Frontispiece: Bickerstaffe glass furnace site showing the depression containing the hearth stones, see page 4 and cf. Fig. 4A viewed from the top.

EXCAVATIONS AT THE *c*1600 BICKERSTAFFE GLASSHOUSE, LANCASHIRE

Ruth Hurst Vose

Summary

The remains of a late 16th to early 17th century wood-fired glass furnace were excavated in Glass Hey Field, Hall Lane, Bickerstaffe, Lancashire (SD 441036) in 1968-69 by the Pilkington Glass Museum, St Helens, Merseyside. The foundations of a main furnace were uncovered, sufficient to suggest a small furnace built to the traditional English rectangular design with parallel sieges running alongside a central hearth. No other evidence of furnace structures was found, and as the natural clay was burnt red in only one area, it is probable that any subsidiary furnaces were attached to the main furnace, deriving their heat from it. Large roughly dressed sandstone slabs were still positioned beneath what had been the central hearth, but the rest of the structure had been destroyed and scattered by years of ploughing. A line of original demolition running from the western end of the hearth beneath the ploughed topsoil, perhaps representing debris raked out from the furnace, consisted of pieces of green-glazed sandstone from the furnace's original interior, hand-made red clay bricks, and a quantity of charcoal from the final firing as well as crucible and glass fragments, including a complete crucible base. The debris line disappeared near a circular 'dump' of the same materials. Crucibles (glass-making pots) were of open round bucket-shape with mainly straight rims. Glass fragments suggested that both broad (cylinder) flat glass and vessel glass were produced, the majority green-tinted, the vessel glass having moulded and applied furnace decoration typical of the products of French Huguenot glass-makers who had emigrated to England from the 1560s, and who at this period were working mainly in the Weald and Staffordshire. A short glossary of glass terms is included on page 24.

Historical background

The only documentary background to the Bickerstaffe glasshouse so far found is a single entry in the Ormskirk Parish Register. This records on 10 December 1600: "A stranger slayne by one of the glassemen beinge A ffrenchman then working at Bycerstaff and buried". As there are no births, marriages or deaths or any other legal disputes recorded concerning French glass-makers in this area, this murder amongst strangers and foreigners in a remote rural community suggests the glass-makers quickly removed themselves from the scene of the crime. This would tie in with the archaeological evidence for only one small furnace operating in the vicinity with no sign of any other main or subsidiary furnaces built nearby. The life of a wood-fired furnace was seldom longer than two to three years (Scoville 1950, 37). The 1841 Tithe Commutation and Award Map for Lancashire had only one field name suggesting glass-making, which was Glass Hey Field adjacent to Hall Lane, presently belonging to Bickerstaffe Hall Farm, and it was on this field that the glasshouse remains were found.

Henry Stanley of Little Hall in Aughton and Cross Hall in Lathom was a younger son of Sir James Stanley, marshal of Ireland in the time of Henry VIII and brother to the second earl of Derby. He acquired Bickerstaffe when he married Margaret Stanley in 1563, and upon his death in 1598, it was inherited by his eldest son Edward, who was created a baronet by Charles I in 1627, and was buried at Ormskirk in 1640. In 1590 Henry Stanley of Bickerstaffe was reported as among the "more usual comers to church, but not communicants", and the Stanleys soon afterwards seem to have conformed entirely and do not appear on the recusant rolls (Farrer and Brownbill 1966, 278). Huguenot glass-makers would hence have been acceptable in religious terms upon Bickerstaffe property. Bickerstaffe Hall, less than half a mile away from the glasshouse, was a shooting box of the Earl of Derby. The fifth baronet, Sir Edward Stanley who became the eleventh Earl of Derby, married Elizabeth Hesketh of Rufford in 1714 and brought up their children in Bickerstaffe Hall and Patten House, Preston (Bagley 1985, 133).

A local inventory for a deceased Ormskirk yeoman dated 1601 confirms that both window glass and drinking glasses were utilised in one of the more wealthy local households at the time. A list of Rauffe Roose's goods and chattels included:

"glass in the parlor windowe	
fyve foote at 4 1/2d	1s 10d
glass in the new chamber	
4 foote & halfe at 4 1/2d	1s 8d
in the clossett 2 foote	9d
in the parlor and the backe syde	
in glass 17 foote	6s 8 1/2d
14 glasses & tenne earthen pottes	2s 0d"

(Inventory of the goods of Rauffe Roose, 20 June 1601)

In 1612 the following items were included in the inventory of shopwares of an Ormskirk chapman, indicating the variety of glasswares available at the time, although spectacle glass would not have been produced at the Bickerstaffe glasshouse:

"2 dosenn of spectakles & cases with the box	13s 3d
2 grosse & a halffe of glasse buttons	10d"

(Inventory of the goods of Rauffe Burnestone Chapman of Ormskirk, 22 April 1612)

References to glaziers and glassmen seem to indicate a brisk trade in glass in the north-west of England immediately prior to the Royal Proclamation of 1615, which forbade the use of wood fuel for glass-making, but these terms were more likely to be applied to dealers in glassware rather than glass-makers (Barker 1977, 7). Bickerstaffe provides the only definite reference to glass-makers in Lancashire at the turn of the century, although a few years later in 1615 the Lorraine Huguenot De Houx family of glass-makers were working under licence from Sir Robert Mansell at the Haughton Green glasshouse, near Denton, in the valley of the River Tame, south-east Manchester, and were joined around 1619/20 by the Pilmey family, also from Lorraine (Vose forthcoming). Haughton Green was a coal-fired glasshouse, but the vessel glass products were very similar to those of Bickerstaffe being of typical 'forest glass' design, and it could be conjectured that either of these families could have worked at Bickerstaffe before moving on to Manchester. The probable use of salt as an alkali in both Bickerstaffe and Haughton Green glass suggests a possible link between the two (see Bickerstaffe Glass Composition, page 16).

A Huguenot family which took the English name of Leaf apparently owned a glasshouse at Warrington, Cheshire from about 1650, and in 1688 leased a property which had an existing glasshouse probably situated at what is now known as Glasshouse Farm near Eltonhead Hall, Sutton, to the south of St Helens, Merseyside (Harris 1968, 106-110). John Houghton's list of glasshouses mentions only two in the Lancashire area: one in Warrington which made window glass, and one near Liverpool which made 'flint, green and ordinary' glass (Houghton 1696). Glass-making only reappeared in the locality of Bickerstaffe during the first half of the eighteenth century when glass was blown near Ormskirk as well as at Prescot and Thatto Heath (Jarvis 1941-42, 144).

Only one other field name suggests that an early glasshouse might have been operating in the south-west Lancashire, now Merseyside area, and that is Glasshouse Close near Carr Mill Dam to the north-east of St Helens, but no further evidence to corroborate this has yet been found (Barker 1977, 7).

Resources

The Bickerstaffe glasshouse was situated in an area once covered by Simonswood Forest, and resembles the remote woodlands and spacious countryside of Lorraine in France, from where Huguenot glass-makers emigrated to England from the 1560s. The French glass-makers would have been attracted not only to the woodland as a ready source of fuel, but also to the deposits of Shirdley Hill sand which run under much of Bickerstaffe soil, and have provided sand to glass-makers, particularly to Pilkington Brothers of the town of St Helens nearby, up to the 1970s. The Bickerstaffe glasshouse was based close to these deposits which are well suited for glass-making because of their low iron oxide content. Fireclay for the crucibles could have been locally obtained or brought in from Stourbridge. Christopher Merret, translator of Antonio Neri's *The Art of Glass* stated that clays from Worcestershire as well as Nonsuch in Sussex were generally used for pot-making (Neri 1662). Stourbridge clay subsequently came into widespread use in Britain for glass-making, and it is worth noting that immigrant French glass-making families were based in Worcestershire and Staffordshire at the same time as the Bickerstaffe glasshouse was in operation (See also Raw Materials for the Bickerstaffe Glasshouse, pages 18-21).

The excavations

Siting (Figs. 1-2)

The Bickerstaffe glasshouse site lies six and a half kilometres from the ancient market town of Ormskirk, four kilometres from Rainford, an important clay-pipe making centre *c*1650-1750, and eleven kilometres from St Helens, which became one of the most important flat glass-making centres in Britain from the 1770s. Situated on the south-west Lancashire plain, the black soils of Bickerstaffe are of high agricultural value, and Glass Hey field adjacent to Hall Lane where the glasshouse was found, is flat open arable farmland with a small pond approximately half way down its northern boundary. The site was found roughly half way between Hall Lane and the pond area on a slight rise in the ground.

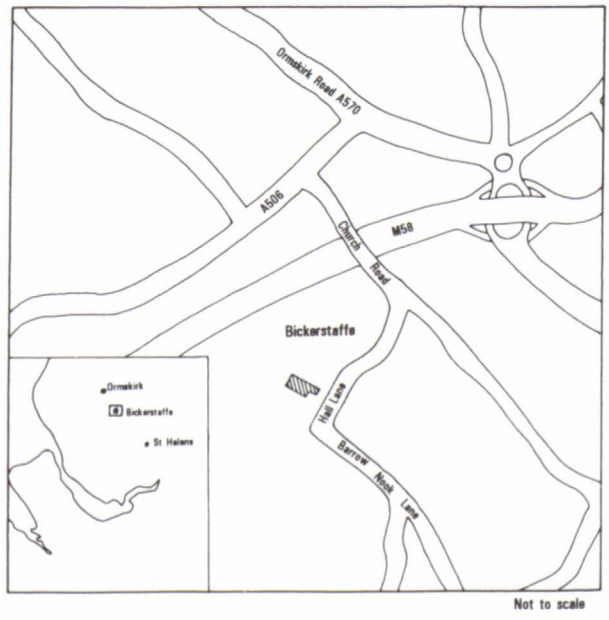


Figure 1: Location of the glasshouse in Bickerstaffe, West Lancashire. Inset: general location map

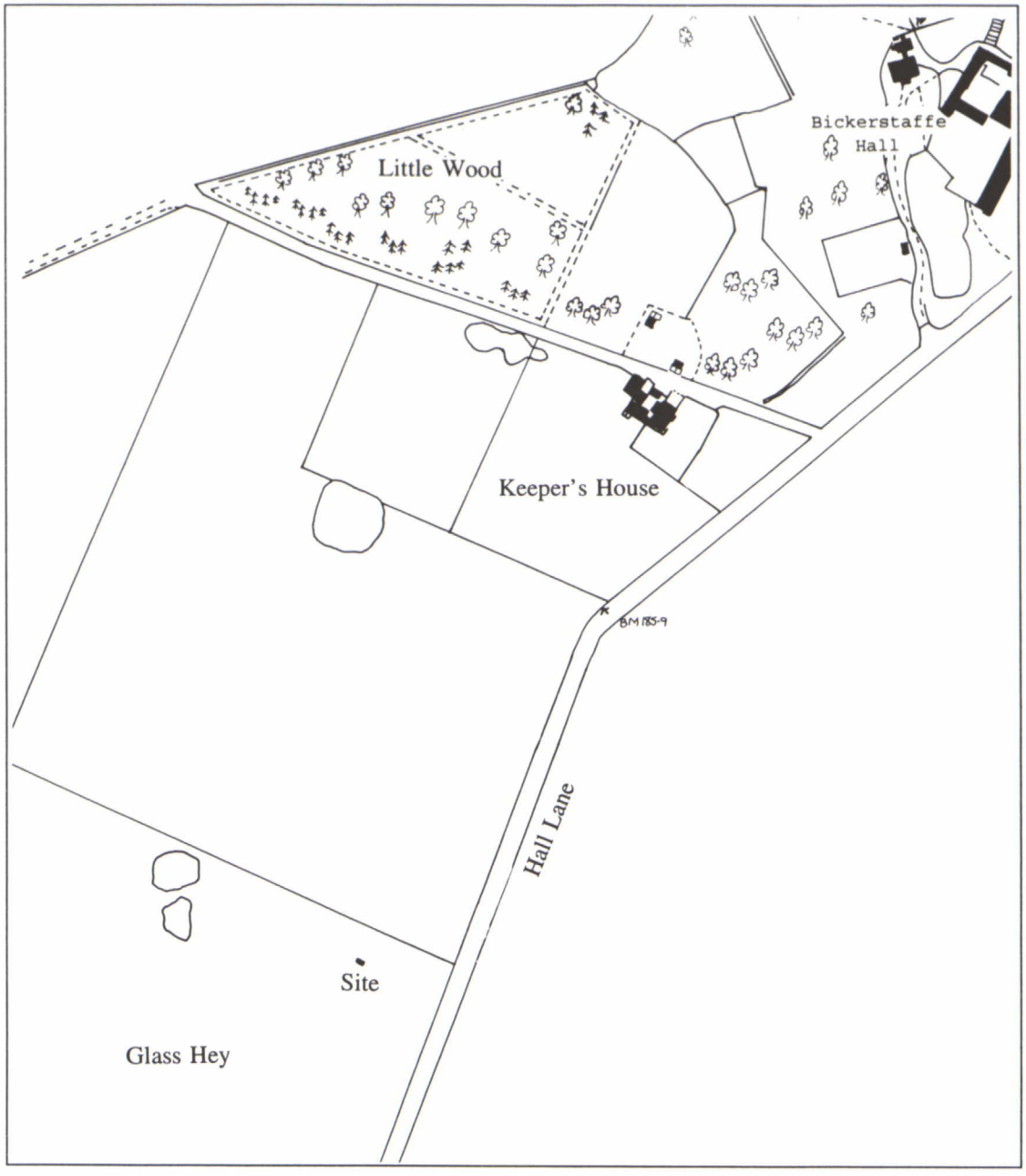


Figure 2: Bickerstaffe glasshouse site based on Ordnance Survey 1955 edition, Sheet SD 40 SW, 6 inches to 1 mile

In 1966 Mr David Pilkington of Pilkington Plc requested the Pilkington Glass Museum of St Helens to locate and excavate the glasshouse which was mentioned in the Ormskirk parish register in 1600. A search of the local records gleaned no further information, apart from the field name 'Glass Hey' in Hall Lane, Bickerstaffe (see Historical Background). An examination of aerial photographs supplied by the then Ministry of Housing and Local Government in October 1966, specifically Sortie No 106G/UK/623, Print No 3287 taken 10 August 1945 which clearly shows Glass Hey field, revealed no crop marks or other indications where the glasshouse site might have been located. Glass Hey field was walked several times without finding evidence of glass-making. However in January 1968 after a hard frost, crucible fragments, glazed sandstone and green-tinted cullet (glass waste) were found in an area about 50 yards square (41.8 sq. m.) between Hall Lane and the field pond. Glass fragments included a milled edge base and an example of chequered spiral trail decoration similar to the finest Weald glass of the late 16th or early 17th centuries. Crucible sherds indicated an open bucket shape consistent with the technology of the period and

indicating a wood-fired furnace, hence prior to the 1615 Royal Proclamation forbidding wood fuel to glass-makers.

On 9 June 1968 Dr Patrick Strange of the Department of Electrical and Electronic Engineering, University of Nottingham, conducted a proton magnetometer survey of the area where the glasshouse material had been scattered. The readings pinpointed a spot approximately 3m (10 ft) x 1.5m (5 ft) on a slight mound in the field between the pond and lane, see page 22)

Excavations of this area then took place at weekends between 9 November - 1 December 1968; 3 - 25 May 1969; and early August 1969. Final measurements on the position of the furnace were taken on 4 April 1970. Imperial measurements were in use at the time of excavation.

First stage—trial trenches A-J: Location of the furnace area (Fig. 3)

Initially a rectangle was staked out, 28.2m (92.5ft) west from Hall Lane gateway to Glass Hey field, and measuring 76.2x54.1m (250x177.5ft) around the location pinpointed by the proton magnetometer survey. The survey had identified an area of high magnetic intensity approximately 3x1.5m (10x5ft), 51m (167ft) from Hall Lane and 19.8m (65ft) south of the cart road which ran along the north side of the field. Volunteers numbered A-J walked the rectangle and collected surface glasshouse finds distributed by ploughing. 'A' began at the corner nearest to Hall Lane, 'J' the furthest, the volunteers walking north/south.

Three 1.8m (6ft) square trenches (A-C) were then dropped, A and B directly over the area identified by the proton magnetometer, and C a small distance away. About 30-45cm of ploughed black sandy topsoil with stones, brick and household debris brought in by manure spreading (1), consistent over the whole site, was then removed down to the natural clay. Trench C although containing crucible and green glass fragments in its topsoil proved negative apart from finding a field drain covered by a line of flat stones. However fragmented reddened sandstone and red burnt soil and clay were immediately found under the ploughing in Trenches A and B. Further trenches (Extension A, D-J) were gradually added, creating an area approximately 7.8m (25.5ft) long and 3-4.8m (10-16ft) wide (Fig. 3). By the end of the 1968 investigations, the area of bright red burnt earth and stones was fully exposed measuring 3.2x2m (10.5x6.5ft) confirming the proton magnetometer survey results. Crucible fragments were found in the red layer. Topsoil (1) immediately over the reddened area (Trenches B,D,F) contained markedly more green glass waste fragments than elsewhere.

Shallow parallel channels running north to south through the clay and reddened area were the result of deep ploughing. A field drain (2) also running in a north/south direction lay 1.5m away from the west side of the reddened area.

A mound of reddened earth and stones with small charcoal pieces continuing west of the main bright red burnt area, lay over what was later identified as a line of debris probably raked out of the westerly end of the furnace (3). Also associated with this was a large piece of green glazed sandstone found close to the field drain (2).

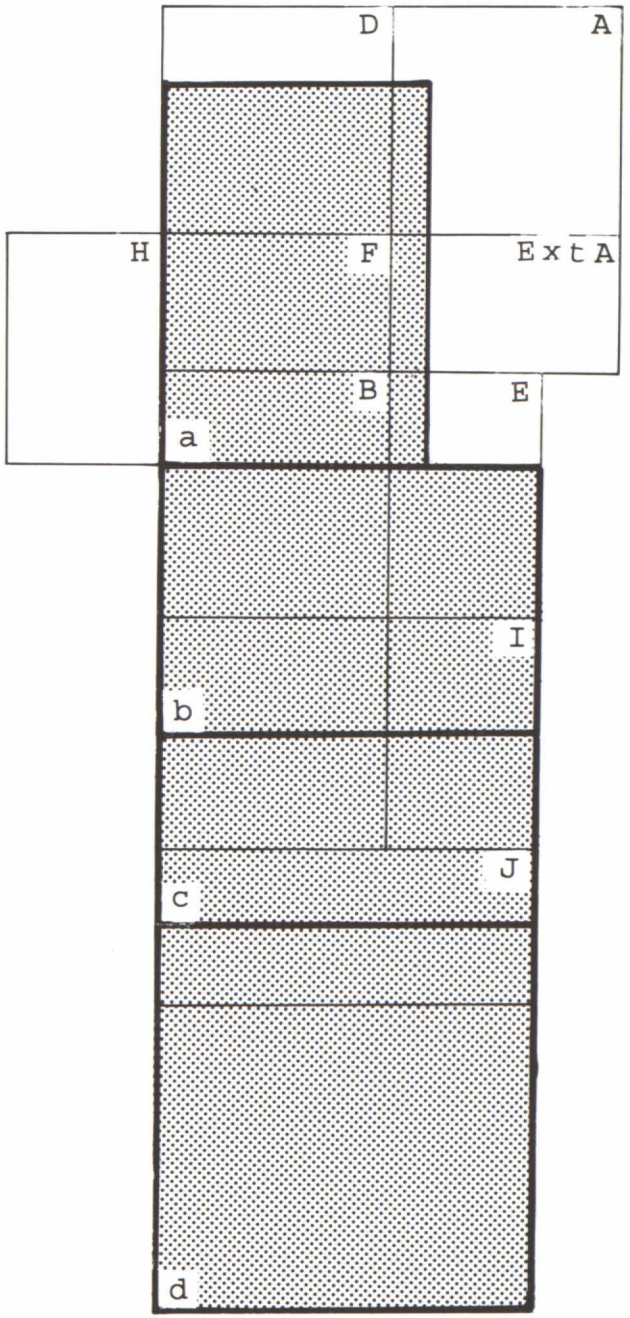
Second stage—extension of the site (Trenches a-d) and location of debris line and waste dump (Figs. 3-4)

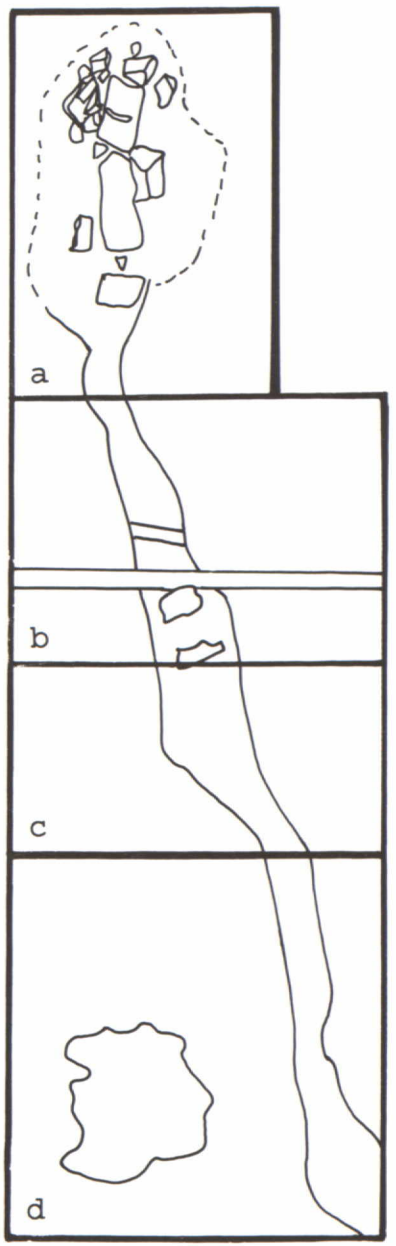
To limit the confusion of trenches in the previous year, it was decided to create three areas 'a-c' over previous excavations, and a new additional 3m (10ft) square trench 'd' on the westerly side of area 'c' (Fig. 3).

Bright red burnt earth and fragmented burnt sandstone, rubble and brick (3) was removed from the furnace area 'a', creating a depression lower than the surrounding natural clay level in which rested a line of large roughly square or rectangular shaped sandstone slabs burnt to a dull red (4). Too low to have been disturbed by ploughing, they represented the only evidence in situ of furnace construction, and almost certainly can be interpreted as the foundations of the hearth. Prevailing winds on the south west Lancashire plain are westerly, and it would appear the glass-makers were making use of this when they placed the hearth line more or less in the direction of the prevailing winds creating a good air flow to burn the wood. The slightly higher burnt clay and rubble at either side of the depression containing the hearth stones suggest where the sieges were situated (Fig. 4A; Frontispiece).

Initially, darker soil going in a westerly direction gave the first indication of a debris or demolition line (3) coming from the furnace area. The line, originating from the west end of the reddened stone slabs tapered into the newly excavated area 'd', passing close to a circular 'dump' approximately 1-1.2m (3.5-4ft) diameter containing broken red brick, sandstone, glass waste and crucible fragments, which lay 4.9m (16ft) from the furnace site (Fig. 4B).

The debris or demolition line appeared to have been raked out of the furnace hearth end (teasehole), either during the life of the furnace or at its destruction. The debris line contained many small pieces of green glazed and unglazed sandstone, green glass and crucible fragments, hand-made rectangular shaped red clay bricks, some partially glazed, and most importantly a large quantity of charcoal throughout, many in large pieces, providing ample evidence of the fuel used by the glass-makers, comprising hazel (33 pieces), oak (28 pieces) and birch wood (12 pieces), see page 22. No complete red clay bricks were found, but of those remaining, end measurements were 6/7cm x 10/11cm, the longest piece being 13cm.





A

B

1968 Trench layout (A-J)

1969 Trench layout (a-d)

1cm = 2ft

Figure 4A: Bickerstaffe excavations, detailed plan of A (top part of Fig. 3), scale divisions = 15mm.

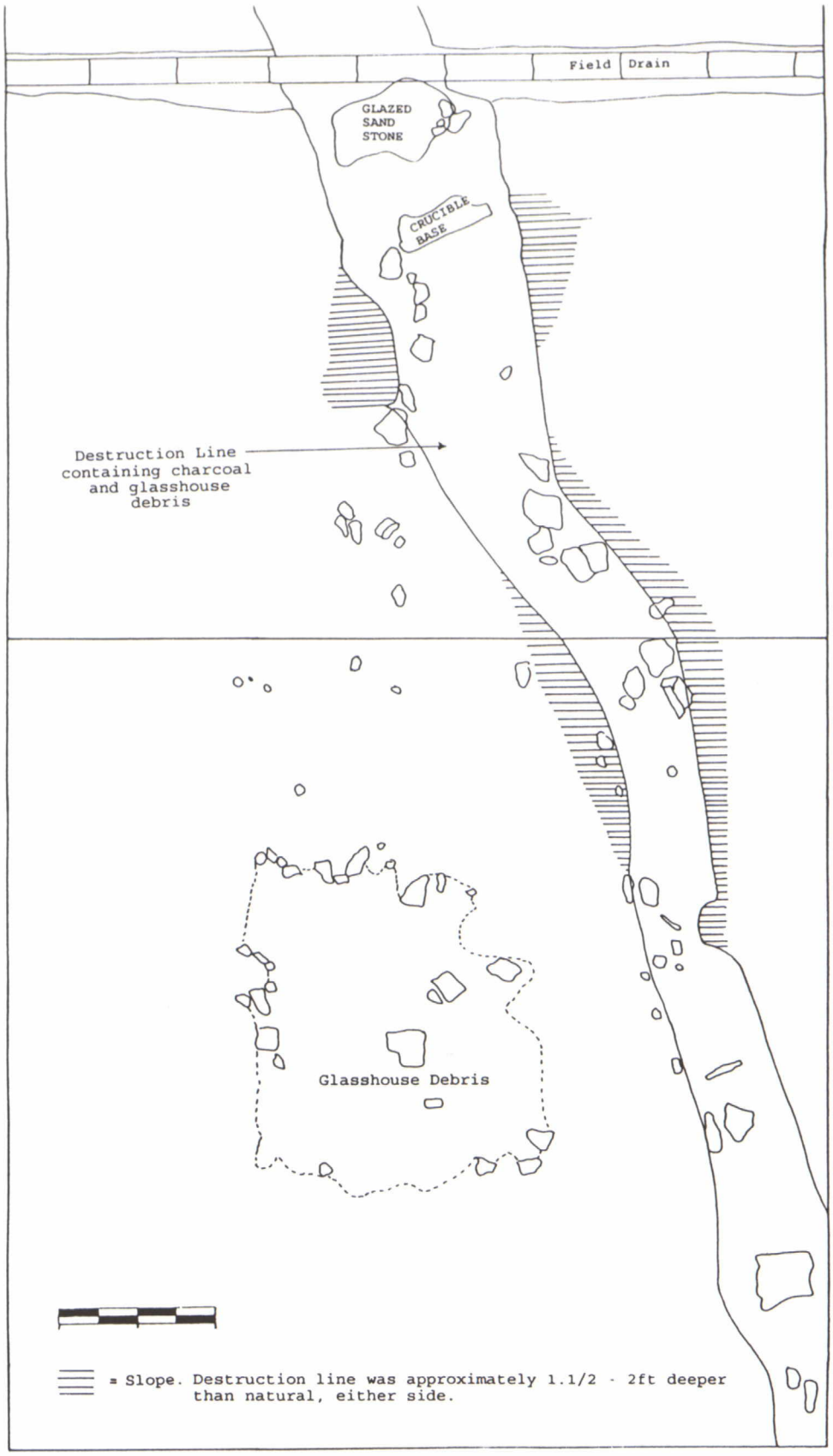


Figure 4B: Bickerstaffe excavations, detailed plan of B (bottom part of Fig. 3), scale divisions = 15mm.

A second field drain was found 9in away and at a lower level than the first (2) dug into the natural brown clay (5), both cutting through the debris line (3). Almost adjacent and west of the drains, but fortunately untouched by them, a complete crucible base (Figs. 4A, 4B, was found resting on its side in the debris line (8) beside a large lump of green glazed sandstone from the furnace interior.

The debris line was removed, leaving a channel in the natural clay which tapered away into the corner of Trench d. The reddened sandstone slabs were lifted to reveal a shallow layer of slightly reddened natural clay and soil beneath which soon reverted back to its normal unburnt colouring. The slabs were put back into their original positions and the site backfilled in 1970. One example 7.5-8cm thick was retained.

Apart from observing that sandstone and red clay bricks formed part of the furnace structure, no further clues were found regarding its construction. What little of the foundations remained suggested the common English rectangular pattern of furnace plan with parallel sieges running either side of a central hearth, which appears to have been the rule from at latest the fourteenth century (Charleston 1978, 23; Vose 1980, 134-43). Any subsidiary furnaces for annealing, fritting, pot arching, and so on, were presumably attached to the main furnace since no other areas subjected to heat were picked out by the proton magnetometer survey in its vicinity. This is in line with the design of northern European furnaces at this period (Charleston 1978, 22). There are no contemporary illustrations of English forest glasshouse sites, but a 15th century drawing of a Bohemian wood-fired glasshouse gives an indication of the main features (Vose 1980, 62, Fig. 5).

The Bickerstaffe finds and archive are now on permanent deposit at Liverpool Museum.

The glass

With significant contexts reduced to a single demolition (3) and construction (4) phase, the vast majority of glass finds dating from the period the glasshouse was in operation were surface finds or from the very disturbed ploughed soil (1) which covered the site. The problems of assessing whether vessel, bottle and flat glass sherds were actually made on site or were imported cullet is ever present at this period. The danger that badly made or discarded items will be over-represented, and the probability that the fragments found may not fully reflect the range of glass produced again contributes to the difficulties in assessing manufacturing patterns (Crossley 1987, 355).

However the 18.58kg of manufacturing waste, i.e. cuttings, shearings, drips, pontil knock-offs and glass lumps firmly established that glass in a variety of green tints from clear pale green to deep amber or completely opaque 'black' glass was produced on site. Of the total, 17.24kg were tinted green, and 1.34kg were 'black' opaque. The green and amber tints were not intentional but a result of impurities in the raw materials used by the glass-makers. It is very doubtful that the black opaque glass was intentionally produced as at the later Haughton Green glasshouse (*c*1615-53) similarly manned by French glass-makers in south-east Manchester (Vose forthcoming), but was the result of an excess of metallic oxides in the raw materials. No black/amber glass was found adhering to any of the crucible fragments, which would be the only absolute proof that such glass was made on site.

In addition to the furnace waste, 1,216 glass sherds were recorded, 969 from clear green vessels, 184 flat glass sherds, 34 amber/black vessels and 29 sherds dating later than the glasshouse period. These were cleaned, marked and bagged according to type.

Green vessel glass (Table 1, Figs. 5-7)

Ninety seven per cent of glass finds were of vessel, bottle and other utility items, indicating that the Bickerstaffe glasshouse was primarily if not completely concerned with the production of vessel glass. It is worth noting that of the many French glass-making families from Lorraine, the production of tableware and other small items (*petit* or *menu verre*) was the province of the families of du Houx, Massey, Bigault, Bonny and Finance (Murdoch 1985, 265). Fifteen years after the murder by a Frenchman at Bickerstaffe was recorded, Isaac du Houx was running the Haughton Green glasshouse only 50km away, producing similar vessel and container products, where legal action to enforce members of the glasshouse to keep the peace occurred on at least two occasions (Vose forthcoming). As this is the closest reference to other French glass-makers in the area one cannot rule out that the du Houx family might have first worked at Bickerstaffe before moving on to Haughton Green and elsewhere, and the glass analysis from both sites appears to support this (see Glass Composition, page 16).

The vessel glass forms found at Bickerstaffe were common to those found on wood-fired glasshouse sites run by French immigrants in England from 1567 to just after 1615, such as Hutton and Rosedale, North Yorkshire dating from the late 16th century (Charleston 1972, 128-150). The forms persisted past the mid-17th century at the early coal-fired glasshouses at Kimmeridge, Dorset, 1618-23 (Crossley 1987, 355-363), and at Haughton Green, Denton, Greater Manchester, *c*1615-53 (Vose forthcoming). A full discussion of forest glass vessel types is given by Charleston (Charleston 1984, 86-93).

G.H. Kenyon originally divided the Wealden glass industry into two phases, Early (1330-1567), when he claimed methods were primitive, with poor quality glass and a limited range of products, and Late (1567-1618), where he maintained methods, quality and range

showed a noticeable improvement, due probably to Jean Carré's imported French glass-makers and their descendants (Kenyon 1967, 16-17). Kenyon stated that in his opinion the Bickerstaffe glass by Wealden standards is from its feel and appearance, undoubtedly Late and probably late Late. The most interesting fragment with chequered spiral trail decoration (Fig. 6:13) is similar to the finest Weald glass and might be as tough as the Woodchester glass (Personal communication, February 1968).

Kenyon describes Late glass 'at its best indistinguishable from modern glass, mostly hard with a sharp fracture, fairly clear, dark blue-green with a burnished surface which is seldom corroded, and much more uniform in appearance than the earlier, poorer glass' (Kenyon 1967, 17). Apart from analysis, a proportion of the Bickerstaffe glass will remain doubtful as to whether it is genuinely *c*1600 or of later date since the fragments are generally so small and damaged by constant agricultural earth movement. Many glass fragments were weathered with a flaking iridescent surface, but in general the metal was sound and of reasonably robust quality consistent with its dating.

A study of vessel base equivalents (EVE) was undertaken (Table 1) despite the paucity of fragments found in significant contexts, since the site was apparently of a single furnace in use for a limited time, and most finds were the result of several field walks over the area immediately surrounding the furnace, and are therefore worthy of assessment. The overall results indicated that 43% of EVE's were from storage vessels, and 57% from drinking vessels. The bases of all plain, nearly straight-sided cylindrical vessels were included in the storage vessel total, but as these were usually indistinguishable from either beaker or bottle form, the 8.5% they represent could be placed in either category.

Storage vessels (Fig. 5:1 and 2)

No complete bottles or bottle profiles were found. Due to the small number of finds, an analysis of vessel base equivalents of storage vessel sherds was not too meaningful, but can be scanned in Table 1. For instance three fragments suggested a small square based bottle form; however two sherds were possibly the result of heat distortion, while the remaining fragmentary sherd hardly established production. A further single base sherd may have been from a square or five-sided bottle. As previously stated base fragments from plain beakers are indistinguishable from bottles and have been classified together. Ten base sherds with shallow kick but no walls were either from bottles or beakers. Eleven base sherds with evidence of a shallow kick and probably plain cylindrical walls 1-2mm thick, varied between 4cm and 9cm diameter, and were also from bottles or beakers. Eleven body sherds apparently from plain cylindrical or bulbous forms bore scratches on one surface only resembling diamond point engraving, as did two rim fragments from cylindrical beakers of 6cm diameter (see Newton's study, Newton 1981, 355-67). Evidence for furnace decoration by the glass-maker for these forms was confined to two sherds, one, 5cm diameter, with moulded vertical rib decoration, and the other, 7cm diameter, the fragment too small to distinguish the moulded pattern. Plain bulbous bottles or flasks were represented by seven base sherds with shallow kick, between 4.5cm and 7cm diameter with walls 2mm thick (Fig. 5:1). Only one example of a plain oval flask was found (Fig. 5:2), base diameter 6.5cm. Four fragments probably from thin walled bottle necks, possibly of the short everted rim type, 1-2mm thick, were between 1.2cm to 2cm diameter. Twenty six comparatively thick walled sherds, mainly 3-5mm, with diameters 2-3cm, were classified as elongated bottle necks. However some may possibly have come from later English wine bottle types with the smallness and worn appearance of sherds making it impossible to be sure. Two sherds may even be pontil knock-offs, waste glass knocked from the end of the glass-maker's pontil, roughly resembling part of a bottle neck. Nineteen small sherds from broad flattened rims belonging to urinals, jars or even dishes, with characteristic rounded edges (*c*2mm) slightly thicker than the walls (1-2mm), varied in diameter from 4cm to 20cm.

Two hundred and fifty-five small body sherds probably from plain cylindrical forms with an average thickness of between 1-2mm, the thickest being 3mm were found, as well as 49 small body sherds probably from plain bulbous forms, again varying in thickness from 1-3mm. 58 sherds from much heavier vessels or containers, average thickness between 5-9mm, could in many cases be from 17th or 18th century English wine bottle forms, although colour and weathering resemble the glasshouse products. 107 other sherds were too tiny or distorted for definite identification as to product.

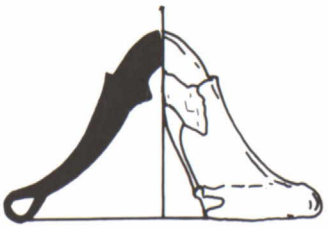
Drinking Vessels (Figs. 5 and 6:3-19)

No complete vessels or even a full vessel profile were found among the many small fragments. Vessel base equivalents suggested that 60% of drinking vessels were wine glasses, 13.85% were beakers with applied foot ring, 13.5% beakers with folded foot and low kick, 10.18% beakers with folded foot and high kick, and 2.17% the latter with moulded decoration. Any decoration of drinking vessels was typically confined to the furnace techniques of moulded and applied decoration common to these forest sites. Moulded patterns such as ribbing were produced by blowing a glass bubble into a mould. Applied decoration was done by applying hot metal (glass) onto the surface of a vessel usually in the form of trails, blobs or prunts.

Fifty-six fragments from beakers with low pushed-in or folded bases were sufficient to indicate production (Fig. 5:4), diameters ranging from 7cm to 11cm. Twenty-eight fragments were from vessels with folded feet with a high kick (Fig. 5:3), diameters ranging from 4cm to 9cm. One example of 8cm diameter had moulded decoration (Fig. 5:5). Seven examples of beakers with shallow kick had applied foot-rings, being a single trail

1

2



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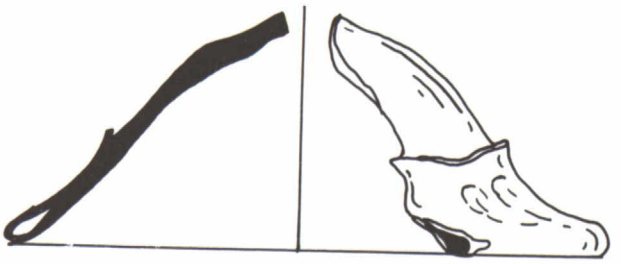

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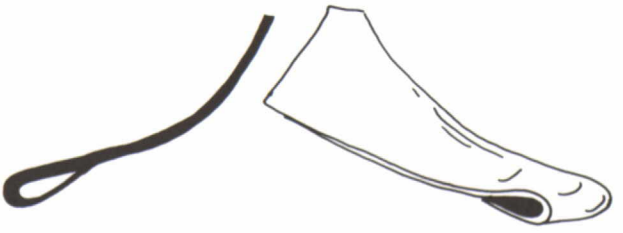

8

Figure 5: Glass vessels, nos 1-8, scale: 1:1

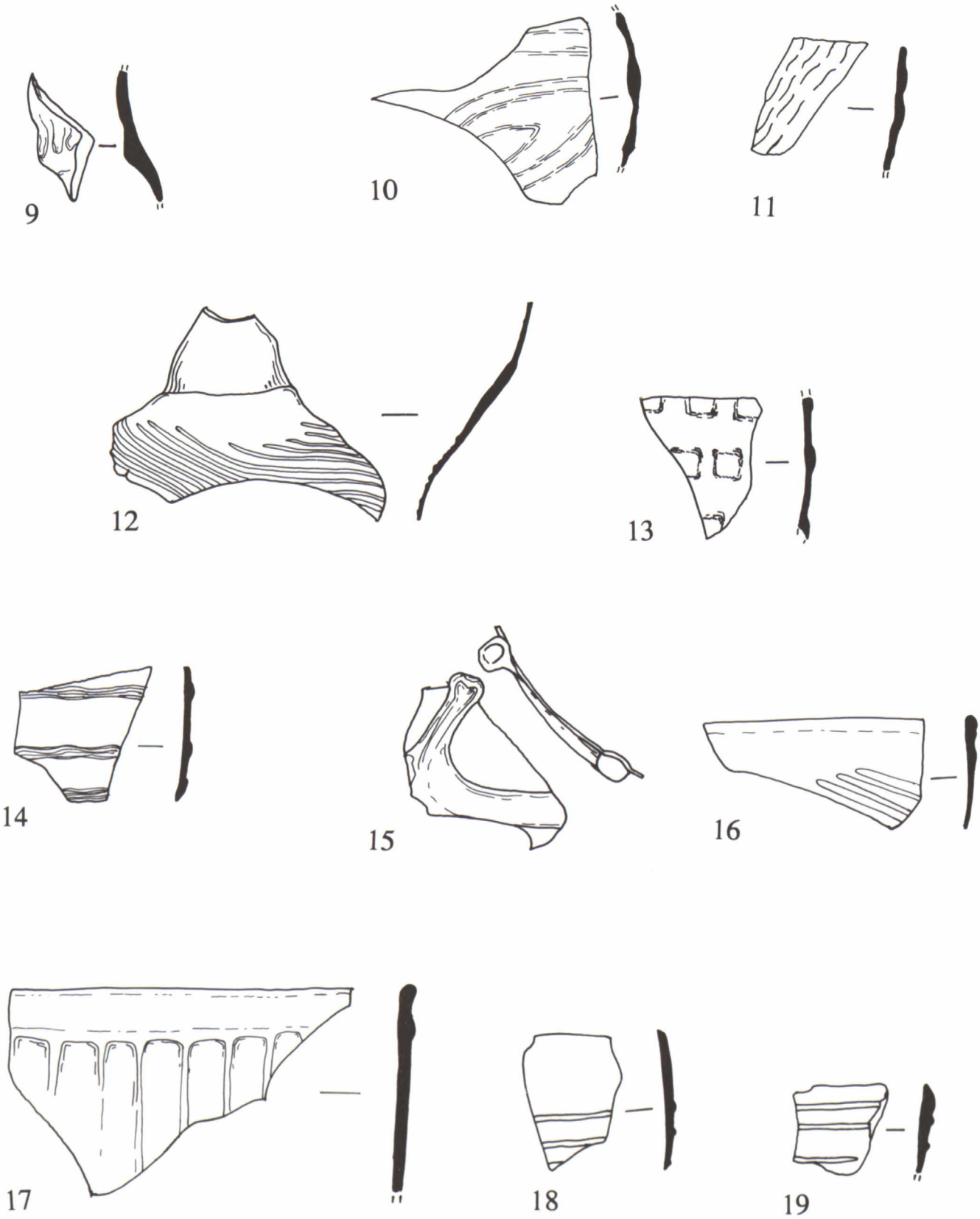

Figure 6: Glass vessels, nos 9-19, scale: 1:1

decorated with rigaree i.e. impressed by a wheel making a pattern of parallel notches, also referred to as a milled edge trail. Other examples have been found on sites including Woodchester, Gloucestershire (Daniels 1950), St. Weonard's, Hereford and Worcester (Bridgewater, 1963), Hutton, North Yorkshire, and the Weald. Three examples also had moulded ribbed decoration under the base which also extended into the body of the cylindrical glass in two cases (Fig. 5:6). Base diameters ranged from 6cm to 8cm.

Wineglasses with folded feet, bases sloping up to a moulded knop then flaring out into the bowl shape were well represented. These occur on Lorrainer sites and are the equivalent of *façon de Venise* or Venetian style glass produced in green forest metal. Examples have been found on such sites as Sidney Wood, Alfold, Surrey (Wood 1982), Rosedale, North Yorkshire and Haughton Green, Greater Manchester. Fifty fragments from folded wineglass bases and a further ten from bases without rim were found. 39 of these had diameters between 7-9cm, the three smallest 5-6cm, and the three largest 11-11.5cm (Fig. 5:8). Nine fragments from plain hollow knops, two heat distorted, were identified, diameters at the widest point of the knop between 2cm and 3cm (Fig. 5:7). A further fragment with moulded rib decoration may have been from a knop or could be glass waste.

Of the 22 body sherds decorated with moulded patterns, 15 had either vertical or spiral ribbing. Vertical ribbing on an angled sherd could be from the bottom curve of a wine glass bowl (Fig. 6:9). A heat distorted fragment where a second gather of glass bears very narrow spiral ribbing (Fig. 6:12) suggests little inflation had taken place since the glass had been twisted and removed from the vertical rib mould, then discarded by the glass-maker. Three examples of lozenge trellis pattern could be distinguished, one very elongated through extra inflation (Fig. 6:10). Only one example of a rarer pattern resembling basketweave in appearance was found (Fig 6:11), where a hot bubble already bearing spiral ribbed decoration had probably been placed again in the vertical rib mould to produce indentations across the ribbing. Thickness of body sherds was again generally 1-2mm.

Applied decoration appeared on 15 sherds, although one was doubtful, the 'thread' marks being the result of deterioration in the ground. In four cases a fine thread of hot glass had been trailed onto the vessel in one continuous line while rotating the vessel on the pontil rod on the glass-maker's chair making horizontal lines irregularly spaced. Two small sherds had thicker trailing which had been flattened once applied to the vessel. In once case the threads had been given indentations by inserting the vessel while still hot in the vertical rib mould (Fig. 6:14). Splendid looped decoration applied to a more rounded or bulbous vessel form was found on three sherds (Fig. 6:15). A more rare form of decoration on these forest glasshouse sites was found on three sherds, being chequered spiral trail decoration (Fig. 6:13). A distinct chequer pattern in relief was produced by applying a spiral trail of hot glass to the gather of glass, then inflating the glass in a vertically ribbed mould, a form of decoration found in Northwest Europe, especially the Rhineland, the Southern Netherlands and England, possibly originating in the Antwerp area during the late 16th and early 17th centuries (Tait 1967, 112). The metal of all three sherds is of good standard with no weathering. Other examples have been found on sites including Woodchester, Gloucestershire, Rosedale, North Yorkshire, Newent, Forest of Dean (Vince 1977, fig. 2, 14), and Haughton Green, Greater Manchester.

Some body diameters for vessels having applied decoration appeared to be fairly large, for besides the more common diameters of 6-7cm, there were four sherds measuring 10cm, 12cm, 16cm and even perhaps 22cm although the smallness of the fragments and the possibility of heat distortion must always be taken into account.

The vast majority of rim sherds found were from plain cylindrical or virtually straight-sided drinking vessels. Of the 96 sherds, 75 were between 6-9cm in diameter, 30 being 7cm. The smallest were 4.5cm to 5cm, and the largest 14cm with a possible 16cm. Rims typically were slightly thicker than the body of the glass and rounded through heat finishing. 18 sherds had moulded decoration stopping just short of the rounded rim. 13 had spiral moulding (Fig. 6:16), four vertical moulding, and one lozenge trellis. Fourteen had diameters between 6-8cm, the smallest diameter sherd 5cm, and the largest 9-10cm with a possible 16cm. Rims decorated with irregular horizontal bands of trailing below the rounded rim, applied as a single thread as described above, were represented by 7 sherds, one heat distorted, with diameters 6-8cm (Fig. 6:18,19).

Jugs/ewers (Fig. 7:20,26)

Handled jugs or ewers were sparsely represented by one plain example (Fig 7:20) and three small sherds which might have been from handles but could be furnace waste. (See also Amber/Black Glass, Fig. 7:26.)

Bowl/dish forms (Fig. 7:21)

Bowl or dish forms were suggested by 14 sherds. Eleven sherds were folded rims from bases or even lids, five with diameters 7-8cm, the rest from 10-20cm, body thickness 1-1.5mm (Fig. 7:21). Two body sherds possibly indicated bowl bases with pedestal foot.

Tubes/spouts (Fig. 7:22)

Thirty-one fragments from tubes or spouts suggested that the production of chemical apparatus such as alembics took place at Bickerstaffe (Fig. 7:22). Chemical or distilling apparatus was often produced alongside vessel glass on forest glasshouse sites (See particularly Wood 1982, 32-36).

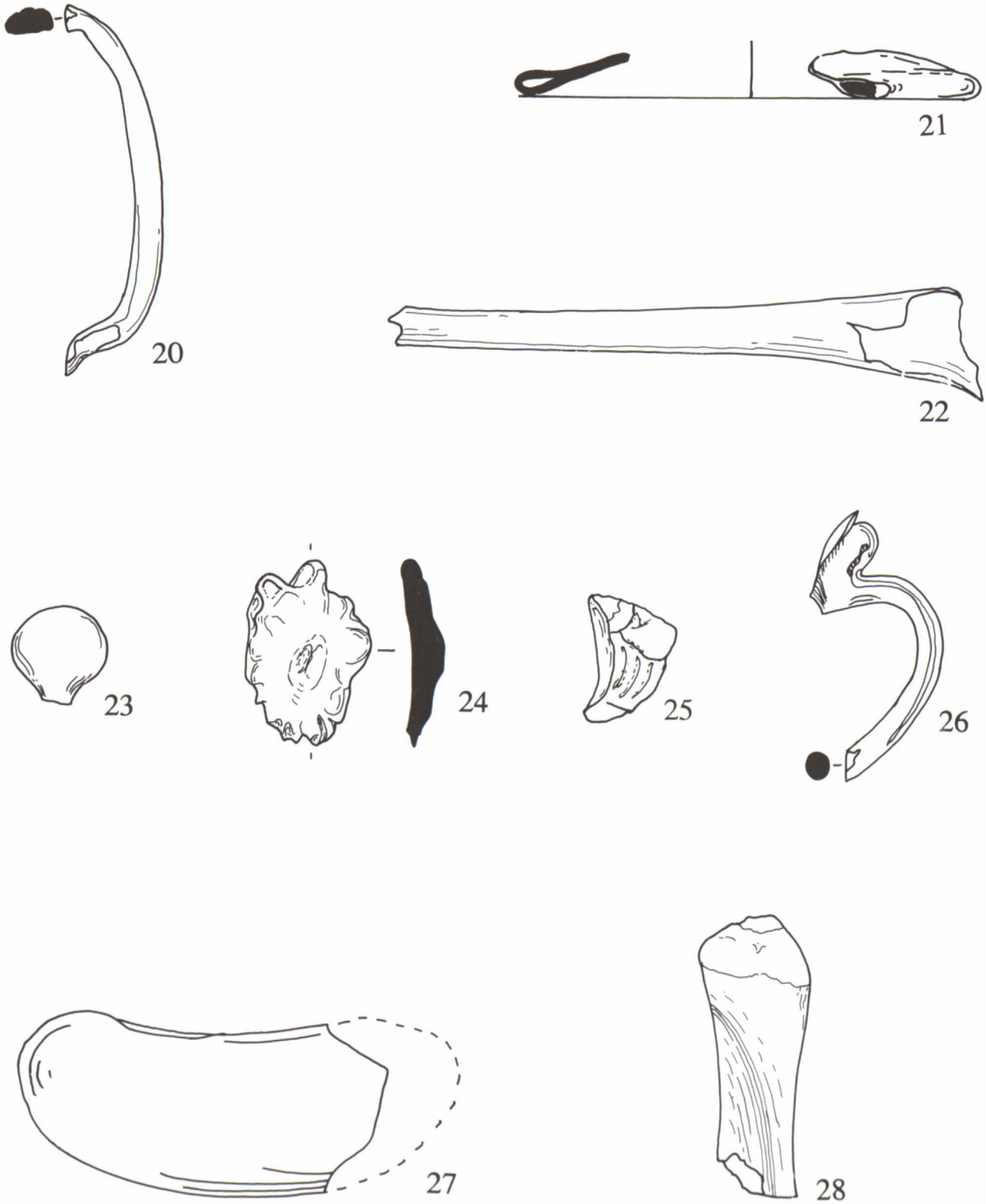

Figure 7: Glass vessels and other objects, nos 20-28, scale: 1:1

Miscellaneous (Fig. 7:23-25)

Six examples of glass resembling ball finials (Fig. 7:23) may also have been waste from the production of glass 'twists', although no twists were found at Bickerstaffe.

Four typical examples of applied prunts were found, where a pad of hot glass had been applied to the hot vessel body, hand tooled into a shape often resembling the 'raspberry' prunt or 'lion's head mask' popular on Venetian style glass in Europe in the 16th century (Fig. 7:24) and imitated by the French glass-makers. Examples have been found on sites such as Woodchester, Gloucestershire, Blore Park, Staffordshire (Charleston 1984, 89), Hutton and Rosedale, North Yorkshire and Haughton Green, Greater Manchester.

Remains of mushroom shaped so-called linen smoothers were confined to two rather slim fragments possibly from a smooth mushroom ended form, 1.2cm thick, and one fragment possibly from a plain solid handle. One fragment came from a vertical ribbed solid handle (Fig. 7:25), similar examples also found on other sites such as Hutton and Rosedale, North Yorkshire.

Amber/black glass

Of the 34 sherds of distinctly deep amber or black opaque vessel glass, the following categories were represented:

Bottle/beaker plain:	2
Bottle necks or furnace waste:	4
Beakers with folded foot and high kick:	1
Beaker with applied milled edge trail, 10cm diameter:	1
Body sherds, plain cylindrical:	13
Body sherds, bulbous:	4
Body sherds, moulded ribbed decoration:	3
Body sherds, applied trailed decoration:	2
Rim, plain:	1
Rim with spiral rib moulded decoration:	1
Jug handle with typical glass drip along outer handle (Fig. 7:26)	1
Folded rim, 16cm diameter	1

Sherds were generally heavier than green glass products, on average 2-4mm thick.

Seven fragments probably from solid cylindrical plain glass handles from linen smoothers were found (see also above), diameters 1.4-2.7cm (Fig. 7:28). One excellent mushroom shaped example also occurred (Fig. 7:27), notably similar to one found at Haughton Green (Ref:HG70/VI/C/13/825).

Flat glass

One hundred and sixty-six small sherds of flat glass in a variety of tints, 11 with surface scratching, average thickness 1.5-2.5mm were found, though three sherds were up to 4mm thick. Eighteen rimmed fragments suggested that cylinder or broad glass was produced at Bickerstaffe. Though small, at least half a dozen had the thickened irregular cylinder rim consistent with the process where a hot blown cylinder of glass was cut at each end, slit down the centre, and flattened to create window glass. Cylinder glass-making at this period was mainly associated with Lorraine, notably with the de Bisval, de Hennezel, Thietry and Thysac families of glass-makers (Rose-Villequey 1970, 570-1), suggesting that the French glass-makers at Bickerstaffe may have been from this region.

Later glass

Twenty-nine sherds of later glass were either surface finds or from the top layer of ploughed soil, bearing no significance to the site. One neck and rim sherd was from an eighteenth century English wine bottle type. The rest were from bottles and window glass of the 19th or 20th centuries.

Glass illustrations

No	Category	Date	Context	Trench	Bag No
Green glass					
1	I 4a	1968	1	-	119
2	I 5b	1968	1	-	135
3	II 1a	9/11/68	1	H	28
4	II 1b	1968	1	-	125
5	II 2a	10/11/68	1	C	18
6	II 4	9/11/68	1	A	36
7	II 7a	16/11/68	1	E	44
8	II 7b	1968	1	-	131
9	II 8	10/11/68	1	G	134
10	II 8	18/5/69	3	d	157
11	II 8	22/5/69	4	b	114
12	II 8	7/8/69	3	b	90
13	II 9	1968	1	-	119
14	II 9	3/5/69	4	b	77
15	II 9	21/5/69	4	b	98
16	II 10b	1968	1	-	136
17	II 10b	21/5/69	4	b	98
18	II 10c	1968	1	-	119
19	II 10c	9/11/68	1	D	54
20	III 1	1968	1	-	119
21	IV 1	10/11/68	1	B	41
22	V	8/8/69	2	b	-
23	VI	10/11/68	1	A	126
24	VI	1968/69	1	-	-
25	VI	1969	1	-	101
Amber/black opaque glass					
26	III 1	3/5/69	1	-	67
27	VI	1968	1	-	127
28	VI	9/11/68	1	H/J	50

Table 1: Green glass (EVE = estimated vessel equivalents, for explanation see Glossary on page 24)

TYPES	TOTAL SHERDS	EVE	% of total base EVE's (total base EVE is 15.42)
1. **Storage vessels: bottles, flasks, phials**			
Base fragments indicate:			
Square bottles	3	3	19.45
Bottles/beakers (no sides)	10		
Bottles/beakers: plain	10	1.31	8.5
Bottles/beakers: decorated	2	0.18	1.18
Bottles: multi-sided	1	1	6.48
Bottles/flasks: bulbous	7	1.01	6.54
Bottles/flasks: oval	1	0.18	1.18
Bottle necks without rims:			
simple, everted	4		
elongated	26		
Rims: flattened	19	1.64	
Body: cylindrical	268		
Body: bulbous	49		
Body: thick	58		
Body: other	107		
2. **Drinking vessels**			
Base fragments indicate:			
Beakers, folded foot, high kick, plain	27	0.89	5.77
-ditto-, with moulded decoration	1	0.19	1.23
Beakers, folded foot, low kick, plain	56	1.18	7.65
Beakers, applied foot ring, decorated	7	1.21	7.85
Wineglasses: knops	11		
Wineglasses: folded foot	50	5.27	34.17
Wineglasses: bases, no rim	10		
Body sherds: moulded decoration	22		
Body sherds: applied decoration	15		
Rims: plain cylindrical	96	6.96	
Rims: moulded decoration	18	1.64	
Rims: applied decoration	7	0.46	
3. **Jugs/Ewers**: handles	4		
4. **Bowls/jars**: base, lid rims	15	0.76	
5. **Tubes/spouts**	31		
6. **Miscellaneous**:			
Prunts	4		
Linen smoothers	14		
Bead	1		
Ball finials	6		
Other	7		
7. **Flat glass**	166		
rims	18		
8. **Amber/black glass**	34		
9. **Later glass**	29		

Bickerstaffe glass composition

G.W.F. Pardoe

The glass composition used at the Bickerstaffe glasshouse is somewhat of an enigma. Physical evidence from the site suggests the glasshouse to have been fuelled by wood. In this case one would expect wood ash to be used as the major alkali source for glass-making and the resultant composition to be high in potash. However, glass analyses show this not to be the case, with relatively low potash levels and most of the alkali present as soda (see Raw Materials, Table 5, page 20, for previous glass analyses).

In an attempt to elucidate the source of the soda one specimen was analysed by the SEM/ED technique (Table 2). This showed the presence of a significant quantity of chloride. Chloride has previously been found in glass samples from the coal-fired glasshouse at Haughton Green (Pardoe, in Vose forthcoming) and led to the postulate in that case that salt had been used as the alkali source, perhaps using rock salt from Cheshire.

For Bickerstaffe the case is less clear-cut. The concept of a simple sand and wood ash batch (see Raw Materials, page 18-21) is appealing and it is conceivable that by using vegetation from the nearby shoreline, or even sea-weeds, the soda and chloride levels in the ash would be increased enough to give the measured glass composition.

Alternatively the addition of salt to the wood ash/sand mix could give the levels of chloride and soda shown in the glass. Volatilisation of alkali chlorides from the melting batch would significantly reduce the potash level from the value calculated for sand/wood ash towards the measured value (see Appendix).

The third alternative, that the glass was made from a mixture of local sand with wood ash and cullet brought in from a coal-fired glasshouse is both historically and practically unlikely. On remelting most of the chloride from the cullet would be lost giving the final melt a chloride content well below the 1.5% measured.

Appendix
To establish whether salt could be used as a source of sodium in 17th-century glass-making, melts of the theoretical compositions given in Table 3 were made.

Glass G1 used salt as the sole source of sodium and produced an opal on cooling. For Glass G2, 50% of the sodium was from salt, the remainder from soda ash. This gave a clear glass. Partial analysis of this glass showed loss of both chlorine and alkali, but not in the R-Cl proportions. It is assumed that chlorine was lost by both hydrolysis and by alkali halide volatilisation.

Melting was done in a glass furnace at 1500^0 using a pot with a lid.

Table 2: Glass sample BS 7/8/69 (3)

	Weight % as oxide*
SiO_2	58.5
CaO	19.7
Fe_2O_3	1.3
Al_2O_3	2.2
MgO	4.9
Na_2O	5.8
K_2O	1.7
P_2O5	3.5
Mn_3O_4	0.6
TiO_2	0.3
Cl	1.5
Total	100.0

*mean of three analyses

Table 3: Glass composition (as Wt % of Oxides)

	Target	Theoretical		Partial Analysis
	G1	G2	G2	G2
SiO_2	57.0	57.0	57.0	
Al_2O_3	4.0	4.0	4.0	
CaO	20.0	20.0	20.0	
MgO	5.4	5.4	5.4	
Na_2O	6.5	6.5	6.5	5.2
K_2O	0.9	0.9	0.9	0.5
Fe_2O_3	1.3	1.3	1.3	
P_2O_5	3.3	3.3	3.3	
Cl	1.3	7.3	3.6	1.2

Three points are shown by the above results:

1. Salt can be used as an alkali source in glass-making.

2. In addition to containing soda the resultant glass can contain significant amounts of chloride.

3. Loss of potash can accompany the volatilisation of soda and chloride from the salt. Indeed, in terms of proportion of initial weight present in the batch the retention of potash (55%) is lower than the retention of soda (80%).

The crucibles (Figs. 8 and 9)

A total of 703 crucible sherds were found comprising 585 body, 41 base, and 77 rim sherds. None gave a full profile of a complete crucible, although one complete crucible base with a diameter of 32cm (Fig. 8) was found on its side in the demolition line from the furnace area (Figs. 4A,4B). Crucibles, or glass-making pots, were used to contain the raw materials for melting in the glass furnace. The sherds indicated that the crucibles, which would have been placed on probably parallel sieges or platforms in the furnace with the fire

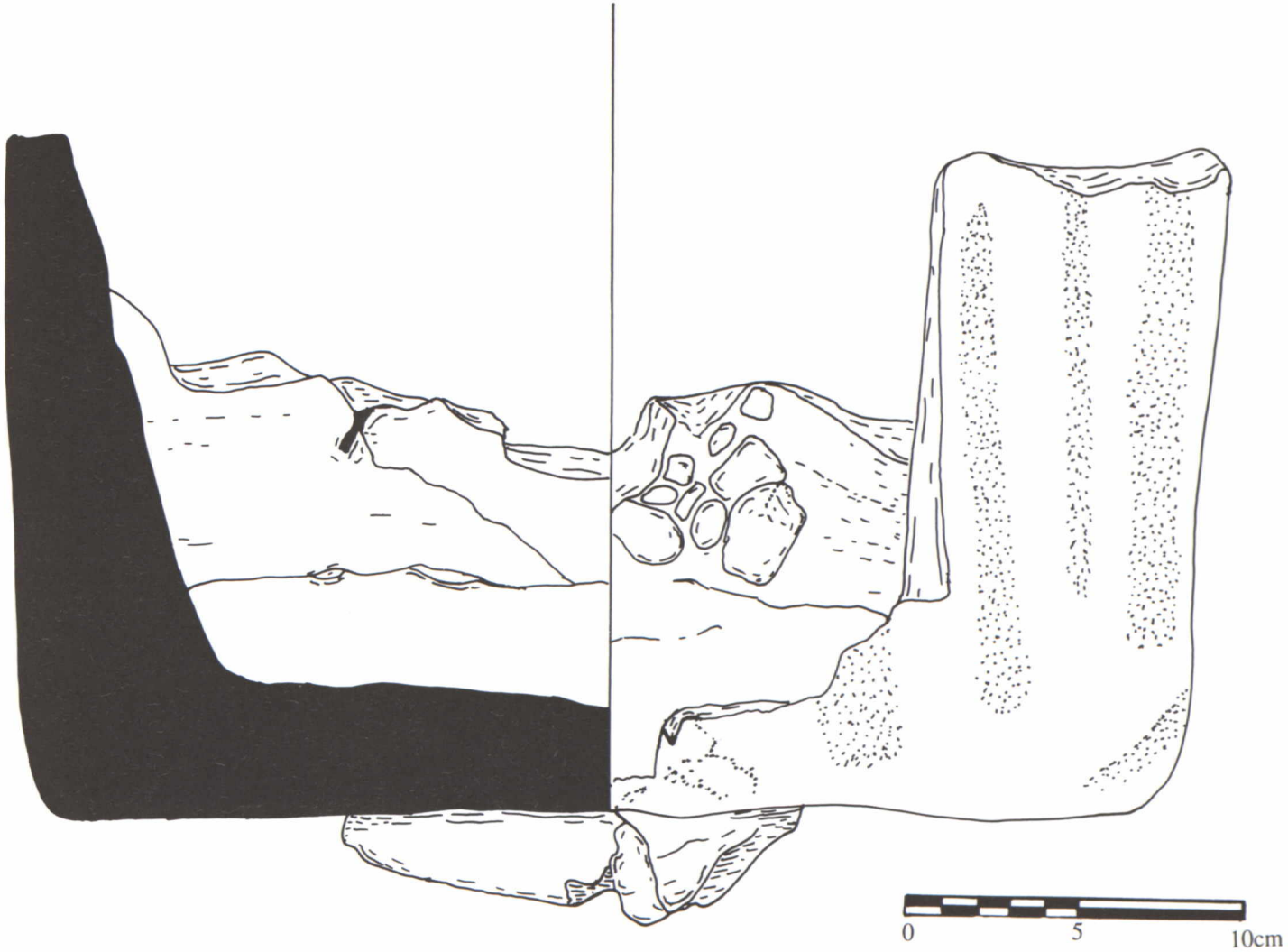

Figure 8: Crucible base, scale as shown.

trough in-between, were of a design common to the period, being of round open bucket shape with mainly straight sided rims, sometimes slightly out- or in-curved, with the rim itself being either flattened or rounded (Fig. 9). Vessel equivalents measured from base sherds equalled 2.58, and rim sherds, 2.53 (see Table 4). Only open pots were used in wood-fired furnaces; closed pots to protect the glass were developed by English glass-makers once coal-fired furnaces were introduced from the early 17th century.

The buff or greyish brown coloured fireclay fabric averaged 1-4cm body thickness though heat and glass erosion in the furnace questions the accuracy of any measurement taken. Many sherds had a green/brownish glaze on both inner and outer surfaces probably caused by soda in the atmosphere of the furnace, a few with a reddish-brown or dark-brown glaze. Some bore pale vertical striping most likely caused by high filling of the pots which resulted in streaks of fluxes running down the sides of the pots until the level reached the normal height by melting. Horizontal puddling contours made by the potter were also observable on some sherds. Glazing covering broken edges was probably the result of pots being broken in the furnace.

Base diameters ranged from 20cm to 46cm, and rim diameters from 22-46cm, with one possibly 50cm. Based on vessel equivalent measurements, it is interesting to note the similarity in percentages of both rims and bases within the various size ranges (see Table 4). Based on a simple sherd count, size distribution within bases and rims are again fairly evenly distributed:

Bases: 20-24cm: 6 sherds; 26-30cm: 6 sherds; 32cm: complete base; 38-40cm: 7 sherds; 42-46cm: 5 sherds.

Rims: 22-24cm: 2 sherds; 26-30cm: 23 sherds; 32-36cm: 14 sherds; 38-40cm: 19 sherds; 42-46cm: 10 sherds.

Table 4: Crucibles

Sherds	Total	EVE	Diameter cm	% of each diameter class
Bases	41	2.58	20-28	32.2
			30-38	52.7
			40-46	12.8
			unknown	2.3
Rims	77	2.53	22-28	28
			30-38	48
			40-46	21
			50	1
			unknown	2
Body	585		Thickness:	1.0-3.6cm

Bickerstaffe crucible composition

Horace Cole and C.F. Griffith

A fragment of fireclay pot was examined. The refractory was dense and of a dark greyish brown colour. The specimen had a slight curvature consistent with it having formed part of a thin walled pot, and the inner and outer curved faces were covered with a thin layer of greenish glass. The glass was crizzled and contained numerous bubbles.

Microscopic examination of a thin section showed that the refractory consisted of a siliceous fireclay in which the quartz grains varied widely in size, several being quite large. The clay showed a slight development into minute rods of mullite, indicating that the pot had probably been heated to at least 1100 degrees centigrade. No 'grog' particles (that is, particles of pre-fired clay) were present. The texture of the pot, and particularly the absence of grog particles, suggest that the pot was of old manufacture and markedly different from glass house pots of present day manufacture.

The chemical composition together with the observations made by microscopic examination show that the pot was made from clay and contains a considerable amount of free silica in the form of angular quartz grains. The quartz may have been an impurity in the clay or a deliberate addition to counteract firing shrinkage and hence premature fracture. It has also been possible to ascertain, from a determined expansion curve, that the pot material had not been used at temperatures in excess of 1200-1300 degrees centigrade. See Refractory Materials (page 21) for analyses of Bickerstaffe crucibles.

Crucible illustrations

Category	Date	Context	Trench	Bag No
Base	25/5/69	3	b	-
Rim	18/5/69	3	d	89

Raw materials for the Bickerstaffe glasshouse

John M. Virgoe

This report sets out to consider some possible questions with regard to glass-making raw materials and refractory clays for the Bickerstaffe glasshouse.

Glass-making raw materials

The starting point to consider the possible raw materials must be the analyses of the finished glass. The available

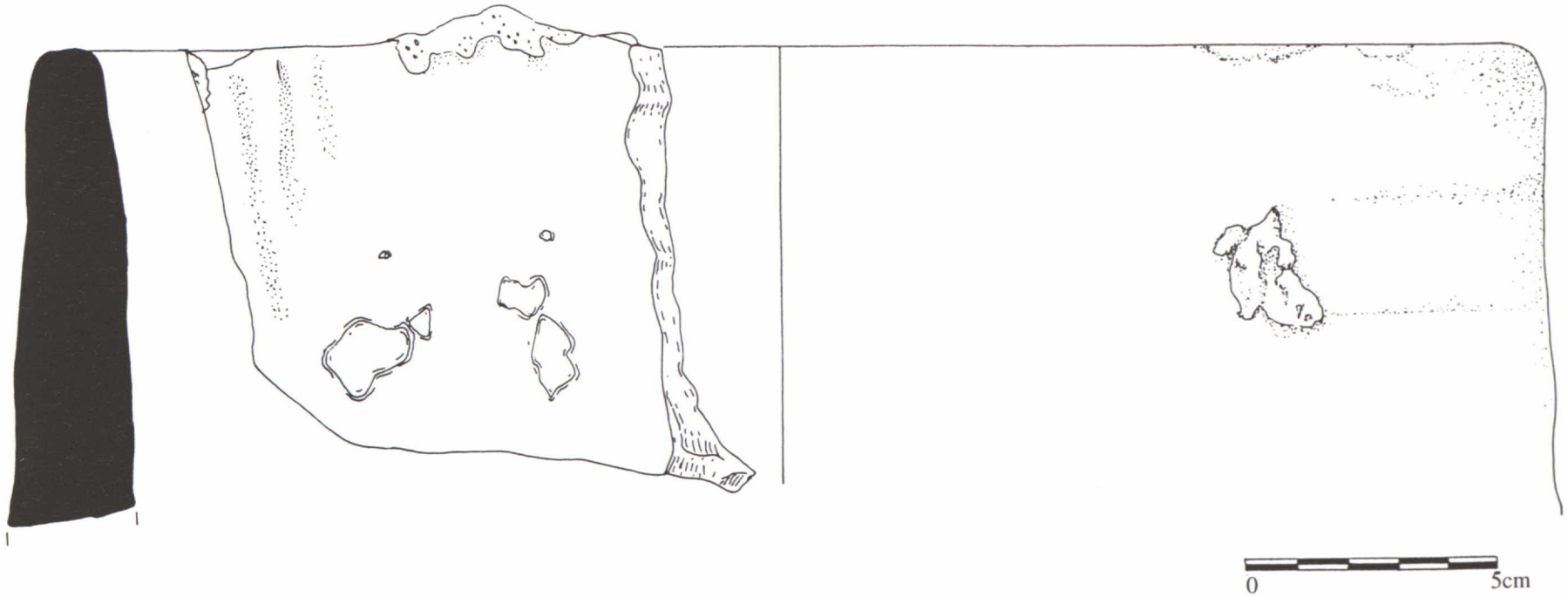

Figure 9: Crucible rim, scale as shown.

analyses of glass from the site carried out in 1968/69 are given below (samples B3, B4: Hurst, 1968, 143; SR77-SR79: Cole 1969).

Table 5: Glass analyses

	B3(1)	B4(1)	SR77(2)	SR78(2)	SR79(2)
SiO_2	60.4	59.4	56.2	59.0	57.4
CaO	19.5	18.2	26.4	17.5	19.4
Fe_2O_3	0.61	0.89	2.2	1.2	0.75
Al_2O_3	2.3	4.1	6.2	6.4	7.7
MgO	4.7	4.6	4.2	4.4	4.8
Na_2O	5.9	5.8	1.4	6.3	6.0
K_2O	1.4	3.0	1.4	3.5	2.8
P_2O_5	3.4	2.9	N.D	N.D	N.D
Mn_3O_4	0.8	0.6	0.3	0.8	0.6
BaO	0.2		T	0.2	0.2
SrO			0.2	T	0.1
SO_3	0.5	0.1	1.2	T	T
Total	99.71	99.69	99.7	99.3	99.75

N.D. = not determined, T = trace

Excluding SR77, the following observations can be made:

Although variable by modern standards, these glasses are in general remarkably consistent.

They are complex compositions, with seven oxides present at a level exceeding 1%. It is highly unlikely that they were formulated as such and that the batch was relatively simple. The majority of oxides were probably introduced in an uncontrolled way as impurities in the raw materials.

The presence of P_2O_5 is highly significant. It is almost certainly an impurity and is not found in modern soda-lime-silica glasses. Although not determined in three of the analyses, it is significant that the P_2O_5 plus Al_2O_3 values for all five analyses is fairly constant. It is probable that in SR77, SR78 and SR79 the P_2O_5 has been reported as alumina. Recently further analyses of small fragments of these glasses has confirmed the general analysis and the presence of P_2O_5, but has also revealed the presence of 1.5% chlorine (see Glass Composition, page 16).

Turner, in considering the chemical composition of various ash materials derived from air dried vegetable matter, commented on their high P_2O_5 content and its frequent appearance in ancient glasses. He also commented on the high lime content, particularly of beech wood-ash, which also contains appreciable quantities of Mn_3O_4, again found in the Bickerstaffe analyses.

The high Na_2O to K_2O ratio is noteworthy. This is unusual in 'forest' glasshouses where the alkali is most likely to be derived from ash from local inland vegetation which almost invariably contains more K_2O than Na_2O. The presence of chlorine may suggest other possibilities, particularly the use of salt. This could have been from Cheshire, or sea salt, if there was production of sea salt on the south West Lancashire coast. A further possibility is seaweed, or kelp, although its analysis (Turner 1956) indicates it contains only slightly more soda than potash and it does not therefore fit well with the glass analyses.

The hypothesis that the batch was a simple one based on two or three components is an attractive one which can be explored further. Unfortunately Turner and his sources do not give analyses for the ash of hazel, oak and birch, which were the species found in charcoal taken from the site (Vose 1972). If these were used to fire the furnace it would be reasonable to use the resulting ash as a raw material if possible.

Turner discusses the composition of beech wood-ash and its variability, and quotes figures for leaves, trunk and brushwood. His figures for trunk and brushwood and an average are given in Table 6 below:

Table 6: Ash analysis

	trunk	brushwood	average
SiO_2	5.4	9.8	7.6
CaO	56.4	48.0	52.2
MgO	10.9	10.6	10.8
Na_2O	3.6	2.4	3.0
K_2O	16.4	13.8	15.1
P_2O_5	5.4	12.2	8.8

It is also possible to speculate that other fuels, namely peat and charcoal may have been used and therefore contributed ash, since Langton makes reference to peat digging in the Bickerstaffe area before the end of the Elizabethan period, and also to charcoal being taken from Bickerstaffe near Chorley at about the turn of the 17th century (Langton 1979).

Sand was almost certainly derived locally. The geological map shows that the site is underlain by the Shirdley Hill Sand which formed the basis for the St. Helens glass industry. It is possible that the two small ponds adjacent to the site may well have been the pits from which the sand was taken.

The analysis of sand from the site (SR89) differs considerably from the analysis of modern glass sands, but all modern analyses refer to washed products, whereas SR89 is probably that of a sample as received. It is possible or probable that 16th-century glass-makers did not wash their sand and the analysis SR89 is representative of such a material.

Sand sample SR89

SiO_2	87.0
Fe_2O_3	1.7
Al_2O_3	5.1
CaO	0.4
MgO	0.6
Na_2O	1.1
K_2O	2.6
Total	98.5

Possible batch

Assuming that the batch contains 60% of sand by weight and 40% of beech ash and that the composition of the sand is that of SR89 and the ash the average given above, then the resulting glass can be calculated to have the following composition:

SiO_2	55.2
CaO	21.1
Fe_2O_3	1.0
Al_2O_3	3.1
MgO	4.7
Na_2O	1.9
K_2O	7.6
P_2O_5	3.5
Total	98.1

Allowing for variation within the raw materials this is a reasonably close match to the analyses of glass from the site with the exception of the Na_2O/K_2O anomaly. This can be balanced by the addition of salt.

We have no data on the bulk density of beech ash, but it would seem likely that it would be less than that of sand. If this is so, then it may well be that a 60:40 ratio by weight equates to a 1:1 ratio by volume. This would then give rise to a batch which consisted of one basket of sand to one basket of ash, which would seem much more likely than 16th-century glass-makers weighing different amount of raw materials out.

Refractory materials

The analysis of samples of crucibles from the site are given in Table 7 (sample B1: Hurst 1968).

These analyses are variable to the extent that it would seem likely that two sources of clay had been used.

Fireclays occur associated with the coal seams underlying South West Lancashire, the analyses of three such clays being given in Table 8 (adjusted for loss of water of crystallisation on firing, Ennos and Scott 1924). An analysis of Stourbridge glasshouse pot fireclay (Singer and Singer 1963) adjusted on a similar basis is given for comparison. No positive conclusions can be drawn. Sample 1 is similar to the Stourbridge material and may suggest that source, but local analyses are merely three chosen at random, and do not consider all possibilities. It would seem more likely that a relatively small local glasshouse would use locally available materials, and the abundance of local fireclays would suggest a local source if the local coal seems were working at that time. This would seem to be so: Anderson (1975) considered that coal had been worked in the Upholland area from at least the beginning of the 16th century, and Langton (1979) indicates collieries in the Stanley Gate and Bickerstaffe areas in the period 1590 to 1689. There seems to be an indication that the Stanley Gate pit was working before 1600.

Table 7: Crucible analysis

	Sample L	Sample B1	Sample
SiO_2	73.1	77.1	55.3
Al_2O_3	21.6	18.8	38.5
Fe_2O_3	1.7	0.91	3.2
TiO_2	1.2	1.0	1.3
CaO	0.2	0.1	0.2
MgO	0.2	0.4	0.5
Na_2O	0.8	0.3	0.3
K_2O	1.0	0.9	0.6
LOI		0.4	

LOI = loss on ignition

Table 8: Fireclay analysis (adjusted for firing loss)

	Upholland 1	Upholland 2	Standish	Stourbridge
SiO_2	60.2	64.9	59.7	72.5
Al_2O_2	27.7	23.4	35.6	24.8
Fe_2O_3	8.7	8.3	2.4	2.1
CaO	0.9	0.6	0.7	0.2
MgO	0.8	0.7	1.6	0.2
$Na_2O + K_2O$	0.5	0.8	N.D.	0.2

The Clay Tobacco Pipes

P.J. Davey

Seven fragments of clay tobacco pipe were recovered from the excavations. These include small fragments of two 19th-century bowls, two probable 18th-century stems and three earlier stem fragments which may fall in the date-range 1650 to 1720. None of these finds can be securely sourced. None are likely to have been used by the glassworkers on the site.

The pottery

P.J. Davey

Thirty-nine sherds of post-medieval pottery were found during the Bickerstaffe excavations. Twenty-one of these consist of varieties of white bodied earthenware of 19th century date, much of it with transfer printed designs. A single sherd from an unglazed vessel, probably a flower-pot and a small red-bodied slipware rim are also probably of the same period. The 13 sherds of dark glazed, red earthenware are much more difficult to date with any precision as the technology of their production was current from as early as 1600 until the present century (Philpott 1985, 87-8). Whilst the majority are probably of later 18th- or 19th-century date, a few may belong to the 17th- or early 18th-century. None of the material noted above is likely to date from the glasshouse production period.

Three sherds in buff earthenware with a pale yellow internal glaze, including the base of a shallow dish, are the only possible exceptions. Although derived from topsoil layers or unstratified at Bickerstaffe, this type of yellow ware is known to have been in production in nearby Rainford by the middle of the 17th century (Davey 1991, 127-8, Fig. 5, nos 4, 5, 7, 8 and 10) and may possibly have been in circulation half a century earlier.

The charcoal from the Bickerstaffe Glasshouse

Graham H. Taylor

Methods
The identification of the charcoal was made by examination of cross sections and radial long sections prepared by fracturing the charcoal in the appropriate plane. No attempt was made to clean the surface as this destroys the surface features.

A lens key (Anon. 1960) and comparative material were used to determine the identity of the woods. A Beck 'Binomax' stereoscopic microscope of 25X magnification was used.

Results
The results of the investigation are summarised below. Only one piece of charcoal could not be identified with certainty, this having been under considerable pressure at some time.

The Relative Frequencies of Different Species of Tree

Hazel (*Corylus avellana* L.)	Oak (*Quercus* sp.)	Birch (*Betula* sp.)	Un-certain	Total
33	28	12	1	74

Conclusions
The preponderance of hazel charcoal is of great significance. It is also significant that the majority of the oak was in the form of large pieces. It is highly likely that the woods of the district were being coppiced at this time, that is all the trees were felled except for an open network of oaks. This allowed plenty of space for the growth of hazel. Every ten to fifteen years the hazel would be cut back to the ground and allowed to grow up again, from the base of the stump. The oak may be from the original felling and the smaller amount of birch from poorer areas nearby.

Archaeomagnetic dating

H.N. Hawley of the Research Laboratory for Archaeology, Oxford visited the Bickerstaffe site on 24 July 1969 in order to take samples for archaeomagnetic dating. Unfortunately there was insufficient material left in situ on site for suitable samples to be taken.

Proton magnetometer survey

A proton magnetometer survey of the site was conducted by Dr Patrick Strange of the Department of Electrical and Electronic Engineering, The University of Nottingham on 9 June 1968, identifying an area 10ft by 5ft (3mx1.5m) worthy of investigation, which upon excavation proved to be the furnace site. A plan of the survey is with the Bickerstaffe archive.

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Glossary

crizzled	deterioration in the glass formed of a network of tiny cracks due to an excess of alkali
EVE	estimated vessel equivalents, for an explanation see Blake and Davey (1983, 24)
prunt	a seal of glass applied to the vessel which may be either plain, moulded or with tooled decoration
cullet	broken glass or glass waste
sieges	stone platforms on which the crucibles containing glass were placed

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