forms (Evison 2000). They mirror the colours found in other forms of working waste; 10 are in blue/green glass, and three are turquoise. While some of the fragments may represent collected cullet intended to be remelted, their association with similarly coloured threads and lumps suggests that vessels of these colours were manufactured at Barking.

Further evidence for complex glassworking comes from the moils, of which five examples were recovered (Figure 10). Moils were the portion of glass that adhered to the iron as it was dipped into the crucible to gather a blob of glass. This gather was then either inflated to form vessels or drawn to create rods, trails or other decorative elements. The glass reacted with the iron's surface, leaving a distinctive iron oxide scale on the inner surface of the moil, a feature seen on all the examples found at Barking. Once the glass on the iron had been formed and separated, the glassmaker



**Figure 11.** Cable rods: (a–c) blue/green overlain with opaque white; (d) clear-tinted overlain with opaque white.

removed the remaining moil from the iron by plunging the tool into water, causing the glass to shatter off.

Two of the moils are opaque white (Figure 10(a–b)) and have identical internal diameters of 15 mm, suggesting that they might have been formed upon the same tool. A third moil is in black glass (Figure 10(c)), and two others are in blue/green (Figure 10(d–e)). Although moils do not indicate the type of glassworking that was taking place at Barking, their colour provides some hints. Blue/green moils could have resulted from blowing full vessels and creating secondary decorative elements such as trails, or the creation of window glass through the blown cylinder method. However, the opaque white and black moils are more definitive. In Anglo-Saxon England, opaque white glass was never blown to create the main body of a vessel or used to make window glass. Instead, opaque white only appears, combined with other coloured glasses, as either twisted decorative trailing on the vessel surface or as part of complex millefiori schemes, both of which are present amongst the other working waste found at Barking (see below).

The final finds indicative of glassworking from Barking are 15 fragments of twisted cable rods, which are sometimes erroneously referred to as *reticella* (Figure 11). Of these, all but one were found along with most of the remaining glass waste in the two pits [805]

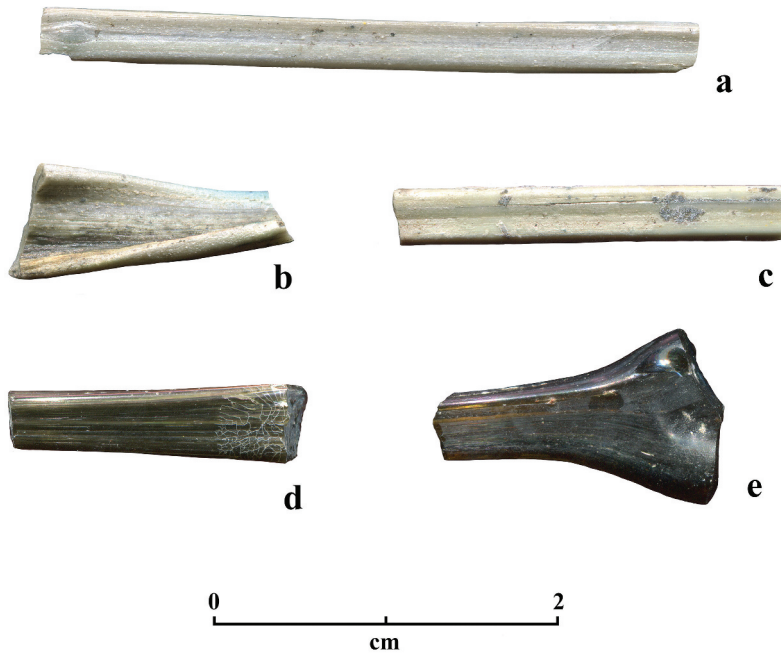
and [880]; the other came from a context (1261) in direct association with the furnace. Such items were formed from two separate rods that were heated, pulled and twisted to create an extremely fine cable; the Barking examples are all less than 1.5 mm in diameter and some as thin as 0.5 mm. Here, usually the larger rod that formed the core was in a blue/green glass, overlain by a finer opaque white one (Figure 11(a–c)), although there are two examples where the core was a clear-tinted glass overlain by opaque white (Figure 11(d)). Such cable rods were used as a surface decoration; they were applied to the still-hot vessel and marvered, or pressed, into the surface. At least one fragment appears to be a distorted, unusable end piece, indicating it was likely manufactured at Barking.

Similar rods have been found on other production sites in England, such as a single fragment of twisted blue overlain by opaque white found at Glastonbury (Willmott and Welham 238, fig. 14; Evison 2000, 190, fig. 1.16). During the most recent excavations at Whitby, a section of a light blue rod twisted with fine, opaque white was recovered. Also from Whitby, and most diagnostic of all, was a prominent end piece from the production of an opaque, white and blue rod (Jennings 2005, 208; Paynter, Jennings and Price 2014). Further sections of finished cable rods come from the probable monastic centre at Kirkdale, North Yorkshire (Rahtz and Watts 1997, 419–422), and emporium at Ipswich (Broadley 2025, 301). The Kirkdale fragment is a small section of a rod with a light blue/green core surrounded by alternating bands of opaque white and opaque yellow, while two fragments from the same rod at Ipswich were overlaid with twisted opaque white and red.

### Millefiori production

One of the most important aspects of the glassworking assemblage is the small but significant quantity of glass used to produce millefiori canes. Millefiori was a process in which rods of different-coloured glass were fused to create complex, patterned canes, which were then sliced to provide insets for high-status metalwork. Their inclusion in the escutcheons of hanging bowls is well attested (e.g. Bruce-Mitford 2005, pl. 4), and they were also used as part of the decorative scheme on the purse lid and shoulder clasps from the Sutton Hoo Mound 1 burial (Bimson 1983, 924–936). Millefiori insets could sometimes be used on other items such as small decorative mounts and pendants; a black and white motif identical to a fragment from Barking (discussed below) has been found on a disc from Great Barton, Suffolk (West 1998, 124, fig. 8.5). However, their complex construction must have meant they were reserved for objects of some status and significance.

The evidence for millefiori glass production at Barking comes in two forms: square-section rods and finished complex canes. Six fragments of square rod, three in opaque white and three in black, were retrieved (Figure 12). These were formed by gathering molten glass on an iron, which was then elongated through pulling before being squared off, probably using a wooden tool known to contemporary glassmakers as a ‘battledore’ (see Bimson 1983 for a more detailed discussion of their manufacture). The presence of squared rods is a unique and definitive indication of the production of millefiori canes. Other processes, such as applied trailing on vessel glass, only required a rod with a circular cross-section, which was then partially or wholly smoothed into



**Figure 12.** Square rods: (a–c) opaque white; (d–e) black.

the vessel's surface. A square rod, or occasionally a triangular one (see below), was only needed when clusters were fused to maintain a tight and consistent pattern through the length of a millefiori cane. One fragment of the black rod is a thickened end piece and clearly shows the pincer marks resulting from its drawing (Figure 12(e)), while the opaque white moils (discussed above) provide further possible evidence for the production of opaque white rods.

In addition to the squared rods, five fragments of completed millefiori canes of four differing designs were recovered (Figure 13). Where measurable, these canes have a width of 3–5 mm. However, this is a somewhat arbitrary figure as the original canes varied in width along their original length. The simplest was formed from nine alternating opaque white and black rods, forming a rudimentary cross design (Figure 13(a)). Given the opaque white and black square rods noted above, this almost certainly was produced at Barking.

The second reconstructed cane is more complex (Figure 13(b)). It is formed from 82 rods and has a chequerboard background of opaque white and khaki green. In each corner is a central black rod flanked by eight blue/green rods, while the centre square panel is reversed, with blue/green surrounded by black and a tiny black central core. The third design is represented by a fragment of manufacturing waste, showing several partially fused canes, presumably a discarded end piece (Figure 13(c)). Formed from 81 rods, the pattern is predominantly cruciform, consisting of alternating blue/green and white canes. Each corner consists of an opaque white rod surrounded by eight black ones. The final identifiable pattern is seen in a well-preserved cane section formed from 81

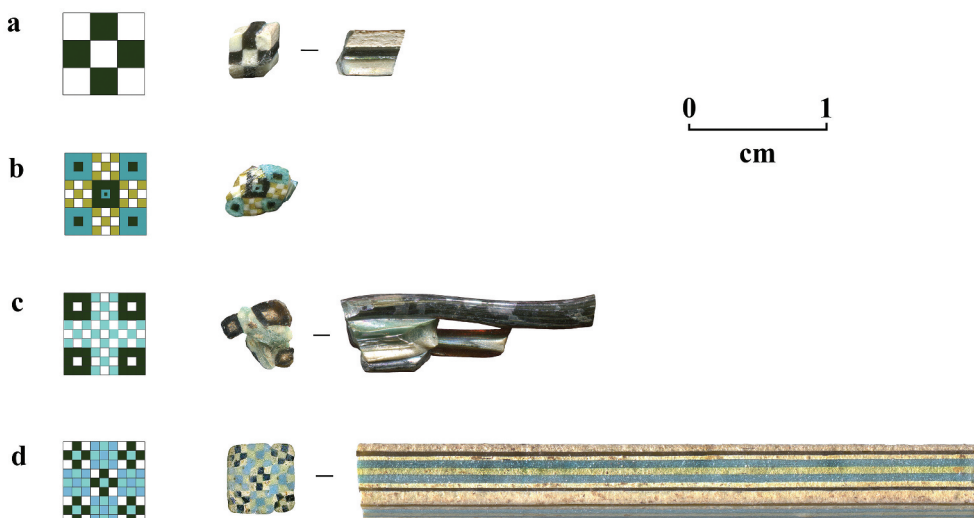


Figure 13. Millefiori canes.

individual rods (Figure 13(d)). Following a chequerboard pattern, it alternates clusters, forming a cruciform shape. The black clusters are surrounded by opaque white, with a blue/green core, and a cruciform shape in blue/green is surrounded by light blue, with a light blue centre. Two further millefiori cane fragments were recovered, but are too fragmentary or distorted to reconstruct. The first consists of an opaque white rod, flanked on all sides with blue/green and a possible outer covering of opaque white, while the second contains elements of opaque yellow and black rods, but otherwise, little more can be discerned.

The presence of millefiori canes has been noted on several Early Medieval sites across the British Isles (for a comprehensive discussion of millefiori production and use in the region, see Willmott 2026). In England, five millefiori canes were recovered from the monastery at Jarrow, three of which appear to be waste pieces, indicating that they were manufactured there (Cramp 2006, 263–266). In Scotland, there are finds of single canes on a beach at Luce Bay, Wigtownshire, that can tentatively be associated with the nearby monastery of Whithorn (Cramp 1970, 333), and at Dunadd Fort, Argyle and Bute (Lane and Campbell 2001, 172–174), while a further cane was recovered during excavations at Dinas Powys in Wales (Alcock 1963, 186–187). There is also evidence for the production and use of millefiori canes in Ireland. Best known are those from Dunmisk, County Tyrone, where five fragments of finished cane were found in association with glass rods and production waste, indicating that they were manufactured there (Henderson and Ivens 1992). Single complete canes have also been found at Lagore, County Meath (Hencken 1950, 127–132) and Garranes, County Cork (Ó’Riordáin 1942, 118–119) and Scotch Street, Armagh (Craddock 1990, 203–204).

## Compositional analysis of the glass

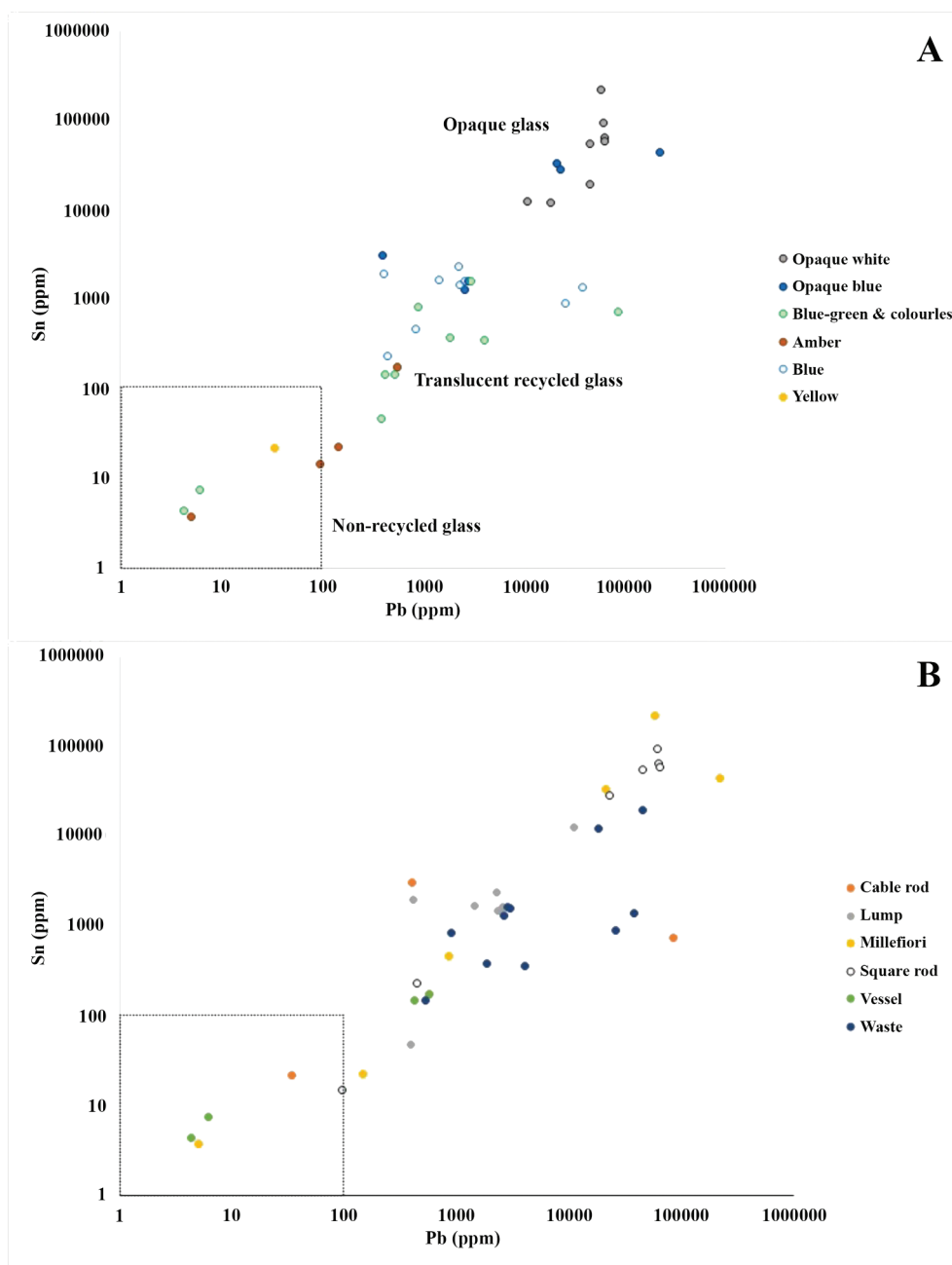
Anglo-Saxon glass is primarily a natron-based glass, generally categorized as either HIMT (high iron, manganese, titanium) (Brill 2006; Freestone and Hughes 2006) or Levantine type (Freestone and Hughes 2006; Paynter, Jennings, and Price 2014; Willmott and Welham 2013). The different compositional groups reflect the origins of their raw materials. For example, in Levantine glasses the local sand geochemistry defines the composition and the ratio of lime to alumina is used to differentiate between the Levantine sub-groups. The presence of heavy minerals (e.g. titanium, zirconium and iron), as well as trace elements such as vanadium and lanthanum further separates the Foy group from the Levantine (I) group (Schibille et al. 2016). Further details on the origins of compositional groupings are provided in Supplementary Appendix 4.

In this period, there is no evidence of primary glass production from raw materials until the tenth century AD. As on the Continent, glassworking relied on recycling glass and/or using cullet (raw glass) traded from the Levant and Egypt (Bertini, Henderson and Chenery 2020; Mirti et al. 2001; Mirti, Lepora and Sagui 2000; Silvestri and Marcante 2011). Such practices are mirrored in ‘recycling markers’ observed as elevated levels of elements, including antimony, lead and copper (Lucas 2023). Repeated recycling (rather than melting fresh cullet) was the dominant practice. It has been suggested as evidence for a shortage of new glass production, possibly due to the restricted availability of the raw materials required (Freestone, Hughes and Stapleton 2008, 42; Govantes-Edwards et al. 2026; Lucas 2023; Paynter, Jennings and Price 2014, 39).

The complexity of Anglo-Saxon glass production in the British Isles is still far from being completely understood, with the insight obtained via compositional study restricted to only a few sites: Wearmouth and Jarrow (Brill 2006; Freestone and Hughes 2006), Glastonbury Abbey (Willmott and Welham 2013), Hamwic (Hunter and Heyworth 1998) and Whitby Abbey and Kirkdale Minster (Paynter, Jennings and Price 2014). Freestone, Hughes and Stapleton (2008) conducted analyses on a selection of Anglo-Saxon vessels from the British Museum. More recently, Sainsbury (2019) compiled published data from other English sites, in addition to undertaking new analysis of material from Dorchester-on-Thames, Oxfordshire and Lyminge, Kent, and Lucas (2023) has added to our understanding of recycling compositions through a study of material from Ipswich, Jarrow and Wearmouth, and Flixborough. Despite these welcome additions, the production of a more refined compositional picture has been significantly hampered by the scarcity of trace-element data.

Quantitative elemental analysis (EMPA) was conducted on a sample of 62 fragments of the Barking glass assemblage (including vessel and waste glass, millefiori, cable, square rods and a range of colours and opacifiers) (see Supplementary Appendix 4). Several fragments were analysed multiple times due to the presence of several different colours, providing a larger dataset ( $n = 74$ ). A separate subset of samples ( $n = 46$ ) was also analysed for trace elements (LA-ICP-MS).

The use of recycled glass at Barking was common, as indicated by elevated levels of a range of elements (e.g. lead > 1000 ppm) (Lucas 2023) in the majority of blue-green or colourless samples (Figure 14). The data also indicate the coexistence of several different glass compositions in the Barking workshop (see Supplementary Appendix 4). Three major compositional groups are present: Levantine I ( $n = 57$ ),



**Figure 14.** Pb vs Sn (ppm) in Barking Abbey glass samples classified by (a) colour and opacification; (b) typology.

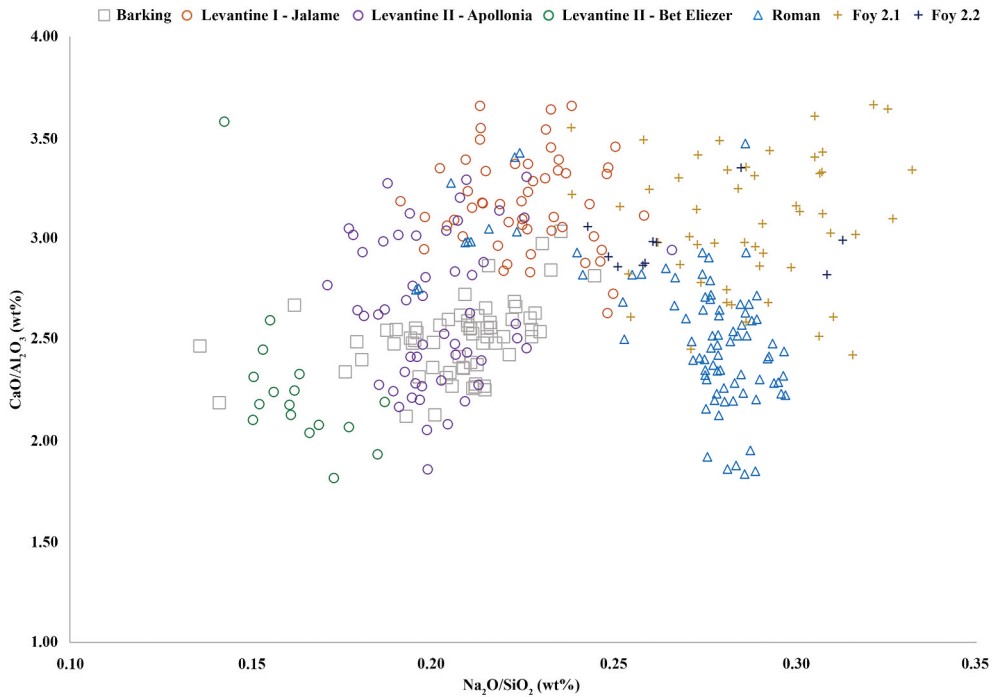
Levantine II ( $n=2$ ) and Foy 2 ( $n=4$ ). Some samples have values that do not fit any known compositions and therefore have been classified as outliers ( $n=11$ ).

The Levantine I glass can be separated into two smaller datasets comparable to the Levantine–Apollonia type ( $n=54$ ) and Levantine–Jalame type ( $n=3$ ). [Table 1](#) and [Figure 15](#) illustrate that the Barking glass is comparable to other known sites of the



**Table 1.** Average compositional values for Barking Abbey glass (Levantine Apollonia, Levantine Jalame, Levantine Bet Eli'ezer, Foy 2). Comparison ranges for each compositional group are also reported (after Brill 1988, 2006 Foy et al. 2003, Paynter, Jennings and Price 2014, Phelps et al. 2016, Schibille et al. 2020). Values are reported in wt%, except for Sr and Zr (ppm). SiO<sub>2</sub> value for Barking Abbey glass has been normalized (see Supplementary Appendix 4).

Compositional Group	Analysis	No. Samples	SiO <sub>2</sub>	Na <sub>2</sub> O	Al <sub>2</sub> O <sub>3</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	MgO	K <sub>2</sub> O	MnO	Sr	Zr
<b>Barking – Levantine (Apollonia)</b>	<b>EMPA/LA-ICP-MS</b>	<b>53/30</b>	<b>71.72</b>	<b>14.89</b>	<b>2.87</b>	<b>7.10</b>	<b>0.65</b>	<b>0.08</b>	<b>0.65</b>	<b>0.75</b>	<b>0.14</b>	<b>394.52</b>	<b>49.18</b>
N1 (Phelps et al. 2016)	LA-ICP-MS	54	71.33	14.31	3.17	8.37	0.48	0.08	0.56	0.62	276.42 (ppm)	498.35	60.35
Jarrow (Brill 2006)	AAS – AES	9	69.45	15.85	2.72	8.44	2.72	0.13	0.95	1.21	0.29	n/a	n/a
Whitby Abbey (Paynter, Jennings and Price 2014)	SEM-EDS	11	69.40	13.73	2.97	6.99	0.69	0.08	0.58	1.86	0.03	n/a	n/a
<b>Barking – Levantine (Jalame)</b>	<b>EMPA/LA-ICP-MS</b>	<b>3/3</b>	<b>69.88</b>	<b>16.48</b>	<b>2.71</b>	<b>7.80</b>	<b>0.78</b>	<b>0.10</b>	<b>0.81</b>	<b>0.94</b>	<b>0.40</b>	<b>442.22</b>	<b>57.98</b>
Levantine Jalame type (Brill 1988)	AAS	52	69.74	15.74	2.74	8.69	0.46	0.09	0.58	0.78	0.63	n/a	n/a
Wearmouth (Brill 2006)	AAS – AES	9	71.55	16.36	2.43	6.91	2.43	0.13	0.82	0.86	0.41	n/a	n/a
<b>Barking – Levantine (Bet Eli'ezer)</b>	<b>EMPA/LA-ICP-MS</b>	<b>2/1</b>	<b>75.14</b>	<b>11.16</b>	<b>2.89</b>	<b>7.40</b>	<b>0.49</b>	<b>0.07</b>	<b>0.66</b>	<b>0.65</b>	<b>0.07</b>	<b>386.00</b>	<b>47.23</b>
N2 (Phelps et al. 2016)	LA-ICP-MS	17	74.64	12.13	3.26	7.36	0.50	0.08	0.51	0.53	192.08 (ppm)	453.46	59.83
Bet Eli'ezer (Phelps et al. 2016)	LA-ICP-MS	5	76.20	11.56	3.32	6.42	0.57	0.10	0.52	0.44	189.48 (ppm)	417.95	59.39
<b>Barking – Foy 2</b>	<b>EMPA/LA-ICP-MS</b>	<b>5/5</b>	<b>70.15</b>	<b>15.79</b>	<b>2.65</b>	<b>6.95</b>	<b>0.77</b>	<b>0.12</b>	<b>0.76</b>	<b>0.70</b>	<b>0.24</b>	<b>379.97</b>	<b>61.20</b>
Foy 2.2 (Foy et al. 2003)	ICP-MS	10	65.91	17.68	2.51	7.44	1.13	0.14	1.00	0.78	1.00	525.00	72.00
Foy 2.2 (Schibille et al. 2020)	LA-ICP-MS	33	67.61	15.75	2.77	7.78	1.00	0.15	1.09	0.97	0.76	448.09	76.81



**Figure 15.** Characterization of barking glass compositions based on  $\text{Na}_2\text{O}/\text{SiO}_2$  and  $\text{CaO}/\text{Al}_2\text{O}_3$  ratios after Brill (1988) and Phelps et al. (2016).

period, suggesting a common influx of raw glass from primary production areas, despite the apparent predominance of recycled material. In the Barking assemblage, the Levantine I Apollonia glasses match glass from Whitby Abbey (Paynter, Jennings and Price 2014) and Glastonbury Abbey (Willmott and Welham 2015). Foy 2 Barking is comparable with Foy 2.2 glass (Foy et al. 2003; Schibille et al. 2020), and Barking Levantine I Jalame is similar to Wearmouth glass (Brill 2006).

The use of opacifiers provides more insight into the glassworking practices occurring at Barking. Analysis has confirmed that tin compounds were primarily used to colour the opaque white glass (see Supplementary Appendix 4). Equally, opaque blue samples contained elevated tin values and were paired with elevated copper values, the latter providing the blue colour. The positive correlation between lead and tin observed in most samples (Figure 15) indicates their introduction via a common raw material. The most convincing hypothesis is that these elements were introduced when small amounts of opaque glass (white or blue) were added to the melt. Tin compounds were commonly used to opacify glass in glass production from the fourth century AD (Tite, Pradell and Shortland 2008). A lead-tin association has also been recorded in white opaque glass from Whitby Abbey and Kirkdale Minster (Paynter, Jennings and Price 2014, 39) and Hamwic (Hunter and Heyworth 1998). The elemental relationships identified here offer

intriguing possibilities for the role of dish-shaped crucibles, given the nature of their glassy residues discussed above.

## Discussion

The excavations at Barking Abbey have produced the most extensive evidence for glassworking found in Anglo-Saxon England to date, and as a result of this study, for the first time, its true significance can be appreciated and its implications assessed. Although the remains of only a single glass furnace are likely to have been fully recognized, the intriguing possibility remains that at least two others might have been encountered in more recent excavations. The one definitive furnace from Barking was better preserved than those previously known from Glastonbury and was subject to more recent and thorough excavation. As a result, we now have a better understanding of the form and operation of an Anglo-Saxon furnace. In particular, the revelation that forced air was used, as indicated by the discovery of a clay tuyère, is significant, as it has implications for the potential temperatures achieved and, thus, the quality of the melt that could be attained. This discovery is complemented by the clay aperture and cover from the now-missing superstructure, demonstrating the furnace's operational sophistication and the glassmakers' ability to carefully control temperatures.

Although highly fragmented, sherds of jar crucibles of a now familiar form and containing blue/green glass indicate that vessels were being blown, and other waste finds demonstrated that these were decorated with plain and cable twist trailing, styles that were popular with a contemporary audience (Broadley 2019, 31–32). Although there is no definitive evidence that window glass was made at Barking, identifying this process is hindered by the lack of distinctive working waste produced during its manufacture. However, given the ecclesiastical context of the furnace, the blowing of cylinder glass at the site must be considered a distinct possibility.

A second type of crucible, a dish-shaped one, was also found at Barking. It is significant to observe that many glassworking sites of this period have been found to contain more than one typological form of crucible. In many cases, this is a combination of dishes or shallow trays paired with a jar or more upright forms. For example, both shallow and taller forms were present among the seventh-century glassworking debris from Maastricht (Saberolles, Henderson and Dijkman 1997, 304). The ninth-century glass workshop at San Vincenzo al Volturno, Italy, contained a range of crucible forms, with half measuring 8–9 cm in diameter, a smaller number of 12–15 cm in diameter and a range of heights averaging 14 cm. This trend continues to be observed in later sites, including finds from Lincoln (Gillmore and Adams 1988), where reappraisal by Bayley (2008) evidenced crucibles for melting blue/green glass and more enigmatic glazed shallow bowls.

Given that the presence of more than one form of crucible related to glassworking practices is not uncommon, how and what different types were used for is often less clear. Evidence for multi-stage processes in glassworking is known to exist at this time. The mid-seventh-century AD Merovingian site of Schleithem, Switzerland, contained a range of glass crucibles that, when analysed, were found to have been used to produce a lead-tin yellow opacifier that was then mixed elsewhere with a colourless soda-lime-

silica glass to make the material for the beads that were also found at the site (Heck, Rehren and Hoffman 2003). The addition of colourants to modify colourless glasses is also observed at some Irish glassworking sites, including crucibles and glassworking debris from the sixth–tenth century AD site at Dunmisk Fort, Ireland (Henderson 1988; 2000, 144). Scientific analysis confirmed that these crucibles had been used to produce opaque yellow glass by adding opacifiers to a low-lead soda-lime-silica glass. The glass was then heated in a crucible for use in either beadmaking or for grinding up for enamel work (Henderson 2000, 144). It is noted that the low melting point of a lead-based glass would have allowed the use of a shallow dish crucible to reheat it. The Pictish monastic site at Tarbat, Scotland, also has a ‘decomposed’ heating dish and indirect evidence of mixing colourless glass with an opacifier to make opaque yellow (Peake and Freestone 2014, 15–18).

While no indication of beadmaking or enamelling was found at Barking, other finds suggest the potential need for different crucible types. The opaque square rods and the complex compound canes they were used to produce are convincing evidence of millefiori production. This identification is supported by the analytical data, which suggest that opaque white and blue glasses were melted to provide further glass for simple working and carefully mixed to produce glasses of a specific colour, such as light blue. This potential range is reflected in the colour palette of the Barking millefiori canes: white, black (in fact, a very dark green), light blue, blue/green and khaki.

Millefiori’s manufacturing at Barking raises further questions about the nature of industrial and craft activity at the site. It is unknown whether the millefiori rods were produced for trade or used on site as decorative insets in metalwork. However, both scenarios demonstrate the interrelated nature of many industrial processes, which is sometimes obscured by compartmentalized typological-based studies. The glassworking activities discussed here were likely just one element in a complex local and national production landscape. Furthermore, this research has highlighted the precise relationship between the early church and the flourishing of specific crafts between the late seventh and early ninth centuries, with a particular focus on glassworking. The revised dating of the furnace to c. AD 730–845 places this activity firmly within a national picture of monastic artistic achievement, which, like Barking’s early monastery, was significantly curtailed by the Viking incursions of the ninth century. Indeed, glassworking of this sophistication and complexity was not to be seen again in England until several centuries after the Norman Conquest, adding further significance and poignancy to this research.

## Acknowledgments

The authors would like to acknowledge all those who supported and contributed to this study. We want to extend special thanks to Leeanne Westwood, Mark Watson and the staff at Valence House Museum for their continued support and for providing access to the Barking Abbey collections and archival material. We are also grateful to have benefited from discussions with members of the Barking Abbey excavation teams, in particular Dr Ken MacGowan, Dr Mike Heyworth and Graham Hull (TVAS), all of whom provided invaluable insight, comments and kind access to original materials. We are particularly grateful to Lyn Blackmore (MOLA) for sharing unpublished data on the ceramics found in association with the glassmaking debris, and we would like to thank Charlene Parrish (Bournemouth University) for her valuable contribution to the initial artefactual phases of the research. A Bournemouth University research grant

supported visits to the Valence House Museum and the Barking Abbey archive. The compositional analyses presented in Appendix 4 form part of doctoral research funded by the Arts and Humanities Research Council of Great Britain (AHRC; award 1524974) to Camilla Bertini. The LA-ICP-MS analyses were made possible through support from the joint British Geological Survey–University of Nottingham Centre for Environmental Geochemistry. Dr Bertini is especially grateful to Dr Simon Chenery (British Geological Survey) for his guidance and assistance. All errors and omissions are the authors' own.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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