THE HIVE OF ACTIVITY AT THE 'GLASSHOUSE' 1585-7 – A WINDOW ON THE DEVELOPMENT OF KNOLE

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In Elizabethan times 'glasshouse' denoted a large, temporary structure covering the furnaces and work areas necessary for making glass. John Lennard, a wealthy Bencher of Lincoln's Inn, was the tenant of Knole (owned by the Crown) from 1570 to 1590 during which time he undertook huge restoration. This included reglazing the house for which a very substantial manufacturing facility on site was required.

A wealth of correspondence between Lennard in London and his steward at Knole detailing the progress of glass production during 1585-7 has survived. This is summarised below together with a brief description of the techniques of glass production at the period, the materials required and the Continental origins of the itinerant 'glassmen'.

Knole is a very large house, with a ground-plan area of buildings of 4.4 acres, arranged around seven courtyards (**Fig. 1**); there is a walled garden of 26 acres, set

Fig. 1 'Knole, more like a town than a house', Virginia Woolf *Orlando*. (Photo by S. Draper.)

in a Park of 1,000 acres. Since the Park was created in about 1460 it has roughly doubled in size. There has been very little disturbance to the land after being brought within the paling. The house itself has been subject to several building, restoration and improvement projects.

John Lennard, tenant of Knole, had chambers in Lincoln's Inn because of his legal work. He was a Bencher at Lincoln's Inn and had been called to the bar, but under a special procedure as he was a court administrator. He held various roles in the Court of Common Pleas, gaining influence and money as his responsibilities increased. Thus, when Wales was divided into shire counties, Lennard set up the court system there, for which Edward VI awarded him a standing fee and enlarged his letters patent – allowing Lennard opportunities to get richer. When the post of *Custos Brevium* (Keeper of Writs) of the Court of Common Pleas became available, Lennard was able to pay the rights holder, Sir William Cecil, an annuity of £240 for the post.[1] In the early 20th century, Lennard's family historian, Thomas Barrett Lennard, studied John's web of leases and properties bought and sold, and other business dealings and accounts, and reckoned John to have had an annual income of £2,000.[2]

As Lennard was often at Lincoln's Inn, many estate matters that would normally have been reported verbally were written down. That is why the glasshouse at Knole is the best-documented glasshouse of its period. Lennard's original documents referred to in this paper (and hundreds more) are in the County Archives in Maidstone and Chelmsford. Transcripts of some were published by Thomas Barrett Lennard in 1905[3] and 1908.[4]

Lennard's lease of Knole had been taken over from Thomas Rolf four years after Rolf's death in autumn 1566.[5] Earlier, in 1561, the Earl of Leicester had commissioned a survey of Knole which detailed its ruinous state.[6] Rolf's lease[7] required the Crown to repair Knole and allowed its tenant to make changes to the house.

Before taking over the residue of the lease in 1570, Lennard commissioned his own survey which valued the necessary restoration work at £304 5*s*. 5*d*. [£900k] and a covenant was put in place that the Crown would do the work. However, by 1587 the Crown had done nothing, deterioration had continued and Lennard had himself now undertaken all that was necessary. He wrote that 'I will take my oath before you that I have laid out in repairing it standing with the covenant £400 & more, besides stone walling the house, & garden, & other voluntary acts for the which I ask no thing'. The Chancellor, on behalf of the Crown, had offered Lennard too little money, and Lennard was not prepared to release the Crown from the covenant. He asked Lord Burghley to rebate his rent by £400 [£1.2M] (i.e. two years free), or to reduce the annual rental by double the Chancellor's offer. He commented that he had saved the Crown money by doing the repairs over the 15 years of his tenancy: 'if it had not been done in time but let go, £1000 [£3M] would not now have done it'. Lennard also notes that he has developed the estate. Lennard's statement that he had spent, on his own account, large sums on 'stone walling the house and garden' is very significant for our understanding of the development of Knole House.[8] If the stonewalling of the house refers to significant work on Green Court, this would make sense.

Lennard spent a lot of money on having window glass made in the late 1580s.

The wood recorded as supplied to the glassmen was valued at today's equivalent of £517,000. He had a lot of windows to put it in, and we find window glass of the right type and period in many of the leaded diamond windows on the inner and outer walls of Green Court.

In the following sections some aspects of making window glass in England at the period are explored, the manufacturing process described and Lennard's unique and detailed records of the Knole glasshouse operations summarised.

Quality problems of English window glass

The best English window glass in the Medieval period came from the Weald of Surrey and Sussex, and from Shropshire and Staffordshire. In 1351 and 1355 white glass from Chiddingfold, near the Surrey/Sussex border, was used for the glazing of St Stephen's Chapel, Westminster, and for the new chapel at Windsor Castle.[9] From the Medieval period onwards, Chiddingfold was one of the foremost English locations for glassmaking. In addition to documentary records of glassmaking, the remains of a number of furnaces from different periods have been found there.[10] The places favoured by the glassmakers were wooded, low and with water nearby – to the point of being boggy. There is a source of white sand very nearby at Hambledon.[11]

However, English glass was often considered inferior.[12] Window glass from Normandy was considered superior to English and other foreign glasses, and fetched the highest price. Indeed, in 1567 the master of a glasshouse at Chiddingfold claimed that he could not make window glass, only 'bottles and other small wares'.[13] The problems with making sheet glass were well known, and foreign experts had presented themselves to the Crown to offer a solution.

Lord Burghley favoured the application from a Huguenot glassmaker, Jean Carré of Arras, to pay the Crown for a monopoly on glassmaking.[14] In 1567 his company gained 21-year rights in making window glass, with conditions on pricing and the training of English glassmakers. From 1570 Carré brought a number of French and Venetian glassmakers into the country and, in spite of a number of complications with the commercial arrangements, and Carré's death, glasshouses were built and began to produce window glass of a very high quality.

Production continued, making the now-fashionable large windows for the great houses, and devouring wood at a rate which began to threaten the vital iron industry. The solution was to adapt the process to use coal, which allowed even higher furnace temperatures and better glass to be made.[15] A monopoly was granted in 1615 and the use of wood for the so-called Forest Glass was banned and had ceased by 1620. Many of the Huguenot glassmakers had moved to places like Staffordshire, where the forests had allowed a glass industry to develop, but where coal was also available, enabling the industry to modernise.

Technique of making Forest Glass

Forest glass made between the arrival of Carré in 1570 and its final demise in 1620 is known as Late Period glass. The manufacture of large quantities of glass took place in the forests for the simple reason that a lot of wood was used in the process

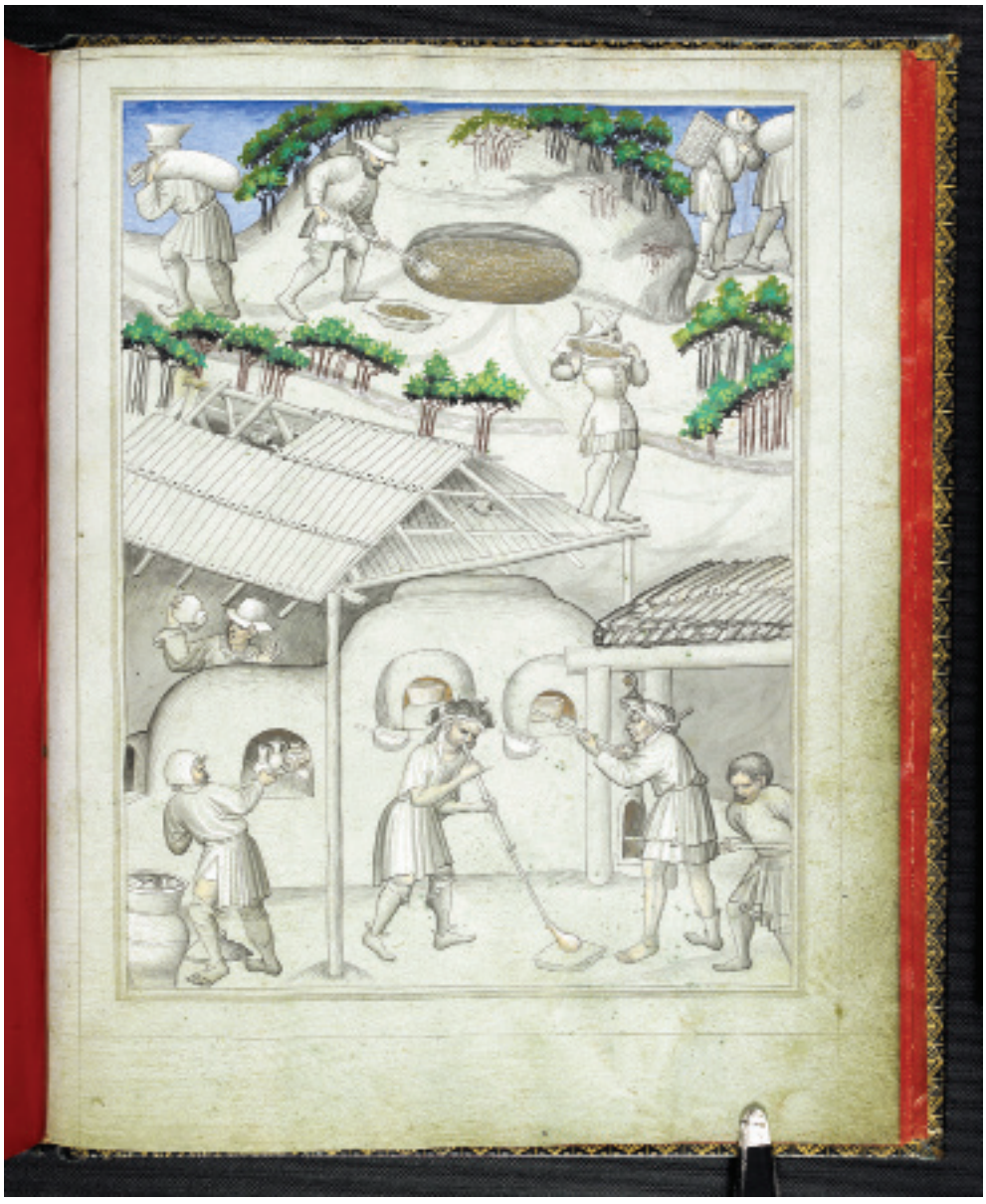


Fig. 2 A medieval ‘glasshouse’; drawing made in Bohemia *c*.1420. Men are collecting wood, sand and vegetation to make the ash. There is a shingled roof over the furnace, and a much stronger structure on which furnace wood is drying. (Reproduced, with permission © British Library Board Add. MS 24189-f016r.)

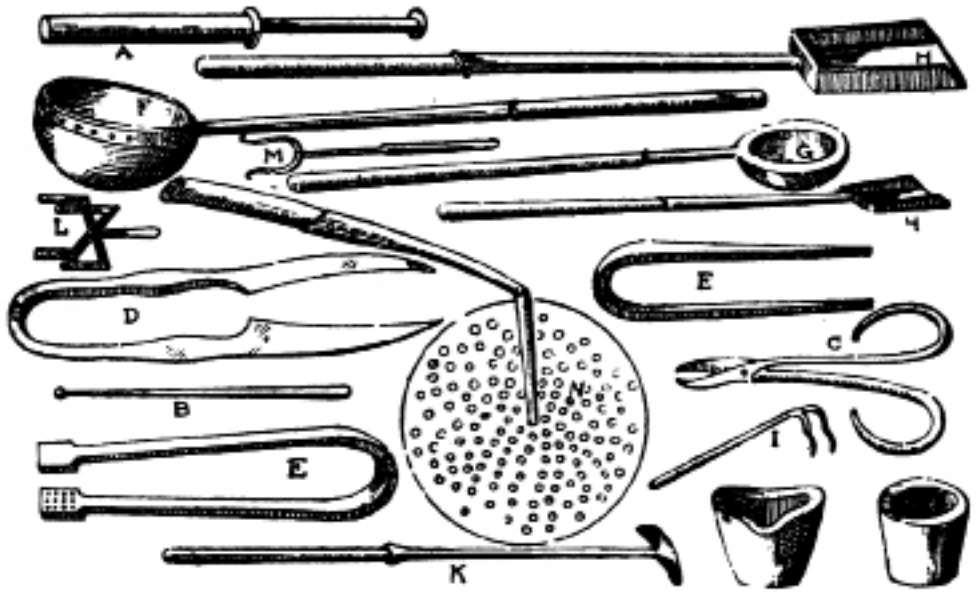
in the form of ash and fuel. Sand was used, but does not melt and fuse into glass at the temperatures that can be obtained in a furnace. All glass requires an alkaline 'flux' that reacts with the sand to help it to melt. That flux could be soda – making high-quality soda glass – potash or lime. For making fine glass vessels the ash was often refined to extract the alkali in concentrated form. Unrefined wood ash contained a mix of minerals that made more robust, green glass and this is what was generally made in England.

The Late forest glass was clearer, stronger and weathered better than anything previously made in England. Fourteenth-century window glass had to be at least 3/16in. thick, which required very strong window structures. Late Glass could be made to 1/16in. or less, and be readily cut into diamond 'quarries' and mounted in a lead matrix.[16] This improvement was achieved by higher and more constant temperatures from improved furnace design, and by raising the calcium content by burning wood that contained more lime, i.e. oak rather than beech, or possibly the secret was to add lime itself.

The basic recipe for glass required two parts by weight of ash and one of sand. If the furnace was burning the right wood, its own-derived ash could be used. The efficient, high temperature, Late Glass furnaces could make a unit of glass with only 100 units of wood. Earlier glassmaking required 200 units of wood. In either case only 1 unit of sand went into every 3 units of glass.

For centuries, glassmakers had used a 3-chamber process to make the glass. All access to the working areas of the furnace took place through apertures made as small as possible to retain heat. Long ladles, stirrers and other tools were used to reach the working pots inside the furnace (**Figs 2 and 3**). The furnace is the centre of activity, starting from the right, a boy is stoking the furnace. In the first chamber, held at 900°C,[17] the founder has put the ingredients into a pre-heated pot. Once it started to melt, the mixture had to be stirred continuously, for a day and a night, until it had consolidated into '*frit*'. The frit was ladled into one of the working vessels in the main furnace, kept at about 1300°C. Each side of the working furnace had two pots, one having frit added to it and forming glass, the other having glass taken out, blown and worked. The final stage took place in the annealing furnace, where the finished glass was first heated to 900°C, then cooled over a day. This allowed the tensions in the glass to be released without any loss of form.

All wood-fired furnaces were reverberatory, they relied on confining the heat inside and maintaining temperature for months at a time so that all the structure, interior shelves and pots were maintained at the working temperature. Late furnaces were constructed from a sandy stone with an outer shell of neat brickwork or stone, at least 30cm thick in total. The top corners were curved so that there were no cold spots and the maximum heat was reflected down into the pots. Brick could not be used for the lining because it would have become glass, and melted. Inside the furnace the pots stood on a shelf which had circular indentations so the pots were kept in place during stirring. Finding suitable clay for the pots, and making pots that would withstand the heat, had been a major issue before the Late Period. Good Green glass required an extra-hot furnace: one glassmaker remarked that it was twice as hot for the workers as when making other types of glass.[18] Pipe clay from sites such as Purbeck was mixed with fire clay from Worcestershire or the Forest of



Glassmaker's tools: A. Blowing-iron with wooden handle; B. Pontil, solid iron; C, D. Shears, D is also used for opening up a glass; E. Two types of procello (pucellas); F. Large ladle for filling the working-pots; G. Small ladle for scumming the pots; H. Shovels to draw out the coals and ashes of the furnace; I. Fork for stirring the pots; K. Rake for stirring the metal and frit in the pots; L. Tool for making Chamber pots; M. Fork for carrying finished glasses; N. Ladle used in alkali purification.

Fig. 3 Drawings of glassmens' tools. (Reproduced from Jean Haudicquer de Blancourt, *The Art of Glass, First translated into English* (London, 1699), p. 32. From <https://books.google.co.uk/books?uid=111102312326549217478>).

Dean to make a strong and resistant pot.[19] Late pots were usually large, often tapered bucket shapes, 30 cm diameter at the base, 35-38 cm at the top and 30-40cm high. The walls were 2-2.5 cm thick and the base 5cm, although some Late pots have been found with walls only 1.5 cm thick.[20] A full pot would hold about 75kg of glass.

The furnace had to have an aperture big enough to allow pots to be changed, and which could be much reduced in size to keep in the heat. This was done with a plug of clay shaped on a frame of sticks and with a 'glory hole' just big enough to allow insertion of ladles, pipes, etc. This plug baked in place and the sticks burned away. It would be removed for pot changing and replaced if it broke.

Ash from different woods has different amounts of sodium, potassium and calcium, and made glasses with different characteristics. Oak, for example, has much higher levels of calcium than beech, so should make glass that weathers better. However, there can be huge variations between batches of ash.

The founder made his frit in batches which consolidated to a smaller volume, and then added it to the 'metal' in the main furnace to form glass. There was much testing: tasting to check the alkalinity,[21] and pouring to check the viscosity and quality of the product. He could use, for example, a different sort of ash for one portion of frit to adjust the quality of the metal. It had to have the right characteristics to be blown into good window glass.

Glass makers reported that even adding colour could make a significant difference to the behaviour of the glass. There were two methods of blowing glass to make a flat sheet - crown and muff. Crown glass is made by blowing a large, thin sphere, then switching the pipe and working and spinning the crown to make a flat disc. The furnace had to have an aperture large enough to allow the disc to be reheated. The remaining bull's eye centre used to be a feature of some old shop windows, but was mainly returned to the melting pot as cullet.

The muff technique was used by the Romans and by most Late Period glassmakers to make 'broad glass'. It produces a neat, rectangular sheet of fairly even thickness and is therefore very efficient in its use of materials, both in manufacture and in cutting. The muff was made by blowing a bubble, then whirling it around to stretch it into a sausage balloon shape. This could be re-introduced into the working furnace as needed, until the desired thickness of glass was achieved. It was then made into a cylinder by opening the bubble end, forming that into a figure of eight, switching the pipe to that end and heating and working the other end until an even cylinder was formed. This was then heated, laid on a last and cut down its length so that it could be opened and flattened onto the last. The sheets were typically 3ft long and 1ft wide. The wooden lasts were smoothed, then soaked in water for a long time before use. In crown glass, any bubbles are in a radial pattern, while muff glass shows bubbles elongated in parallel lines. The plumber used flint tools to cut the glass, and had his own moulds to make sections of lead matrix.

John Lennard's Glasshouse at Knole

Sometime before June 1585, Lennard and the glassmakers had reached an agreement to produce glass at Knole for the House. The whole operation was carefully planned. We have the record of the first stages of the plan as they were carried out. A memo of account records the volumes of wood delivered to the glasshouse, and the value of the wood charged to the glassmakers' account.[22] A price had clearly also been agreed for the glass produced, which allowed the glassmakers a good profit. We know the value of some of the glass produced, but not the quantities.

Lennard's steward at Knole was Roger Puleston. He kept accounts and wrote reports to Lennard at Lincoln's Inn. As a result we know more about the operation of the Knole glassmaking facility, and especially about its consumption of wood, than for any other. In 1905, Thomas Barrett Lennard published three documents concerning the Glasshouse.[23] These were Puleston's account for wood and the glassmen's initial supplies. In the archives there are also some account entries that shed further light on the glasshouse, and a heated correspondence about wood supplies, between Lennard and Edward Cranewell, with whom Lennard jointly owned parts of Whitley Forest, west of Sevenoaks. The glassmaking operations at Knole were huge, both in scale and in their demands on Lennard's resources and business relationships.

Between June 1585 and February 1586 a total of 697 cords of wood were delivered to the glasshouse. A cord is a standard measure for firewood. Where the wood was being cut, the woodsmen used a measuring cord 4ft long to set up sturdy posts 8ft apart and marked at 4ft high. Wood, cut into 4-foot lengths, was tightly

Fig. 4 Cord of wood (https://en.wikipedia.org/wiki/File:Cord_of_wood.jpg).

stacked. Typically, this wood came from coppices. Where logs were used, they were split down their length into suitable thickness.

A cord of wood is 3.26 cubic metres (**Fig. 4**), and, once dry, the wood weighs about 1.37 tonnes. The cords gathered up to February 1586 would have been dry enough for burning from autumn 1586 and their weight reduced to 930 tonnes. The wood was stacked loose at the glasshouse site to dry. With logs in alternate directions and space between logs and stacks to allow air circulation, the wood store occupied 2¼ acres.[24]

The last 28 cords (about 38 tonnes) to arrive, on 19 February 1586, were with a complete glassmaking 'starter kit'. The glassmaking operation was relatively mobile. Teams moved into the estate of a large house and worked there for a year or two, making glass for the now-fashionable large windows. The kit comprised specialist items including:

Pot clay: two loads of clay to make 12 pots, but we don't have information about where this clay came from, nor how big the load was.

Zaffran: 4lb of 'safron', a cobalt pigment, often called 'zaffran', from Iran or the Levant and traded through Venice. The 4lb would be enough give a good colour to 1.8 tonnes of glass. The glass at Knole shows the natural green of forest glass, purple from manganese (which could also balance the green to produce a colourless glass), and cobalt blue (**Fig. 5**).

6 glass-blowing pipes,

'4 stones for making an oven, 3 siles' and other materials and equipment. The 4 stones may be the 'sieges' (shelves) within the furnace chambers, and the 'siles' (sills) for the working area outside the furnace chamber.

The Knole glassmakers also brought leftovers from their previous project, 178 bushels of ash (6.5 cubic metres),[25] which would allow the founder to get started and to assess and incorporate the local ash and 4 bushels of 'frit'. The whole set of materials brought onto site was valued at £18[£54,000].[26] A kit of that size occupied many carts and wains, and took some time to arrive. By the time all was delivered, everything necessary for the glasshouse was on site.

Local stone, bricks and construction timber, and shingles were easy to provide. Suitable sand was readily available locally. White sand from Maidstone was used

Fig. 5 Mauve and green-tinged leaded glass in situ at Knole; a) internal view, b) external. (Photo by S. Draper.)

in 1662 and sand from Reigate and Fairlight had been used from the 13th Century.[27] The Knole sand is from the same geological formation as these last two, and may well have been suitable.

The glassmakers were able to build their furnace and accommodation, and get ready to make and fire pots. Once the heat of summer was over, the furnace was fired and glass production could begin. However, all was not well. Knole is a very big house and needed a lot of glass – more than the furnace could make in a single winter, and hundreds of tons more firewood were needed, to dry ready for a second winter of production. To be ready in time, in July 1586 Lennard's staff had to begin cutting and stacking the wood that would be burned from autumn 1587.

Rights to the wood from some parts of Whitley and Milrodde Woods came with the Manor of Knole. This is where Lennard had harvested much of the first year's 900 tonnes. Earlier in his career, in partnership with Edward Cranewell, he had bought rights to timber in other parts of Whitley from the Manor of Otford. Income from these woods was enormous (equivalent to £150k per partner, per annum) and the partners were very jealous of their own rights and responsibilities in maintaining the hedges and fences and ensuring that they received payments from

Fig. 6 Cranewell's letter with Lennard's red-ink draft reply. (Reproduced by courtesy of Essex Record Office D/DL C44; photo by S. Draper.)

each other for every piece of work and cutting operation carried out. Letters were exchanged with escalating accusations of bad faith, cheating, not paying for work, damaging the regeneration of the woods, and more. Lennard kept Cranewell's letters and drafted his replies on them in angry red ink (**Fig. 6**). A great deal about the management of the woodland can be gleaned from these letters, both men liked to be on top of every detail and included every scrap to promote their cause.

Cranewell's correspondence provides the vital information that the woods were coppiced. Coppices are created by cutting relatively young trees just above ground level. Fresh shoots spring from around the stump and grow rapidly into long, straight timbers. They must be harvested before they get too heavy. The ideal harvesting period varies from 7 years for chestnut and hazel up to 20 years for oak. Beech doesn't coppice well. With a seven-year harvest the landowner divided the woodland into seven sections harvested yearly, in turn. Cranewell complained about his 'spring', the new shoots produced from recently harvested wood. Lennard's carriers had opened the bars of the fences and damaged the hedges, allowing stock and wild animals in to eat the tender shoots and leaves, and endangering future income.

In woodlands with livestock, such as the deerpark at Knole, the 'lop and top' method of pollarding would succeed where coppicing could not (**Fig. 7**). The low branches were removed and the entire top of the tree cut off. The logwood

Fig. 7 The two types of coppicing, (above) conventional and (right) 'lop-and-top'. (Photo by S. Draper.)

produced could then be cut up at leisure. New shoots, safely above the reach of livestock, grow quickly, but harvesting requires the use of ladders and takes much longer than in a coppice.

A new deal was forged between Lennard and Cranewell, but by April 1587 it was under strain. As before, Cranewell provided lots of detail about quantities of wood, revealing that only 351 cords, about 480 tonnes, were sent from Whitley and Milrodde.

In other letters Cranewell writes of thefts of wood from Whitley.[28] In one he states that if certain tenants in Whitley are searched, 'you shall not fayle to fynd corde wood uppon their fyers & in their houses'. Lennard needed the glazing project finished quickly, so he commissioned a second glass furnace. He needed a further 500+ tonnes of wood. He had to return to Lincoln's Inn just as the glasshouse went into production about the end of October 1587.

In the twelve months up to 1 October 1587, Henry Croucke, shingler, made 10,000 shingles in Knole Park, 600 of which were carried to the upper glasshouse, the rest remained within the Park.[29] These 600, laid overlapping 3-deep, would cover a roof of about 30m^2. This is plenty to cover a new furnace and its working areas, which were within the existing glasshouse complex, as Puleston's letters in November make clear.[30] These summarise the situation on glass production, security, and the shortage of wood. Glass production was getting underway, and the value of glass produced was already outstripping that of the wood supplied. Wood was being produced only within the Park, and the woodcutters weren't able to cut it half as fast as it was carried away because they were having to 'lop and top', or to harvest from pollards. The Park was recently secured with new palings and shores for the fence. Puleston wrote:

> The outward Courte gate is locked evry night at supper tyme and all the night after supper also; the Towne gate and all the gates in the park are kepte locked both

> night and day. I spake with Lawe and he came thether where Adams worketh and vyewed the treese and he sayed he would take up as much as would suffice his torne. All the glass he brought home not by horse load but by carte loads and he handsomely placed in the Chamber where your worshipp apointed as you shall see at your retorne – there are two locks on the dore to make all fast.

Puleston was at pains to report that the key glasshouse personnel were working diligently and effectively. Uniquely, he tells us exactly who was there, and what they were doing, which is more than we know of the operation of any contemporary glasshouse. In charge was Mr[31] Onoby (see below).[32] Mr Valyan had returned on Friday 3 November 1587, and Puleston wanted him to work as before. Onoby consented:

> 'Valyan hath undertaken the charge of the one halfe of the glashowse and Ferris worketh with him on the same side, and the other half Onoby hath, but he doth not worke, for on that side Mr. Brusell and the other younge man worketh and Onoby is dressing and heatinge his furnesse for on Monday next he meaneth to begin to worke there.'

Onoby was evidently dressing his new furnace in the upper glasshouse, which took a little longer than hoped. He was to be assisted by Mr Brussell, his son.

The origins of the glassmen

Jean Carré brought both Huguenot and Venetian glassmen to England to work on his glassmaking enterprises. The Knole team's senior two, Valyan and Onoby, appear in records elsewhere before 1587. Valyan has been identified as Pierre Vaillant.[33] On 7 October 1576 he was one of the 'glassworkers from the glasshouse at Buckholt' admitted to communion at the Walloon church at Southampton.[34]

Mr Onoby is of particular interest, as he constructed and worked the second furnace at Knole. His son was Mr Brussell, so Onoby appears to be his first name. At the Burgate estate in Hampshire a record has been found,[35] dated 8 December 1586, of Ognybene Luthery, a Venetian, who had 'of late erected a house, furnace, and oven on the wood of Henry Smyth gent. of Burgate'. At that time, the Burgate estate included Vann Copse, where a Late furnace has been found.[36]

Given that Puleston used a phonetic system for names, Ognybene might easily have become Onoby.[37] There is no direct link between our Onoby, Ognybene, and that furnace, but it is highly suggestive. The Vann Copse furnace is unusually narrow, as if it could hold only two pots and would be worked from just one side (**Fig. 8**). Onoby's new furnace at Knole was to be worked by just Onoby and his son, which suggests it might be similar.

Evidence of the Knole Glasshouse?

Attempts have been made to identify the exact site of the Knole glasshouse;[38] investigators looked for heaps of ash and quantities of leftover glass in, and outside, Knole Park. However, it was generally assumed that these facilities would normally be sited on the top of the hills, to get maximum draught.[39] As shown above, this siting assumption is incorrect. Sites are low down, maybe on a slight

VANN FURNACE, FROM THE NORTH-WEST, SHOWING THE HEARTH TUNNELS AND FIRE CHAMBER.

Fig. 8 Excavation of Vann Furnace, 1931. (Reproduced, with permission, from *Glass Industry of the Weald*, Plate XXII.)

slope just above water. Without a chimney, and needing to keep the glass hot while it was worked, a low, more sheltered site was used. Valuable stone shelves, ash, frit and any cullet were carefully removed from the sites when the team moved on. A site outside the Park is most unlikely, every gate to the Park being locked, and the

valuable wood and the glasshouse were kept within it.

At least the bases and fire chambers of furnaces might still be found. If one of the furnaces is narrow, as at Vann Copse, then Onoby's involvement in both is even more plausible. Much of Knole Park has been largely undisturbed since 1460, with little tree growth on the floor of the valleys, which were clear for riding and deer hunting. Post holes from the Glasshouse structure may be identifiable.

> 'The early excavations were confined to examinations of melting furnaces. Little attention has been given to exploring other important elements of the glasshouse, such as the layout and relationship of subsidiary furnaces, the areas in which materials were prepared and stored and the arrangements for assembling fuel. This information would be of particular interest in relation to a post-immigrant, window producing, glasshouse'.[40]

At Knole, we just might have exactly what archaeologists are hoping to find!

APPENDIX

CALCULATIONS OF QUANTITIES AND VALUE OF GLASS PRODUCED

The purpose of this section is to address the economics of the glassmaking activity at Knole. Only for Knole do we have enough data to form a complete model of the economics of Late period glassmaking. Three questions are addressed, all are cross-checked with other records to ensure the answers are reasonable:

How much glass could have been produced by the men and materials available?
What was the probable value of that glass?
What profit was made by the glassmakers to pay their team?

Quantities of Glass – Carré's Estimate: Jean Carré and Anthony Becku were given the exclusive right to make window glass in England for a term of 21 years in return for a payment to the Crown of one halfpenny for 'each glass of three squares'(*trois tables carrées*). This was the same tax as on a square foot of imported glass. Carré's application estimated an annual tax return of £40-50 for a furnace operated by four men.[41] Presumably these four were just the Masters, and were assisted by apprentices, stokers and others.

Glass was normally priced per sq. ft. Taking a 'glass of three squares' as 1 sq. ft., Carré was estimating production of up to £50 x 480 (halfpence per pound) = 24,000 sq. ft. per annum of glass from a double-sided furnace.

Quantities of Glass – What could have been made: from the Knole glassmaking accounts, we have complete figures for the quantity of wood delivered between June 1585 and February 1586:[42] 679 cords or 930 tonnes dry weight. This wood was burned in the glassmaking campaign of autumn 1586 to summer 1587. We have incomplete figures for wood delivered to the glass house for burning from autumn 1587.

Carré's patent application says 'at certain times of the year as at the height of summer the furnaces will be out for eight or ten weeks during the great heat'.[43] The furnaces therefore ran for about 42 weeks, during which they burned all 930

tonnes, a rate of 3.16 tonnes per day.[44] Quite a few stokers would be needed, even equipped with the wheelbarrow which came as part of the 'starter kit'.

A typical yield of ash from wood is only about 1-2%, so using the recipe of two parts of sand to one part of ash means it would take 67kg of wood to produce ash for one kilo of glass. It has been estimated that, including fuel, 150-200 kg of wood would be needed per kilo of glass.[45] That assumes that the wood for ash had to be burned separately from the fuel in the furnaces in order to ensure quality. Late window glass is characterised as 'high lime, low alkali', making it consistently stronger and more weather resistant.[46] At Knole there are three obvious ways the glassmakers could have boosted their lime content with local materials: burning oak fuel, using lime-rich sand from ragstone, or adding lime from the Downs. Any of these would allow furnace ash to be used for the glassmaking and reduce the requirement for wood to 80-130 kg per kg of glass. The calculations below assume that the ideal of 80 kg is optimistic, and are based on 200 and 100 kg of wood per kg of glass.

Wages: in 1569, Carré's co-patentee, Becku, complained of the glassmakers, 'Their wages be greate, for the principall workeman hath 18*s* daylie and for that he is bounde to make 3 cases of glass which is of his part not accomplished and yet paid for'.[47] With a wage for a skilled workman at that time of 1*s*. daily, this 18*s*. must have been for the whole team, which is confirmed by the value calculations below. Lennard's arrangement with Onoby was more financially astute. He charged the glassmakers for the fuel wood, and credited them for the glass produced. The more efficiently they operated, the more profit they would make. A profit of 18*s*. daily is a reasonable guide to what was needed to pay the team.

Price of Glass: there are a number of records of window glass prices for the end of the Late period (1600-1620). The inventory of a Petworth glass merchant priced window glass at 3d. per sq.ft.. The proposed new house at Petworth had 9,732 sq. ft. of glass, estimated at 6d. a sq.ft. and the same price was quoted for new glass at what is now Southwark Cathedral. Both the latter included lead and fixing, so 3d. a foot for 'window glass is not far out'.[48] Between 1601 and 1620 the price of window glass in the lower Thames area (Windsor to Kent) was about 75% of the price in 1581-1590.[49]

Becku's complaint (see *Wages*, above) was that the glassmakers should have made 3 cases of glass worth 30*s*. daily. At 4*d*. per sq. ft. this comes to 90 sq. ft., or 22,640 sq. ft. per working year[50] – very much in line with the patent application.[51] A 1580s price of 4*d*. per sq. ft. therefore seems a good basis for estimating the value of the Knole glass. The calculations below compare prices of 4*d*. and 6*d*. per sq. ft. of glass.

Table 1 compares the amounts of glass produced and the profits made at different glass prices. Two different rates of wood consumption per kg of glass are assumed. Although glass was produced only for 42 weeks of the year, the workers had to live on this money for the whole year, so daily profits are calculated for 52 6-day weeks' work.

With efficient operation of the furnace, using 100kg of wood to make 1kg of glass, and a price of 4*d*. per square foot, the glassmakers would get 19*s*. per day

TABLE 1. AMOUNTS OF GLASS PRODUCED AND PROFITS MADE

200kg wood per kg glass	Cords	Value	Wood Weight (tonnes)	Glass (tonnes)	Glass[52] (sq.ft.)	Glass value 4*d*/sq.ft.	Glass value 6*d*/sq.ft.
Jun 1585-Feb1586	679	£113	930	4.65	12,298	£205	£307
Profit						£92	£194
Profit/day						5*s* 11*d*	12*s* 6*d*

100kg wood per kg glass	Cords	Value	Wood Weight (tonnes)	Glass (tonnes)	Glass (sq.ft.)	Glass value *4d*/sq.ft.	Glass value 6*d*/sq.ft.
Jun 1585-Feb1586	679	£113	930	9.30	24,595	£410	£615
Profit						£297	£502
Profit/day						19*s* 0*d*	32*s* 2*d*

over a full year. These figures were established above as the most plausible. The area of glass produced is also consistent with Carré's patent application and with Becku's complaint (see Wages, above).

In comparison with the 9,732 sq. ft. required for the proposed new house at Petworth, the amount produced for Knole seems very great, especially as a second production campaign was needed at Knole. However, Knole is exceptionally large – 'more like a town than a house'[53] – with an enormous area of glass that has not changed significantly since Lennard's project.

ENDNOTES

1 Thomas Barrett-Lennard, 1908, *An Account of the Families of Lennard and Barrett. Compiled largely from original documents* (privately published), pp. 15-16, 128-131. From https://www.scribd.com/document/159147885/An-Account-of-the-Families-of-Lennard-and-Barrett. £240 is worth £720,000 today, converting by a wage/income equivalence of £1 in 1580 to £3,000 in 2017.

2 Barrett-Lennard, *An Account of the Families*, p. 87. (Worth £6 million today.)

3 *The Antiquary Magazine*, Vol. 41 (London 1905), from http://www.archive.org/details/antiquarymagazin41londuoft.

4 Barrett-Lennard, *An Account of the Families*, p. 139.

5 Essex Record Office, Chelmsford [hereafter ERO] D/DL F155 Copy of Will of Thomas Rolf of [no parish given]. Lennard's copy of Rolf's will shows that Rolf left everything to his executors, which is why Lennard offered them each 600 marks for the residue of lease of Knole.

6 Kent History and Library Centre, Maidstone [hereafter KHLC] U269/E336/1 *c*.1561 'The manor of Knole'. States that Knole House is 'rainous' [ruinous] and in decay, made for the Earl of Leicester.

7 KHLC U1450/T6/30 Manor of Knole; Panthurst park in Sevenoaks and Chevening; Whitclif wood in Sevenoaks Weald; Skenehill; Westwood; Hurste; Jenkyns Commons. Earl of Leicester to Thomas Rolf; landlord and heirs only to occupy mansion house when they like but not upper gate house or any other premises. Tenant has power to alter and rebuild mansion house as he thinks

proper: draft (1566). Thomas Rolf's 99-year lease began on 25th March 1566, but he died in the autumn of 1566.

8 Mathew Johnson (ed.), 2017, *Lived Experience in the Later Middle Ages*, The Highfield Press (St Andrews), pp. 119-120.

9 G.H. Kenyon, 1967, *The Glass Industry of The Weald* (Leicester University Press), pp. 27-29.

10 *Ibid*., pp. 154-170.

11 *Ibid*., p. 35.

12 John Blair and Nigel Ramsay (eds), 1991, *English Medieval Industries: Craftsmen, Techniques, Products* (London), p. 266.

13 Kenyon, *Glass Industry*, p. 84.

14 *Ibid*., pp. 120-124. Jean Carré and Anthony Becku were given the exclusive right to make window glass in England for a term of 21 years in return for a payment of one halfpenny for 'each glass of three squares' (*trois tables carées).* Carré's patent application estimated an annual tax return of £40 to £50 per furnace. Carré set up permanent glassworks at Crutched Friars in London and at Fernfold (near Chiddingfold, Surrey). *Calendar of Patent Rolls* 9 Elizabeth I: Part XI, pp. 146-147:

'8 Sept. 1567. Licence for 21 years for Anthony Beccku alias Dolyn and John Carr, born in the Low Countries under the dominion of the King of Spain, to erect in any place in England, wherever they can agree with the owner of the place, furnaces, buildings and machinery for making glass for glazing and to make there glass for glazing as made in France, Lorraine and Burgundy ; from the present date ; no others to practise the art, unless employed or licensed by them, on pain of forfeiture to the Crown of the glass so made, and instruments and 100l. for every offence ; the licensees to pay for all glass made the same sums as are payable by stranger merchants for the same glass when imported, and to render account of glass made to persons appointed by the Crown for that purpose; the licence to be void, if the licensees shall not before Christmas, 1568, make such glass or set up and keep working two furnaces for that purpose ; the licensees to instruct fully in the art a convenient number of Englishmen apprenticed to them according to the custom of the City of London, for which purpose the licensees are hereby licensed to take apprentices. At their suit: they have undertaken to make enough of such glass for the use of the realm and cheaper than that imported, and also to teach the Queen's subjects their art'.

15 Hugh Willmott, 2005, *A History of English Glassmaking AD 43-1800* (Stroud), p. 95.

16 The diamond-shaped pieces of glass were known as 'quarries' or 'quarrels', their shape being the same as that of the head of a crossbow bolt, also known as a quarrel.

17 Ian James Merchant, 1998, 'English Medieval Glass-Making Technology: Scientific Analysis of The Evidence', PH.D. thesis (University of Sheffield), pp. 167-170. Temperatures actually achieved in the furnaces were measured by analysis of the formation of different minerals and crystal structures in frit, crucible fragments and glass deposits recovered from Medieval and Late furnace sites. In Tudor times furnace temperatures could be gauged by colour, 900°C is orange, 1300°C is light yellow. From https://www.paragonweb.com/Kiln_Pointer.cfm?PID=464.

18 Michael Cable (ed.), 2006, *The Art of Glass by Antonio Neri* (1662), translated into English by Christopher Merrett, with an Introductory Essay by W.E.S. Turner, The Society of Glass Technology (Sheffield); Merrett in *The Art of Glass*, p. 303, which is Merrett's p. 245.

19 Merrett *The Art of Glass*, p. 304, which is Merrett's p. 246 'those for Green Glass are made of Non-Such clay, mixed with another clay brought from Worcestershire, which bears the fire better than Nonsuch, but both together make the best pots'.

20 Kenyon, *Glass Industry*, pp. 55-58.

21 Turner, *The Art of Glass*, p. 10.

22 *Ibid.*, p. 127.

23 *The Antiquary Magazine*, vol. 41, pp. 127-129.

24 Stacking the logs in alternate directions, with plenty of space between logs to allow quick drying, each cord would make four stacks. Each stack would be 4ft square and 4ft high (a practical height for an unsupported stack). Allowing a 2ft passage between stacks means that each cord would occupy four, 6ft square spaces, 144 square ft. With 679 cords delivered by February 1586, that is 97,776 square ft, 2.24 acres.

25 A bushel was a standard basket for holding loose goods, such as grain or peas, and held eight gallons. Ash was used in a tanning, fulling and other processes and sold for 6*d*. a bushel.

[26] *The Antiquary Magazine*, vol. 41, p. 128. The glass makers were given 108 cords of wood (at 3*s*. 4*d*. per cord = £18) without charge to their debt, in exchange for the kit.

[27] Turner, *The Art of Glass*, p. 28.

[28] Barrett-Lennard, *An Account of The Families*, p. 139.

[29] ERO D/DL E61 Bundle of accounts and miscellaneous papers mainly relating to Kent tied together by leather thong. Item 23.

[30] ERO D/DL C44 Letters of John Lennard, pinned with contributor's proofs for *The Antiquary Magazine*.

[31] Puleston appears to have use Mr as the title for a Master glassmaker.

[32] Barrett-Lennard calls him Oneby, but every reference in Puleston's letters, except the first, is clearly written as Onoby, with the 'o' and 'b' written as separate characters. In the first instance alone, the 'o' and the 'b' are joined up, which often makes an 'o' look like an 'e'.

[33] *The Antiquary Magazine*, vol. 41, p. 164, note of a letter in the *Sevenoaks Chronicle* of 9 April 1905 by Mr E. Wyndham Hulme, of Sevenoaks.

[34] Willmott, *English Glassmaking*, p. 79.

[35] *Ibid*., p. 78.

[36] The Vann Copse furnace is of the distinctive, 'winged' design. Very few remnants of glassmaking were found, as if the site had been carefully cleared and all the specialised stones removed.

[37] Ognybene is still a name that appears in Italy near Venice.

[38] Gordon Ward, 1980, *Sevenoaks Essays* (Sevenoaks, 1980), pp. 17-19; 'At The Painted Gate'; David Eve, 1998, 'Reinterpreting the Site of Knole Glassworks, Kent', *Post-Medieval Archaeology*, 32:1, 139-142.

[39] Mr. E. Wyndham Hulme also wrote in *The Antiquary Magazine* Volume 41 p164 'It would also be interesting to fix the site of the furnaces, which would probably have been built on the highest ground in the park so as to obtain a forced draught'.

[40] Colin Jeremy Clark, 2006, 'The Glass Industry in the Woodland Economy of the Weald', PH.D. thesis (University of Sheffield), pp. 258-260.

[41] Kenyon, 1967, p. 121.

[42] *The Antiquary Magazine*, Volume 41, p. 127.

[43] Kenyon 1967, p. 121.

[44] Clark, 2006, p. 191, 'a drop in temperature by more than 200-300°C could seriously affect the working life of a furnace'.

[45] Michael Cable, 1998, 'The operation of wood-fired glass-melting furnaces', in P. McCray and D. Kingery (eds), *The Prehistory and History of Glassmaking Technology*, pp. 315-330.

[46] Clark 2006, pp. 175-176. Late glass 'has a higher lime content ('high lime, low alkali' type). It is not clear how a greater volume of lime was introduced without a corresponding rise in alkali concentrations, and raises the question of whether this was achieved by the introduction of a different ash source, or a lime product such as chalk or limestone, available locally from the Downs'.

[47] Kenyon 1967, pp. 110-111.

[48] Kenyon 1967, p. 89.

[49] D.W. Crossley, 1972, *The Performance of the Glass Industry in Sixteenth-Century England*, *The Economic History Review*, Vol. 25, No. 3, p. 423. Stable URL: https://www.jstor.org/stable/2593430.

[50] All glass production calculations assume a working year of 42 weeks of 6 days. Furnace consumption is based on 42 weeks of 7 days.

[51] At 100 kg of wood per kg of glass, that 90 sq.ft. would use 3.4 tonnes of wood, so 2.48 cords valued at 3*s*. 4*d*. a cord, total 8*s*. 3*d*. With 18*s*. for the glassmakers, that makes total costs of 26*s*. 3*d*., leaving Becku with *3s*. 3*d*. for himself, if the glass was made.

[52] Assumes an average thickness of 1/16in. Kenyon, 1967, p. 30. A lot of the observed Late glass at Knole contains bubbles which show that it was made in haste. The 'metal' needs to be left in the furnace at full temperature for longer to allow the bubbles to clear. Bubbled quarries are relatively thick, others are irregular in thickness.

[53] Virginia Woolf, *Orlando*, Kindle Edition (2012), p. 115.