A 16th Century Glasshouse at Knightons, Alfold, Surrey

by ERIC S WOOD

CONTENTS

FIGURES

PLATES

A SIXTEENTH CENTURY GLASSHOUSE: KNIGHTONS, ALFOLD, SURREY

by ERIC S. WOOD

The Background. After the Roman period, and sporadic small-scale glassmaking in Saxon England, glass was made in England more or less continuously from the first half of the 13th century. This industry was based on local materials, and used potash derived from forest products for flux (instead of the soda used by the more southern inheritors of the Roman Expire). Its main concentration was in eleven adjacent parishes in the north-western Weald of Sussex and Surrey, centred on Chiddingfold in Surrey until the mid-16th century, and subsequently on Wisborough Green in Sussex. The next largest concentration was in Staffordshire, and other isolated sites are known from Cumberland, Yorkshire, Cheshire, Herefordshire, Gloucestershire, Hampshire, Sussex and Kent; in all some 75-80 sites at present known. Of these more than half are in the Weald. Coal-firing was first applied to glassmaking in 1611, and this, coupled with the prohibition on the use of wood in 1615, led to the removal of the industry away from its forest roots into the towns and industrialised areas, and changed its nature.

The fullest account of the Forest industry is G.H. Kenyon's The Glass Industry of the Weald (1967), which deals with every relevant aspect. Kenyon lists 42 sites in the Weald (of which Knightons is the last). Of these, some 13 are Farly (see page M42), and have to fill nearly 350 years; 16 are Late, covering 50 years; the rest are difficult to classify. The first dated site, Blunden's Wood, is early 14th century. There must be more to find. Moreover, the state of preservation, and the completeness of excavation, of the known sites, has been far from even, and much work remains to be done, both quantitatively and qualitatively, if the many problems of the industry are to be solved. Knightons indicates some of these very clearly.

The economic and historical aspects of the industry, particularly its later phases, are dealt with exhaustively in that other essential work, Eleanor S. Godfrey's masterly survey The Development of English Glassmaking 1560-1640 (1975), which Kenyon was able to draw on in its earlier thesis form.

These two books will be the standard reference works on the Forest glass industry for many years to come. Work since 1967 will necessarily have to be related to Kenyon, and either confirm or refute his propositions. He was able to include (page 208) a brief note on Knightons (his no. 42), but the present paper provides the material for a reappraisal of the importance of this site. Although I was able to discuss many of its points with him before he died, I greatly regret that he did not live to see it finished. He has been much in my mind during the writing, and in great measure it is a memorial to him, however inadequate.

Many of the results of the excavations at Rosedale and Hutton, Yorkshire (Crossley and Aberg 1972), too late for Kenyon, are also relevant to the Wealden industry; and the careful researches of Anite Engle (Engle 1977) have thrown much new light on the "Late" glassmakers, and on other aspects too. Several sites have, since 1967, been discovered in the Weald, and excavation of these may yield some fresh facts.

Two are in Chiddingfold (Surrey) parish: Tugley Wood (on Peytowe land) and Rovehurst; two are in Shillinglee Park, Plaistow (Sussex).

In addition, two sites have been excavated on Glass Brow, Ditcham Woods, Buriton (Hampshire) -- publication by Elizabeth Lewis, Winchester Museum, forthcoming-- they are poorly preserved, but seem to have rectangular furnaces of Late date. The sites at Rovehurst and Tugley are mentioned by Kenyon (1967, 155) as only "remotely possible" glass sites; it is satisfactory that they have now been identified. Outside the Weald, two other sites are now suspected in Farndale (North Yorkshire), to add to the Rosedale - Hutton group (per Mr. Raymond Hayes, FSA). The furnace recently excavated at Kimmeridge (Dorset) is of the Vann winged type, but has flues to permit shale to be used as fuel (1618-1623) (Dorset Evening Echo 19 April 1980; and Crossley (1980)).

The importance of Knightons itself will be apparent from this paper; it throws up many problems which will have to be solved eventually for full understanding of the Forest industry.

Discovery. The site was found by F.W. Holling, FSA, then curator of Guildford Museum, in May 1965. Mr. Holling was walking in Sidney Wood, Alfold, when he noticed the usual signs of a glass-house -- low mounds; burnt soil, stone etc; glazed stones and clay; crucible; and pieces of glass. He notified G.H. Kenyon, the authority on the Wealden glass industry; they examined the site, and found glass of "Early" type on the bank. Glass and crucible fragments collected before the excavation were lodged in Guildford Museum, Castle Arch, under the reference no RB 1577, which has been given to all material from the site lodged subsequently.

Although the site is just inside the western boundary of Alfold parish, it was decided, to avoid confusion with the site some half-mile to the east in Glasshouse Copse, already known as Sidney Wood (Kenyon 1967, no 38), to call it Knightons, after the house visible from it to the west in Dunsfold parish, and Old Knightons a quarter-mile to the south. Knightons is no. 42 in Kenyon's list of Wealden sites (Kenyon 1967, p 208).

The site seemed to be extensive, and untouched. It was thus of immediate intrinsic importance. Search at the Guildford Muniment Room produced no records of its date or of the identity of the glassmakers.

The Site -- Ownership. The glasshouse site is in Sidney Wood, a large area of woodland owned by the Forestry Commission, and part of Chiddingfold Forest. Permission to excavate was readily given by the regional Conservancy of the Commission. The local foresters, Mr. Francis and Mr. R.C. Stern, were interested throughout, and kept a friendly eye on the site (which in fact suffered no damage during the years it was open and being worked on, except from the weather). Warm gratitude is due for this cooperation.

Location. The site is at TQ/0170.3410; 9 miles SSE of Guildford, 4 miles SW of Cranleigh, 6½ miles SE of Godalming, and 1¼ miles W of Alfold village. It is just inside the western boundary of Alfold parish, with the bank separating this from Dunsfold only a few yards away. It lies one mile north of the Sussex border (Plaistow parish), and is in the heart of typical traditional Wealden glass country.

Geology. The soil on which the site stands, and the whole area of Sidney Wood, consists of a stiff yellowish to buff clay of the upper part of horizon 5 of the Wealden series (between sandstones e and f); it is classified h^{1e} (Geological Survey 1" map, sheet 301, Solid and Drift (Haslemere), 1969). The colour is the effect of weathering in the surface levels of a grey clay (Thurrell et al 1968, pp 19, 53). There is only a thin (3 - 4 inch - 7.5 - 10 cm) layer of humus.

Topography. The part of Sidney Wood in which Knightons stands is covered with oaks planted between 1880 and 1900, with an uneven undergrowth of hazels. The site is immediately west of the forest track which leaves the Dunsfold-Alfold forest road at the lodge by the 17th century house of Old Knightons, and some ¼ mile along this path. Just at that point the track is joined by a path crossing the forest from the north. The glasshouse lies on the edge of a bank which falls over a distance of some 85 feet (27 m) to a small stream some 20 feet (6 m) below. Another smaller stream runs under the canal and forms one side of the western claypit; The Wey and Arun Junction Canal (cut in 1813 and abandoned in 1867) passes only 40 feet (12.5 m) from the site (to the east). (See general map. fig. 1; and detailed location plan fig. 2).

The narrow path which now joins the track at the site was once continuous with it, and is shown on the first edition 6 inch O.S. map (1874-80) as the only path through this part of the wood. On the 1920 edition a loop is shown leaving this path at the corner where the glasshouse is; this has recently become the betterworn path. There is no way of knowing how old the path is. But it makes a suspicious curve round the glasshouse in the 1874 map, and cuts right through the eastern claypit of the site. It is therefore younger than the glasshouse, at least in its northern continuation. The part of it between the site and Old Knightons could have been the original access track; it has some iron slag metalling.

Petrology. The stones of which the structures are made are a buff fine-grained sandstone. A sample was kindly examined under the microscope by Mr. A.L. Jewell, Curator of Haslemere Museum (4.11.78), and determined as sandstone from the Hythe Beds of the Lower Greensand. It contained sponge spicules and glauconite. Mr. Jewell made a hydrochloric acid effervescence test for globigerina, present in Bargate, the other common stone used for building in this area, but the test was negative. Another characteristic of Bargate, mica, was also absent.

The Hythe beds sandstones centre locally on Blackdown, which is composed of them, and pieces are common on the Weald clays for several miles round, representing head carried down from this hill.

The Owners of Sidney Wood. The history of Sidney Wood itself unfortunately throws no light on the glasshouse, but is of some intrinsic interest. Manning and Bray (1809, ii, 68) records that the manor of Shalford Bradeston, which seems to have included this land, was owned by Walter de la Pole in right of Elizabeth his wife (the de la Poles were Earls of Suffolk). In 1413 he granted to William Sedenye and Agnes his wife land called Rykhurst in Alfold (thenceforward called the manor of Sidney, alias Rickhurst or Hedgecourt). This Sidney came from Cranleigh; the Sidney family is recorded in a deed of 1313 regarding lands in Alfold -- they had held Baynards in Pollingford. The Sidneys appear to have owned the manor until late in the 16th century. In 1595-6 Richard Ireland died possessed of a house called

Sydneys, which he held of the lord of Pollingfold. (Is this the house now known as Sydney Farm? An Ireland was probably lord of Clapham manor in 1503, and Irelands occur in the east of Surrey, as well as an Agnes Ireland who married Thomas Quennell of Lythe Hill, Haslemere, who owned the ironworks at Imbhams). (VCH,iii,78). Richard Ireland's sister and heir Elizabeth was a minor at his death, and it was probably from her that the estate passed to the Dorrington family, who held it from the early 17th century to the mid-19th century.

In 1728 or 1729 - Dorrington and his wife, and Francis Dorrington, let it to Mr. Kinsey, but it was purchased about this time by Sir John Frederick, Bt, lord of the manor of Hascombe, with which manor it descended until the 19th century (it was also partly in Dunsfold). (Sir J.F. died in 1755 aged 73). In 1903 it was the property of George Wyatt, but was bought before 1911 by J.E. Sparkes and H. Mellersh.

The Forestry Commission acquired Sidney Wood -- 94 ha -- from E.M.Mellersh in 1925. They have since added land at the north end. (None of the families mentioned above seems to have any connection with the glass industry, and Henry Smyth (see page M9), is still the most likely link with Knightons, although the manner of his relationship remains obscure).

Manning and Bray say that a wood on the Sidney estate of between 300 and 400 acres retains the name of the family, and is called Sidney Wood. "In it", they continue, "were some houses for making glass, which are long since (1809) decayed, but a field is still called Glass-house Field. It is not known what sort of glass was made here". The discovery of the two sites in the wood has mitigated this ignorance!

The early maps of Surrey -- Norden 1594 and 1607, and Speed 1611-2 and 1676 (the last reissued in The Theatre of the Empire of Great Britain, shows a Glashouse (sic) west of Awfold, and south of the Arun -- Sydney is shown to the south-west of this. Kenyon (1967, 203) thinks this is the Sidney Wood site (no. 38), and I agree; its position south of the river must be an error. It is likely that Norden would have shown only a glasshouse which was actually working at the time, or had ceased only within

the very recent past. Sidney Wood is a "classical" Late site, and fits this prescription, whereas Knightons does not. But Manning and Bray's source seems to imply that there was a tradition of more than one glasshouse in the wood. Perhaps yet another remains to be found! The Glasshouse Field may be a clearing in the part of the wood where no 38 stood.

The first map to show Sidney Wood seems to be John Seller's Map of Surrey, of c 1693. It is shown as a wood in Roque's map of 1762, but apparently only the western half of it. This in itself, if accurate, supports the existence of a field where the eastern half of the wood now is. The 2 inch survey of 1810 shows the wood, indicated conventionally as woodland; the 1 inch survey of 1816 (published under the authority of Col. Mudge at the Tower), shows the wood in outline in its survey version, but in its county sheet version marks woodland only in a narrow and irregular band (¼ - 1/3 mile (406-541 m) at the most) along the canal[1]. This does not seem to represent the full extent of the tree cover at this time, and the economy of mapping is not easy to account for (unless a canal eye's view was intended), for a map attached to sale particulars of a sale of Sidney Wood and Farm in 1819 (Guildford Muniment Room, ref. 85/2/1 (2), no (17) shows the western half of the wood (that within the estate) as fully treed. But the eastern half may have then still been a field anyway -- the date is not far from that of Manning and Bray. Knightons glasshouse is not shown on any of these maps (or indeed on any map at all). In fact, the timber cover differs from west to east. The western half, which seems to have a long history as a wood, was planted or replanted with oaks from 1880 to 1900 (per Mr. Stern, Forestry Commission). These oaks extend over the whole area west of the canal, both north and south of the E-W road through the wood; they also stretch eastwards on both sides of the road as far as the N-S ride which crosses it. North of this, and east of the N-S ride, the cover is close-planted and mature conifers, with only a small area of deciduous trees by the eastern lodge and along the eastern edge of the wood. The other glasshouse is within the conifers, and it may be that these represent what was formerly Glasshouse Field.

---

(1) All these maps are in the collection of the Surrey Archaeological Society at Castle Arch, Guildford.

Henry Smyth. The facts about this man, who has a possible relevance for Knightons, have become slightly confused in recent publications on glass history (e.g. Godfrey 1975, p 16, followed by Engle 1977, p 3), and it is worth setting them down again.

Henry Smyth, merchant of London, obtained the first licence or patent under the new Tudor trade policy, in 1552. The licence (Pat Rolls, Ed VI, IV, p 323; 26 April 1552) may be summarised thus: Whereas Henry Smyth of London, merchant, intends to bring certain strangers into the realm expert in making "brode glass" such as is commonly called "Normandy glasse" (1), whereby divers of the king's subjects "may be sett to worke and gett their lyvyng and in tyme learne and be hable to make the said glasse them selfes" and instruct others;

Licence to the said Henry Smyth to bring from beyond seas such persons as are expedient for working the said "grasse" (sic); and for twenty years to make the said "Normandy glasse anywhere within the realm"; and no person without his authority "shall attempte or presume to make any kinde of the said brode glasse commonly wount to be called Normandye glasse or any other fytte for wyndowes", on pain of forfeiture of all glass so made. (English. By privy seal).

For the purposes of this patent Smyth could either have taken over an existing glasshouse, or started a new one. Winbolt (1933, p 11) says the Smyth "proposed to bring over workmen from Normandy, but the death of the king prevented the glassmakers, strong Calvinists, from coming". Kenyon (1967, p 111) repeats this without comment. But I cannot find the evidence on which Winbolt based this statement, and this is not the only possible course of events. Knightons yielded a coin of 1550, and has a new (for England) annealing furnace of specifically French, indeed

---

(1) The term broad glass was later confined to muff window glass, and the products of Lorraine, but in the mid-16th century is was used indiscriminately to cover crown window glass (and Normandy glass) as well (Godfrey 1975, p 16).

Normandy, type, designed for crown sheets. Smyth may have been laying his plans before the patent was granted, and have been ready to bring his Normans over at once. If Knightons was the glasshouse in question (and it certainly looks a strong candidate), they may have stayed until Edward VI's death in 1553, and then returned. But, it is just as likely that they stayed on in their secluded woodlands, unmolested by the change of royal religious policy, and moved on only when the life of the glasshouse came to its natural end.

The new annealing furnace may have been added to existing Early-type furnaces. That abandonment may have been sudden may be indicated by the nearly fresh coin, by the uncleared-out annealing furnace, with crown, flask and crucible still lying where they fell, and by the very large cullet store. But the Late glass in the cullet is unlikely to date as far back as 1553. Was the glasshouse closed officially, not for religious reasons, but because it was exceeding its licence by making glass other than window? or was it stricken by plague? The true facts, if Knightons was Smyth's glasshouse, will continue to elude us.

It is not known what interest Smyth had in our area in 1552, nor whether he held lands in Sidney Wood, Alfold or Dunsfold at any time. But that he had an interest in this part of Surrey very soon afterwards is shown by a conveyance of 1553 by Sir Thomas Holcrofte and his wife Julia to Hen. Smyth, citizen and mercer of London, of property of Guildford, Wonersh, Shalford and Bramley (Surrey Record Society, volume: Surrey Fines 1509-58, Fine no 1032).(1) It seems unlikely that this Henry Smyth and that of the 1552 patent were not the same man. Moreover, the Smyth family recurs in the district later. The Loseley MSS (348/86) in the Guildford Muniment Room (2) show that Henry Smith senior and Henry Smith junior, citizens and mercers of London, bought land in Hambledon and Godalming from Giles Hull in 1573. On part of this land (Lower

---

(1) I owe all these references to Miss. G.M.A. Beck of Guildford Muniment Room.

(2) With acknowledgments to Major J.R. More-Molyneux.

Burgate Copse, then in Godalming parish), the famous glasshouse known as Vann (Kenyon no 35), with its Late winged furnace, was built by Ogniabene Luteri in 1586. There is no direct proof that either of these two Henry Smiths is the Henry Smyth of the 1552 patent, but again the probability is overwhelming, and the latter could be the Henry Smith senior of 1573. If this is the case, it shows not only his continuing interest in this part of Surrey, (1) but his involvement in the glass industry as well. It strengthens the speculation that Knightons might have been on his land. But of course it is always possible that the glasshouse may have been set up by someone else from Normandy, not connected with Smyth at all -- members of the Bongard and Cocqwell families were in the neighbourhood not much later (Engle 1977, 10); or someone else could have come over.

---

(1) Henry Smyth (junior) Esq., who died in 1627, left land to found a charity in Alfold (producing £4.10.1 annually for the poor); I cannot find whether this land was actually in Alfold, where it was, nor when it was acquired.

The Excavation. Although the site was not in danger of clearance or development, it was decided to excavate it at once, in view of the rarity of such sites, recorded or not, and the paucity of recently or completely excavated glasshouses. The Surrey Archaeological Society (through its Excavations Committee) sponsored the investigation, which was in the charge of the writer, who had already excavated, for the Society, the 14th century glasshouse at Blunden's Wood, Hambledon (Wood 1965). For the first two years the development of the excavation was shared by Mr. Holling, the discoverer of the site. The excavation took place at somewhat irregular intervals -- but the optimum working period was very short, essentially for only a few weeks in Spring and Autumn, owing to the stiffness of the clay -- sticky in winter and rock-hard in summer -- and the incidence of midges, mosquitoes etc, which had a direct controlling effect on the number of volunteers! The work spread from 9th October 1965 to 26th May 1973. Completion was ensured by a determined effort by members of the Guildford Group of the Surrey Archaeological Society.

The site was visited by G.H. Kenyon, FSA (6 times); Mr. Kenyon's interest in the site was unfailing, and his knowledge freely shared -- his support until his death on 16th January 1977 was of the utmost value; also by Dr. D.B. Harden, FSA; R.J. Charleston, FSA; G.H. Tait, FSA; Mrs. E.S. Godfrey; Mr. D.E. Hogan; Mr. D.W. Crossley, FSA; and several other authorities. Their comments and advice were of the greatest value, and I am deeply grateful to them.

Methods. The remains (lowest courses) of the structures of the glasshouse were mostly only 1-3 inches (3-8 cm) below the surface, and some of the stones were actually visible. Excavation was carried out in a spirit of enquiry rather than of formal system. Squares were opened, with dimensions which seemed appropriate to the feature to be excavated -- where the evidential signs were thickest -- then, as each structure etc. emerged, it was opened up completely. The object was the total excavation of the glasshouse, to uncover all its structures and ancillary features, and to determine its full extent. Like most glasshouses, its relatively short life resulted in no, or minimal, stratification.

Each trench was given a letter, retained as the trench was extended, and the finds labelled accordingly. The structures revealed were renumbered or named in the light of the growing understanding of the site and its development and articulation. The letters and numbers are:

Square
A -- furnace 4
B -- furnace 1/2
C -- cullet store
D -- edge of bank, stone "floor"
E -- furnace 3
(F4 -- first name for F1)
(F = furnace)
X -- posthole area SE of F1 and F3
Y -- pit by F2 ("pond")
Z -- waste tip in "yard" pit
AA -- between F2 and stone "floor"
trial trenches or holes out from F3 and X
BB -- between F3 and track
ZA -- trench in "yard" to find edge of waste tip
ZB -- trial holes in "yard"
(Furnace names changed as work proceeded -- F1 was called at first the SW furnace, and later the square furnace; F2 the 'medieval' furnace). For the purpose of making a general plan of the site, a baseline was laid down along the west side of the woodland path, beginning at the lip of the bank. It was found that this had to be 65 feet (20 m) long. At this point (where the path joined the track) another baseline was run off at right angles, south of F3 and F4, to the edge of the large claypit (this needed to be 40 feet (12 m) long). These baselines were marked off by pegs at 10 foot intervals. On this basis a grid of 10 ft. squares could be laid down (and lettered) over the whole site, and drawing done square by square.
(The above is for record only; the account given in this paper is based entirely on the structures etc. as revealed by excavation).

THE EXCAVATED FEATURES

The excavation uncovered the following elements. The relative position of these can readily be seen from the generalised plan at Fig. 3.

The Furnaces.

Furnace 1. This occupies a central position in the glasshouse, and was evidently the original main working furnace. It lies at an angle of some 35° to the lip of the bank, and is some 24 feet (7 m) away from it. This position does not appear to represent a significant orientation in relation to the bank. In fact, none of the Knightons furnaces appears to be consciously oriented, either to the bank or to each other. F1 lies roughly NE/SW. Kenyon (1967, p 81) says that four furnaces in the Weald are sited with their long axis east and west, three north and south, and two others neither. He suggests that "it appears to be a matter of individual choice". In the case of F1 at Knightons, the furnace seems to be too far away from the edge of the bank to benefit from updraughts; and the hearth (see below) was at the NE end, not that of the prevailing winds, the SW. It looks as though the planners of Knightons were concerned not with orientation, but presumably only with convenience in relation to the site available. Experience must have shown that, once the fire got going, whichever end it was lit from, the direction of the wind was not material.

F1 is a normal medieval Northern type main furnace, rectangular with central flue and parallel sieges along the long sides. The walls are made of irregular stones, but well set. The south wall had been robbed out, but the trench was clearly visible, and the dimensions could be accurately ascertained. The west wall was complete and intact, and continued round the NW corner for about 1'6" (48 cm). The rest of this wall was robbed, and went underneath the overlapping F2 (see below). The dimensions are: outside 14'6" by 10'6" (4.46 x 3.23 m); inside 11' by 7'6" (3.36 x 2.3 m). The flue was 2'6" (76 cm) wide, as were the sieges. There were three crucible positions each side. The sieges are now only some 3-4" (8-10 cm) high; but these must be merely the foundations for stone and clay benches 2-3 feet (60-90cm) high, as in the Wealden examples figured by Kenyon (1967, fig 10,

p 77). These, with the rest of the furnaces, have been completely robbed out, and there is no evidence for their original height. (Plate 1). At the NE end of the flue was a patch of glass waste, hard and solid, 30" x 19" (75 x 48 cm) and 4" (10 cm) thick, the result no doubt of a burst or overturned pot. Outside this, in the access-gap for the fire, was the hearth, represented by purple cindery clay; outside this again the clay was red, and passed out into the yellow natural. Being closed off by a wall at the SW end, it is clear that F1 was fired only at one end, the NE. Blunden's Wood was fired from both ends (Wood 1965, fig 5), and Kenyon (1967, 76) points out that Wealden furnaces may be fired from either end, or both. Dorothy Charlesworth (1967, 131) took the view that the apparent firing of Blunden's Wood from both ends would be better interpreted as firing from one end and an area of burning at the other due to raking out. But she is now (personal communication 1970) prepared to accept double-ended firing at Blunden's Wood. There seems however to be no firm rule, and even late furnaces might be fired at one or two ends. As there is no evidence for the superstructures of any of the Knightons furnaces, there is no way of knowing how the draught was maintained.

The NE end of F1 was covered by a layer of what on first excavation looked like mortar. This formed a patch of some 5 feet (1.5m) by 8 feet (2.45m). It ran from the south edge of the flue to the south edge of F2; some 5 feet (1.5m) square lay inside the furnace. This was partly covered by a larger spread of stones (8'3" x 7'3" - 2.56 x 2.23m), some burnt, some not, mixed with earth (not clay). These stones could not therefore have been direct fall from the walls or roof of either furnace, but must have been discarded in this area after the "mortar" layer had been deposited. But in fact the layer turned out not to be mortar, but very hard (?trodden) greensand. It is possible to interpret this as all that is left of a heap or <u>store of sand</u>, placed where it was for convenient access from F3 (or F2), after F1 had been dismantled and been replaced by F2. The sand is unburnt, and is presumably what was left over. The layer is only some ½inch (1.5cm) thick, and rests on a layer of clinkery or burnt waste material, c 2 inches (5 cm) thick, which represents the hearth area of F1.

Furnace 2. At some stage in its life, and for an unknown reason, Furnace 1 was completely dismantled, and replaced by another of very similar form so close by that it overlapped the old site. Perhaps Knightons was taken over during its life by a new team of glassmakers, who was F1 as oldfashioned or inefficient, and replaced it by something better. Perhaps it just had incurable defects. The new furnace is well-built of good stones; the only surviving corner was made of one large square stone. It was of the same general type, but narrower than F1. It measures 14' x 9' (4.3 x 2.76 m), outside, with walls 18" (45 cm) thick; so internally it was 11' by 6' (3.38 x 1.84 m), which one may presume is the optimum for this type of furnace. The sieges were 2 feet (60 cm) wide, and the flue the same. There were again three crucible positions each side.

F2 was built with its south side almost entirely covering the former north side of F1. The SW corner is placed just where the cut-off N wall of F1 ceases, and may have used the same stones. Both are robbed so fully that the actual relationship is obscure. F2 is aligned slightly slanting in relation to F1, and its SE corner overlaps F1 by 2-3 feet (60-90 cm). It is several inches higher. (Fig. 4).

A probe was made into the extent of burning at the hearth at the NE end. This showed deep red soil for 25" (62.5 cm) down, until digging was prevented by water. The lower few inches of this were mixed with grey, and were paler, but there were no signs that the effects of burning had ceased; they couldcolour the soil for 2-3 feet (60-90 cm). At Blundens Wood the heat had reddened the soil for 2-3 feet (60-90 cm) all round the main furnace, and under the flue for a foot(30 cm) down. (Wood 1967, 58). Either the heat at Knightons was greater, or its life was longer, than at Blundens Wood.

At the NE corner was a pit, about 4' x 2' (1.2m x 60 cm) and 7" (17.5 cm) deep. This contained yellow clay mixed with burnt clay, and a small fire had been lit in it. The pit cut into the corner of the furnace, and may therefore have postdated or accompanied its robbing.

F2 was robbed probably within a century or so after it ceased to operate. The NW corner was deprived of stones, and the cullet from

the store next to it had encroached onto the furnace wall-trench. This must represent natural slumping of the cullet, or its being pushed out by the tree (see page 20).

Furnace 3. This is a long rectangular-type furnace 12 feet (3.6m) south-east of F4. Its long axis lies NE-SW. It was almost entirely robbed out, and at first presented a mass of burnt material difficult to interpret. But intensive effort established the following approximate dimensions:

The furnace is 14 feet (4.25 m) long outside, by 7'9" (2.3 m); the inside measurements are 12'6" by 6'3" (3.84 x 1.92 m). The central flue is c 1'6" (45 cm) wide. It was not possible to be sure whether the furnace is fired from one end or both. The sieges had three crucible positions on each side. The two at the north end were about 2 or 3 feet (60 or 90 cm) from the corners, and measured some 1'6" x 2'-2'6" (45 x 60-75cm). One could be made out about 3'6" (1.07 m) from the south-west corner, and another somewhere near the middle of the east side (fig. 5). The furnace, and particularly the sieges, were liberally scattered with lump glass, frit and "scum" from fritting. Large pieces of crubible were also found.

Furnace 4. F4 consisted of two squarish chambers joined together so that the east wall of one chamber was continuous with the west wall of the other (Plate 2). The chambers were not however back to back, but set diagonally -- one was further north than the other. A gap of some 2 feet (60 cm) in the common wall evidently represented a passage for hot gases to pass from one to the other (see fig 6). This arrangement seems to preclude one continuous superstructure; the furnace must have had two "domes" with connecting passage, like Trestenshult (fig 31, page 42).

The remains consisted of the two lowest courses only of the outer walls. The floors of the chambers were made of a layer of clay with small pieces of stone, 1-2" (2.5-5 cm) thick, resting on the natural yellow clay. The stones of the walls were roughly squared, giving a neat effect almost like that of a well-laid masonry construction. The floors of both chambers were reddened with heat.

The stones of the walls were reddened on the inside (Plate 3) but not on the outside, except for a few obviously burnt throughout. Some of the stones in the bottom course had glass spill on their upper faces. These, and the other stones burnt through, must be reused, implying that F4 was built later than F1, and used some of the material from it. The natural clay surrounding F4 was unburnt; this implies that the heat reached in this furnace was only moderate, and not that required for full melting (see page M36).

The stones were mostly some 9 inches (22.5cm) square, and laid in two rows side by side, with clay (not mortar) between, making walls 18" (45cm) wide. The west chamber had internal dimensions of 6'3"x 3'10" (1.92 x 1.17m), and the east chamber 7' x 5' (2.15 x 1.53m) (see plan at fig 6).

The extant remains of the west chamber were exceptionally well-preserved, and this chamber, at least its lower part, could be visualised with confidence and accuracy. The east chamber was not so entire. The west wall, and short lengths of the two return walls, were intact, but the rest of these, with the whole of the east wall, had gone. However, the sharply-defined edges of the burnt chamber floor enabled the position of these walls to be determined.

Nothing of the higher courses had survived, but there must have been access openings for the fire and to insert and withdraw the glass. The layers of crown found in this furnace make it certain that one of the functions, if not the main function for which it was designed, was the annealing of crown sheets. The most convenient way to insert flat sheets nearly a yard (up to a metre) across (see page 10) would be to have a horizontal slit-like opening, perhaps one or even two courses high and a yard (metre) or more wide, low down in the wall of one side of the furnace. (For discussion of this see page M38).

Clearance of the clay, stones and some bricks fallen from the superstructure uncovered the following:

west chamber - a large part of a crucible with a dark magma underneath it (Plate 4)

a bottle neck and base (Plate 5)

a roundel

crown in two main areas, one consisting of a pile of four large pieces of rim on top of each other (Plate 6)
a lump of iron near the east wall

east chamber - a base silver shilling of Edward VI (1550) -- see page M32
crown glass in SE corner, in a pile of three layers

These contents might seem to imply that most of the annealing was done in the west chamber, and other processes in the east chamber. But this may be apparent only, and the point is discussed on page M38. Tiles in the filling confirmed that this furnace was under the shed roof.

This furnace gave the impression of being exceptionally well and carefully built, as though by a specialist. The stones were squared and regularly laid, unlike those of the other furnaces. A short section of the west wall of the west chamber had been displaced inwards a few inches (perhaps in the demolition or robbing of the furnace) but had stayed in one piece.

Space between F3 and F4. A curious and essentially unexplained feature came to light in the space between furnaces 3 and 4. The side walls of the east chamber of F4 are continued towards F3 by narrow bands of stones, running in somewhat sinuous lines towards, and meeting, the west wall of F3. They are at a lower level by one course than the walls of F4. The stones are of different sizes, and loosely lying. The southern line has no distinguishing features. The northern one leaves F4 about 1'3" (37.5cm) wide, curves south and becomes wider, up to 3 feet (90cm), as it reaches F3. At the point of the curve the stones widen out to enclose a round cavity 1'3" (37.5cm) across; here the stones are about 2 feet across. The cavity contained decomposed wood, identified as oak (see page M47). The clay between the lines of stones is unburnt, but outside there is burnt material and lump glass.

These lines of stones were thought of during the excavation as walls, but their purpose is far from clear. They may in fact be the remains of a floor between the two furnaces. The cavity containing wood

need not be a posthole, though it is shown as such on the plan, but may merely be an old tree pushing up among the stones. It is not in a position to contribute to the problem of the shed.

Cullet Store. This occupied a convenient position just west of F2, and clearly so that the addition of cullet to the mix for melting could be done with the minimum effort. The heap was large, and appeared to have two phases. It was some 6 inches (15cm) deep, closely packed. It had not been noticeably disturbed since it was abandoned.

The earlier part was some 8 feet x 4 feet (2.5m x 1.25m), running E-W. The bulk of this was on the bare unburnt clay, and thus seems to date from an early phase in the life of the site, presumably in that of F1; it also antedates the "floor" (see page M21). There was no sign of a container, which, if it existed, must have been perishable. The heap had slumped all round, onto the floor to the west and north, and at one point had overlapped the robbed wall at the west corner of F2, over an area 40" x 32" (1.02m x 82cm). At the west end of this heap lay the shorter arm of the roughly L-shape -- a squarish extension some 4' x 4' (1.25 x 1.25 m), clearly added at a later date. This rested on part of the stone on clay floor, and seems to represent a basket or two, dating from after the floor was laid down.

The floor did not encroach on the heap; on the contrary. Unfortunately a substantial tree, with its roots, had pushed up into the east end of the heap, but apart from what is trapped by this, the heap was fully excavated, and virtually all the contents recovered. The cullet included a number of types obviously brought in, but also was broadly representative of the products of the glasshouse. (see page M54).

Possible Shed. A trench (X), with sides of 6 feet (1.84m) was taken out roughly halfway between the north-east corner of F3 and that of F1 (6 feet (1.84m) from F3, 7 feet (2.15m) from F1), to test what appeared to be a blank area, but which could have contained structures. The clay here was sterile and unburnt, but some stones were uncovered, forming a roughly triangular shape with sides about 3 feet (92cm) long. Inside was a cavity contain-

ing a large piece of crucible (7" high x 6" wide - 17.5 x 15cm) standing against the NW side, and an indeterminate iron object at its base (Plate 8). The stones of this feature was burnt, but the clay round and inside it was not. The cavity was itself roughly triangular, 14" (35cm) at the wide (NW) end and 6" (15cm) at the other, and 8-9" (20-22.5cm) deep. There was no trace of decayed or burnt wood in the cavity, and no discoloration of the soil. Yet the most reasonable interpretation of this is as a large posthole, from which the post had been removed before it decayed. It could not have been a place where heat was applied, and the burnt stones presumably came from clearance of Furnace 1, or from later repairs to furnaces. The upright crucible might be a wedge, although it may be there fortuitously.

Test excavations round it, and further out from the furnace area, all proved quite sterile, and there is no doubt that the glasshouse came to an end in this direction at this point. This could well be the site of one of the main posts of the shed. Tile was found in this area (and see page M34). Search was made for other postholes of this or any size, but none was found. The inference must be that the other posts were resting on padstones (stylobates) or timbers. One such possible padstone was found close to F4 (see page M33). But in fact the outline of a shed (a normal feature of glasshouses) was not established.

<u>"Floors"</u>: Much of the ground not occupied by structures was covered with a spread of stones, particularly in two well-defined areas. The larger lay between F4 and the edge of the bank, an area of some 30 feet x 12 feet (9 x 4m). Some stones were loose, some firm, and the top layer was trodden in and mixed with bits of burnt stone, clay and glass. There were several distinct patches of burnt stones among the spread. These could represent small fires, e.g. for cooking, or heating some object, or derive from the dismantling of F1. As said on page M20, it seems most satisfactory to assume that this spread postdates the earlier part of the cullet store (it cannot antedate it, but could be roughly contemporary) and to place its deposit as contemporary with the building of F2. Similarly, it runs up to, but not underneath, F4, so is either contemporary with, or later than, this. It antedates the second phase of the cullet store.

The extent of this spread suggests that it cannot be solely the result of the dismantling of F1, and it is probably best to regard it as a floor, to keep the workers' feet out of the mud.

The other main area was between F3 and the track. Here there was a close-packed layer of burnt stones etc. on top of the clay, petering out at 9 feet (2.76m) or so at the edge of the track. This again looks more like a floor than casual waste thrown out from round the furnace, and may be at or near the entrance to the glasshouse. In favour of this, this area produced a larger number of tiles than others, which suggests a building of some sort, even if only a porch or lean-to at the end of the shed. There is also (see page M19) the possibility that the space between F3 and F4 was covered by a floor.

Claypits. At either end of the site are two very conspicuous features, distinct and artificial hollows, one just beyond F4, the other close to F2. It is convenient to call them claypits, but their real functions are not certainly established.

The larger hollow lies between the glasshouse and the streamlet which crosses the main track some forty feet (12.30m) west of the structures. It was at first thought of as a yard for access by horses or carts to and from the glasshouse. But a closer look showed that it did not reach the track at all. The glasshouse in fact stands on a low natural platform some four or five feet (1.20-1.50m) above the streamlet, and with a low bank some 40 feet (12.30m) across running down to this. The cutting begins about 34 feet (10.46m) from the track along the streamlet, turns in towards the glasshouse, runs north for 42 feet (12.92m) (its east side being only some 3 feet (92cm) from F4), and turns back towards the streamlet, but leaves a tongue some 14 feet (4.30m) wide before it peters out. The gap thus left is about 16 feet (4.90m) wide, and it was probably through this gap that the pit was dug, starting at the streamlet. (see fig 3). The waste tip (page M24), is about halfway along the east side of the pit. The pit is, as may be expected, irregular in shape, and is some 25 feet (7.69m) from west to east. This pit cannot therefore be regarded as a yard. It seems to be merely a claypit cut into the side of the valley of the streamlet. The clay removed may have been used for building and maintaining

the furnaces, or if it predated the glasshouse, just carted away. The pit certainly predates the time when it was used to empty the waste tip into (page M24). Apart from this tip, there are no signs of use; trial probes to check the surface and extent of the pit revealed a quite sterile soil, with no traces of treading etc. The topsoil in the middle of the pit is thicker (5-6" - 12.5-15cm) than on the site itself (3-4" - 7.5-10cm), but this need have no significance for comparative dating -- it is as likely to represent soil-creep down the slope as anything else. The question of contemporary access to the glasshouse remains unresolved. It must have been by way of the track from Old Knightons, and there are indications that the entrance might have been in the area of F3; there are no indications of special loading facilities.

The other pit was known to the excavators from the beginning as a pond. This appears at first sight to be a long crescentic cutting, with its ends resting on the edge of the main bank down to the stream. In fact it is a roughly rectangular trench some 20 feet long by 8 feet wide, (6.15 x 2.46m) and 2-3 feet (60-90cm) deep. The western outlet channel leads off the end of this at right angles, and goes to the bank-edge, where it is two feet (60cm) wide and some 6-9 inches (15-22.5cm) deep. The east end is cut by the path -- some 5-6 feet (1.53-1.84m) wide -- which leads from the track northward into the wood, and which is therefore later than the pit. The pit where it is cut is some 5 feet (1.53m) across, but on the other side of the path it is merely a narrow channel like the western one, bending back parallel with the path and close to it, onto the bank edge (fig 3). The earth from the cutting has been upcast in a heap between the pit and the bank. The pit is not far from and at right angles to Furnaces 1 and 2.

The pit and upcast were sectioned. The pit had a gently rounded profile, and was cut through soil containing burnt material, which occurred also in the upcast. This implies that it was cut after F1 was dismantled and its remains spread. If it has to do with the glasshouse at all, it could thus be contemporary with F2. If it postdates the glasshouse its purpose is obscure. The path is later than the glasshouse (which it avoids), later than the "pond", (which it cuts across), but is shown on the O.S. map of 1874-80.

The Forestry Commission could offer no suggestion or record as to the use of either of these pits -- military, sporting or quarrying -- if not connected with the glasshouse. Certainly the cutting of the western pit antedated the deposition of the waste tip within it; and the eastern pit, with its rounded bottom, is not an ordinary pit for getting clay, so would seem to have no connection with the canal. It seems reasonable to regard both these pits as integral features of the glasshouse. The larger and irregular (western) one is likely to have been used as a source of clay for building and repairing the furnaces, and for closing the glory-holes during founding. The smaller (eastern) one,which has overflow channels at each end on the edge of the bank, could have been kept filled with water, for washing materials, vessels and tools. It could also have been used for making potash -- the ash from the fuel wood, and from other woodland plants, had to be extracted with water, sometimes with the addition of lime-stone (calcium carbonate) to the wood before burning, or quicklime (calcium oxide) to the ashes afterwards, to form potash (potassium carbonate or potassium hydroxide) suitable for glassmaking (Nicholls 1979, 59).

Another possible purpose of such a pit might be the preparation of the clay for potmaking, which had to be mixed with water, kneaded, and stored to mature (Harrington 1972, p 42). (The other glasshouse in Sydney Wood has a pond close by).

Waste Tip. During the investigation of the western claypit a very important feature was met with. A trench taken down the bank of the pit opposite the NW corner of F4 revealed, at 5'6" (1.69m) from the top of the bank, a vertical cutting in the bank, (see Plate 9). This vertical edge was 28" (70cm) deep, of which the upper 15" (37.5cm) was topsoil (3-5" - 7.5-12.5cm) and soil-creep. The lower 13" (32.5cm) was full of material which clearly represented waste from the clearance of a furnace or furnaces -- burnt soil and stones, broken crucible and glass. The tip extended in a broad fan from the point first met with; it reached the surface 8 feet (2.46m) from the edge of the cutting, and waste material showed up for some 4 feet (1.25m) beyond that. It extended for some 8-9 feet (2.46-2.76m) in width. The waste was thrown from the top of the bank, i.e. direct from the nearest point to the furnaces; the heavy pieces, stones and crucible, were nearest to the site (Plate 9).

The vital importance of this tip is obvious -- from it can be deduced some of the actual manufactures of the glasshouse, instead of having to rely on the very uncertain witness of the cullet store. In the event types were few, being mostly crown, flask and alembic, with a piece of smoother. The full range of probable products was not present. But the pieces accorded with those already found in the annealing furnace (F4).

A somewhat unexpected feature of the waste tip was a considerable number of oyster shells. This throws an interesting sidelight on the diet in what must have been a fairly remote spot - or were they a source of lime?

Extent of the glasshouse. Trial trenches were dug at various distances out from the known structures, all round the working area, until the soil ceased to show traces of burnt material etc. We were satisfied that in this way the limits of the glasshouse were determined. No other structures were found, and it is reasonably certain that the entire glasshouse, with all its components, has been uncovered, and is reflected in the general plan at fig 3.

Reliability of Attributions. The excavation of a site like Knightons, so close to the surface, and not stratified in the normal archaeological sense, entails a margin of doubt in the attribution of objects found to the structure or area where they have occurred. Thus the topsoil contains broken pieces of glass which were left lying where they fell during the glassmaking process -- these are of course indistinguishable from the rest of the cullet; pieces of crucible; broken or useless pieces of brick, tile etc., regarded as unusable when the materials were removed. But it also contains a few objects incorporated at any date after the abandonment of the glasshouse, and having no intrinsic relation to it -- these include the clay pipe, the canal period pottery, and recent bottles. The cullet store itself, and the waste tip, both appeared to be undisturbed, and the assemblages they contained may be safely taken as contemporary and diagnostic. The furnaces had glass etc. lying on their burnt floors, so below the topsoil. Thus, the crown in F4, and the frit in F3, may confidently be accepted as indicating unquestionable uses of those furnaces. But although the effort to

attribute must be made, absolute certainty in all cases cannot be expected, and in one sense the site and its associated objects (except those demonstrably unconnected) have to be treated as an indivisible whole.

Crucibles (and see pages M55-60). A very large number of crucible fragments was scattered all over the site; some occurred in the furnaces, in the Waste Tip, and even mixed with the cullet. But relatively few were diagnostic, and only three or four pieces were large enough to draw valid conclusions from.

Two groups can be distinguished, thin-walled and thick-walled. (see below for dimensions). The thickest are bucket-shaped, with straight walls; the thin ones have walls which may be slightly curved or barrel-shaped, but seem to aim at being normally straight but incurving slightly at the top towards the rim. The rims are distinctive to Knightons. They are pinched over to form a projection on the inside of the pot. The top of the rim may be flat, or convex, or sloping inwards. In the thin pots the projection is usually pinched to a sharp edge; in the thick ones the edge may be rounded off. But the affinity between the two types is clear. The body is buff, usually rather pale, with an admixture of sand. A few have grooves or scratches which may be intentional decoration. (fig 26:66). One has a lightly "frilled" rim (fig 26:63). The attempt was made to retain a representative range, but it was not possible to be sure that the proportionate occurrence of the various features had been established. The apparent preponderance of thick over thin may not be real. This range is listed below; questions raised by it are discussed on page M55.

Thin-walled type. The walls range from 1.1 to 1.8 cm thick; at about 2 cm they grade into the thick type, but this figure should be regarded as arbitrary. The base is some 24 cm in diameter, the rims 32-38 cm. The angle of side to base is about 80°. There is no evidence for the height, but the F3 slab is 37 cm high, with no signs of base; some 40-45 cm might well be thought of.

Details -- rim piece, 2 cm thick, rim 3 cm wide, rising to the sharp edge (F3)

-- large part of side of pot, with 11.5 cm of rim. (This was found in 12 pieces, but could be joined into a slab 21 x 37 cm; 3 more pieces from the same pot came from nearby). 1.3 cm thick, upper few cms taper off, and the rim is only c 1 cm wide. Diam at rim c 37 cm. Walls straight, but incurving slightly towards rim. Flecks of yellowish (?Early) glass adhering. (On floor of N chamber of F4).

-- piece 1.1 cm thick, with small flecks of glass adhering

-- rim piece, 1.3 cm thick, rim 2 cm wide, flat on top, glass adhering inside; outside an incised horizontal groove 2.8 cm below top, and a curved line below it (which presumably forms scallops round the pot) (F1/2)

-- rim piece 1.5 cm thick, rim 2.5 cm wide, slightly convex (F4)

-- rim piece, 1.4 cm thick, rim 2.3 cm wide, top sloping inwards; outside, two incised grooves 1 mm wide, at 1 cm and 1.5 cm below rim (Cullet Store)

-- rim piece 1.8 cm

-- complete base and lower part of pot, filled with a mass of fused cindery frit. Straight walls 1.5-1.7 cm thick, at an angle of 75-80° from base. Base 24 cm (9½") diam. One side stands to 20 cm high, and this could be half the original height of the pot. (Plate 10)

-- rim piece, 1.1 cm (7mm below rim), rim flat 1.8 cm, diam c 32; incurved slightly to rim (F1/2)

<u>Thick-walled type</u>. The sides range from 2 to 2.8 cm thick; the base can be 5 cm. The base is some 28-33 cm in diameter; the rim up to 40 cm. The walls rise at an angle of some 80° to the base. The height cannot be stated from the Knightons evidence, but some 40-50 cm may be a reasonable figure.

Details -- base piece, with walls 2.5 cm, and up to 3 cm just above base. Diameter at base c 30 cm; the walls seem to swell slightly outward (F3)

-- piece 2.8 cm thick, broken off just above base, which is c 32 cm in diam. (F1/2)

-- pieces of massive pot, 2.3 cm thick, with thick lump of Late glass adhering. The base is flat, and the walls straight. The corner between the base and walls is rounded inside, and 5 cm thick here
-- rim pieces 2.3 and 2.6 cm thick (from "floor")
-- 12 fragments of a very massive pot, including 13 cm of rim. 2.8 cm thick, rim 3.5 cm wide, with narrow rounded edge; diam. at rim c 40 cm. The walls are straight. Groove filled with pale green glass (?Early) 2 cm below rim. (F3)
-- large piece, 2 cm thick, completely coated inside with what appears to be glaze, but is no doubt glass (F1)
-- rim piece, with two bold incised grooves at 1 and 2.3 cm below rim (fig 26:64)
-- piece with 10 cm of rim, grey, 2 cm thick, rounded off to a flat pinched rim projecting 3 mm inside. 1 cm below top, two interlacing incised lines, forming long lozenges with curved sides, 6 x 1.2 cm (fig 26:66)
-- large piece 18 cm across, with part of base and side; glass underneath and lump 10 cm across inside, of good Late glass. Wall 2.5 cm thick, base c 33 cm diam. (Waste tip)
-- piece with crossed lines (irregular) incised

Anomalous rims. Five examples were found with rims quite different from the above, which are all of the standard Knighton pinched-in variety.

1. one piece, 2.3 cm thick, has a rim flattened and rolled over on both sides of the pot, with greater projection on the inside (2.5 cm wide at top, projects 2 mm outside, 5 mm inside). (Waste tip). (fig 27:68)
2. One piece with wall 1.7 cm thick; rim has depressed top and rounded projection inside (2.8 cm wide, projection 1 cm by 1 cm thick)
   Another, wall 1.7 cm thick, but similar rim form, projecting 1.5 cm.

Another similar, but thinner and less regular. These three come from the posthole area, and could all be seen as parts of the same pot. (fig 27:69)

3. One piece, whitish clay, massive turned-over rim, with rounded projection towards the inside. Wall 2.4 cm thick, rim 3 cm across, flat top, sloping up; projection 1.3 cm thick, projects 2 cm. 3 incised grooves, 2-3 mm deep, at 1.3, 2.8 and 4.3 cm below outturn of rim. (Posthole area) (fig 27:70)

All these rims convey a heavy and "squashy" impression, and strongly suggest another maker than the man who produced the "standard" type.

The dimensions of the Knightons pots may be compared with those at Jamestown (Harrington, 1952, p 39-40; 1972, p 42 - 44). Except for two small ones, the pots were all approximately the same general size and shape. They had flat bottoms, about 2 inches thick, with vertical or slightly outflaring sides, 1 to 1½ inches thick. They fell into three size ranges -- A, 10 3/8" high, 15¾" diameter, capacity 90-95 lbs; B, 12¼-12¾" high, 16-17½" diam, capacity 130-145 lbs; C, 10¼-10¾" high, 14½-16" diam, capacity 65-85 lbs. Types A and B were imported, type C was made from the local clay. All are comparable to pots excavated from contemporary English glasshouses.

An interesting suggestion has recently been made by Six (1976, p 137), in respect of a glasshouse of the late 14th century in Germany, Lemkenbrink. Here Six distinguishes pots for working (Häfen für die Endschmelze) from pots for fritting (Häfen für die Fritte). The former have base 10-12 cm diameter, walls flaring at an angle of 125°, 22-25 cm at shoulder, and mouth c 25 cm wide; the latter are larger, and have wide mouth -- base 16 cm, mouth c 40 cm wide. This is remeniscent of the complete base described above.

<u>Iron</u>. Several pieces of iron were found, in different areas of the site, even in the cullet store. They are mostly heavily corroded and encrusted, and in some cases are too far gone to be identified. But they can be divided into:

Blowing-irons (fig 28,71) One piece appears to be 1.2 cm in diameter, with hole 3 mm; this piece seems to terminate in a knob 3 cm across.

-- another has a pipe 1.7 cm diam. outside.

(The poor state of the blowpipe pieces made it impossible to check whether they had been made by folding over, and in short lengths joined together, or by some other method. They are certainly in short lengths).

Pontils. These are often difficult to distinguish from blowpipes,

one, from the cullet stores was 1.5 cm diameter

one, from F1, was 2 cm diam;

one, from F3, was 2 cm diam., with knob 5 cm across

A rod, 1 cm diameter and some 9 cm long (from F4) was embedded in a lump of burnt clay so hard that it is difficult to be sure whether the rod is a narrow pontil, or part of a larger and more complex iron object. The lump is 18 x 9 x 6 cm, excluding the rod, which sticks out from it tangentially. Much of this material indeed looks like iron. A bar, 8 cm long, came from F3; this was slightly curved, but whether with heat or as part of an object (say a horseshoe) is not clear.

Pontils come in various sizes, and the largest might have quite prominent knobs, for collecting large gobs. Insofar as the state of corrosion allows, some of the Knightons pontils were of these dimensions. (Flavell and Smale (1974, fig 73, p 81) illustrate three sizes).

Strap. -- broken piece, 2.5 cm wide, 1 cm thick, widened at one end, the other bent over, and up at its rounded end, where is a subtriangular hole, 7 x 4 mm. This is less encrusted than the other pieces, and less friable, but it came from the waste tip, and thus dates from the glasshouse. It appears to be a fastener for a chest or the like.

-- strap, 12 cm x 4 cm x 5 mm. (F3)

-- strap, 8 cm x 2 cm x 5 mm

-- a piece from F4 has three nailheads corroded into it.

Various. Indeterminate lump from F4.
From the posthole area

-- a lumpy piece, with rod each side
-- a lump
-- a bar, 1.5 cm diameter, with end bent over at right angles

From F4, a flat piece with rounded and slightly curved edge, 5 cm across, 7 mm thick; this was broken off, and unidentifiable.

Nails. Two sizes:

-- 3.5 cm long, 1 cm wide head
4.5 cm long, 1 cm wide head - both with square section shanks - heads too corroded to determine form.

(both from F4 area; the larger could be for fixing tiles, the smaller for use with iron strap).

(The iron is no doubt Wealden. There was an iron forge only about a mile away, at Burningfold. This is first mentioned in 1567, (Schubert 1957, 369), but almost certainly existed a few years earlier. There is no information whether it made tools, or indeed where the glassmaking tools came from).

Pottery. (see page M60)

1. 4 sherds of saltglaze stoneware, brown speckled on grey; 3.5 to 4 mm thick.
   From rounded pot. From cullet store. (On other Wealden sites this ware is associated with Late glass (Kenyon 1967, 188)).
2. A sherd of plain buff ware, gritty, unglazed, with flat rim, 5 mm thick, was found in the cullet store. This exactly matches 6 sherds, evidently from the same pot, from F4 area. These can be joined to form a piece of shallow bowl, perhaps for water, c 13 x 7cm. This has the rim (6 mm wide) along one edge, and the beginning of the turn at the base on the other. Diameter at rim c 16 cm (6½")
3. A small sherd of green-glaze ware, from the cullet store.
4. 4 sherds (from F3 area) of pale red ware, 6 mm thick, oxidised black on both surfaces; grey inside where thicker. The largest sherd turns to a flat base.

Streaks of lead glaze have spilt down on both sides -- perhaps accidentally splashed in firing from some pot above it in the kiln. From storage jar, 16th century.

5. 1 sherd of pinky-buff gritty ware, blackish outside, unglazed; 5 mm thick. Could be 16th century. From original discovery of site.
6. Buff ware, 5 mm thick, with thick bright yellow glaze. 1 sherd has 13 cm of rim, rounded, 8 mm wide; c 30 cm (12") diameter at rim. 1 sherd has 11 cm of turn to flat base. Wall rises at 60°. 12 small sherds or flakes also. From F3 except for one piece from F4. Mixing bowl or large deep dish, late 18th-early 19th century.
7. 1 sherd and a crumb, from square B (outside F4), of blue and white transfer-printed willow-pattern earthenware, 5 mm thick, from a large shallow dish. After c 1790.

Coin. A coin was found in the layered deposit of crown glass on the floor of the south chamber of Furnace 4 (24" (60cm) N of SE corner, 4" (10cm) from wall, 4½" (11.25cm) deep, in burnt clay below topsoil), and thus deposited contemporaneously with the glass, which had shattered during annealing.

The coin was examined by the Department of Coins and Medals, British Museum. It is a shilling of Edward VI, 1550, of base silver. Obverse, bust of king, crowned, to right; inscribed (EDW)ARD VI D G AGL FRA(NC) (H)IB REX. Reverse, arms of England (quarterly France and England), in oval cartouche, in scroll, between letters E R; inscribed TIMO(R) (D)OMI(NI) (F)ONS VITE M D L. Mint mark probably lion. Present dimensions 1.1"(28mm) diameter, 1 mm thick. The coin is not countermarked, and is in "very good" condition. (See Sutherland 1973, p144 and Pl 64 (513); and Seaby 1980 p 147 -- no. 2473).

The issue was devalued by Elizabeth, and withdrawn in 1560 (when it was countermarked with a portcullis); but most went out of use -- only about a quarter were marked. Fine silver is found in hoards until the late 17th century, but base silver is unlikely to circulate after two or three years of minting -- this coin is

nearly new. In this case this probably means 1550-1553. But there is a long chance that it was found, or turned up in circulation, later than 1560, and deliberately thrown away, as (a) it would then be worth only 4½d or so, and (b) its use was illegal, and incurred the penalty of ear-cropping. Whether it is more likely to have been thrown away in some remote spot, or furtively dropped into a furnace in a busy glasshouse, is a matter for conjecture. Subject to this ten years' uncertainty, this coin is crucial for the dating of the glasshouse.

Miscellaneous Objects

1. Associated with the glasshouse

Lead (fig 29) -- Two short lengths of lead came were found in the cullet store. These evidently came in with discarded window glass. One piece is only an inch (27 mm) long, but undistorted. It is double, i.e. with two flanges each side, to separate and support two panes. It is 4 mm wide at the glass-bearing edge, and the flanges are 1.5 mm deep. The flanges are flat, not rounded like the late Saxon came figured by Harden (1961, p53, fig 3.5 top). The lead is only 1 mm thick, and the whole came seems very lightweight. The other is c 5 cm long, but bent over twice and twisted; it is much worn down. It is not easy to measure accurately, but appears to be of the same dimensions as the piece described above.

Bronze (?) (fig 29) -- A penannular object of thin wire (1 mm) was found in the cullet. The wire is bent round into a circular ring 2.5 cm across; the ends do not meet, and one is bent back away from the gap. Use indeterminate.

Oyster shells, of a small, narrow type, were found in the waste tip.

A large flat stone was found by the south-west corner of F4. This was c 13" (32.5 cm) long, by c 8" (20 cm) wide, and about 7" (17.5 cm) thick. It was roughly rectangular in shape. It stood on a pad of clay. This was at first taken for a marver, but later consideration inclined to regard it as a base (padstone) for one of the principal posts of the shed (see page M21). If this is the case then no marver was found.

Bricks. Several bricks or fragments of bricks were found, scattered widely over the site. They vary in size. The only complete one measured 9" x 4½" x 2" (22.5cm x 11.25cm x 5cm); another was 4" (10cm) wide x 2" (5cm) thick. These measurements are within the limits of the Flemish-type bricks introduced into England in the third quarter of the 13th century, and later (from the mid-14th century) made here (Davey 1961, p83). But they cannot well be used for dating, because this size-range continued until a larger size came into use in 1784. An attempt was made in 1571 to regulate brick sizes to 9 x 4½ x 2¼"; the Knightons bricks are of unregulated sizes, so could, and no doubt did, antedate 1571. The bricks are light red, and soft (they can be scored by the thumbnail). It is not clear what kind of building these bricks come from. They were apparently not used in the furnaces, unless at higher levels than have survived. Perhaps they come from some part of the shed or stores. The bricks from the nearby canal locks or huts had no frogs either, but measured ? x 4½ x 2⅝", and can thus be distinguished from the glasshouse bricks, by size as well as texture. For comparison, the bricks in the house of Old Knightons are of two sizes: one, in the nogging between the timbers on the first floor -- 8¼ x ? x 2½"; and those which presumably encase the timbers on the ground floor -- 8½ x 4 x 2¾". These seem to be unregulated sizes, predating the late 18th century.

Tiles. Several fragments of tile were found scattered mainly over the area of the site likely to have been covered by a shed; most were in the F3/posthole area, and in the F4 area. These point to the shed having been tiled. The tiles are flat (Morse's type C, his "Germanic", used as fireproof substitutes in countries where wood shingles were used for roofing, and thus here continuing naturally the Forest glasshouse tradition of this type of roofing). They are c ½" (1.5cm) thick, but the full dimensions cannot be given as no complete tile was found (no doubt the good ones were all robbed). They have holes for attachment by nails or pegs: the hole found was 1.2 cm diam. at one end, 5 mm the other; it was 3.2 cm from one edge of the tile, 9 mm from the other. Suitable nails, 4.5 - 5 cm long, were also present.

2. Not associated with the glasshouse

These came from the topsoil over the site, and are mostly quite clearly extraneous strays.

Flint. Three pieces of a cortical flake; no signs of use (F4 area)

-- small chip

-- good neat blade, 4 x 1.5 cm; wholly worked, triangular section.

There is no evidence for the use of any of these pieces in the glass processes, and they should be regarded as fortuitous occurrences.

Bone-- distal end of probably sheep femur

-- piece of rib, probably sheep, 6.5 cm long. This appears to be rubbed smooth on one side, as though used for smoothing something -- wood or pottery.

Clay pipe. Lower part of bowl with nearly 2 cm of stem. The bowl slopes gently, at 60° on its upper surface and c 45° on the lower. Diameter of bowl 1.5 cm externally, 8 mm inside; stem 1 cm dia., hole 2 mm. Foot short and plain. This appears to fit Oswald's type 4 (1650-80) or 6 (1680-1710) -- cf Oswald 1967, fig 21.

Bottles -- fragments of a dark green wine bottle of 18th century type.

-- fragments of a modern soft drink bottle

DISCUSSION

The Functions of the Furnaces. F1, succeeded by F2, is without doubt the main or working furnace, providing the glass for immediate making-up into usable (or saleable) products. There is no obvious reason why F1 was dismantled down to its bottom course, and replaced on nearly the same spot by F2; nor evidence how long each remained in commission. But they are placed centrally within the glasshouse area, and in fact the structures are so disposed that there was little room for manoeuvre. The structures had in practice to remain where they were first placed. The glasshouse seems in fact to have been confined within a quite small area between the path, the edge of

the bank, and the two claypits. We do not know why it could not expand beyond the path or the pits (the bank being too steep in any case to be used), but perhaps the glassmakers were leased or granted only a well-defined plot of land to build on. F3. from the bulk of the finds in it, and their concentration in that area, is clearly the fritting furnace.

(Harrington (1972, p 29) raises a doubt whether fritting as such was carried out at Jamestown; the ingredients may there have been placed directly in the melting pots. This must be borne in mind, although at Knightons a considerable quantity of frit and "scum" was found). It may be relevant that when samples of burnt clay were taken from the furnaces for archaeomagnetic measurement, those from F3 were found not to be sufficiently well fired to give significant results. Fritting required a temperature of some 700-900°C, whereas working needed up to 1200°. This does not preclude the use of F3 for other lower-temperature processes, (e.g. pot-arching or even pot-making), but in fact these seem to have been carried out in F4. Its use for fritting (which in a Late glasshouse was normally done in the wings or horizontal chambers of the main furnace) implies that it was in use parallel with, and contemporaneously with, F1/2, and was an integral part of the glasshouse at all times. (This does not rule out its possible function as a stand-by -- either to supplement F1/2, or replace them if they were out of action).

F4 is equally clearly, from the finds within its two interconnected chambers, a special furnace for annealing. (see below)

The glasshouses at Rosedale and Hutton (Crossley and Aberg 1972) provide a useful parallel to this layout. There the main furnace was of winged type, where fritting, potarching etc. could be carried out in the wings. Close by was a separate annealing furnace, with chamber smaller than at Knightons, no doubt designed for the spreading and/or annealing of muff, if window was made there at all. One winged main furnace therefore economically replaced two furnaces in an Early glasshouse; but there was still need for a separate annealing furnace, if window was produced.

Knightons may most economically and reasonably be regarded as being all of one period of use, involving the simultaneous existence of F1/2, F3 and F4 (but F4 was rebuilt or repaired at some time, unless it was built after F1 was dismantled -- it has burnt stones facing outwards in its lower courses).

The replacement of F1 by F2 can be seen as having taken place during the life of the glasshouse, and with no change in the other elements. A furnace could last at a pinch for up to 20 years (but see below), but no doubt accidents could happen, or faults come to light, serious enough to necessitate complete rebuilding. In such cases a stand-by, in this case F3, would be useful to have. (A conceivable alternative sequence would be for F1 and F3 to be the original glasshouse; F1 later to be rebuilt as F2, F4 built partly from the stones of F1, and F3 retained.)

There are precedents for having two main furnaces. Kenyon (1967, p 81) discusses the problem of multiple furnaces, and cites the examples of Chaleshurst (nos. 3 and 4), Glasshouse Lane (no. 14) and Brookland (no. 23), which had two furnaces 40-50 yards apart. At Malham Ashfold (no. 29) and Woodhouse Farm (no.32) there were probably two or three; at Sidney Wood (no. 38) the area covered by the shed was so large that more than one furnace may be suspected. This practice is not confined to either Early or Late glasshouses; it was presumably necessitated by the rough and no doubt accident-prone structures themselves, although there might be an economic reason. A breakage rate of up to say 50% (it is still up to 30% in a modern factory), may have involved using two working furnaces to produce enough glass to keep the annealing furnace filled to optimum capacity, or at least make it convenient to have supplementary furnaces to leave the main one free to be used entirely for working. This may have been the situation at Knightons.

This brings in the vexed question of the life of a furnace, on which the authorities differ widely. Milet (1871, p. 33) suggested, for Normandy, a life of only about 8 days for a crucible, and some 12-15 months for a furnace. Godfrey (1975 p. 143) cites a case of a French furnace which collapsed twice during the first year of firing, and quotes Merret's experience (1662) that the crown of a greenglass furnace could "rend in a quarter of a year,

or else furrows be made in it". She accepts that "extensive repairs were necessary several times a year, and the life of a furnace was seldom more than two to three years". This life would be longer if the operation of the glasshouse were seasonal (Kenyon 1967 p. 117), but this would not apply to professionally-run houses, which Knightons presumably was. These figures might appear to call in question the skill of the furnace-builders. Yet it has to be accepted that they were working with the crudest of materials, and it is probably unfair to criticise their results. The marked standardisation of furnace forms, down to actual agreement of measurements, may imply good communications between glassmakers or furnace-builders, and perhaps patterns. But it may also imply the existence of specialists, employed or called in to build and repair furnaces. Milet (1871, p. 32) indeed refers to a statement by Haudicquer de Blancourt (in De l'art de la Verrerie, 1697, p.33) that "une seule race de maçons en France, originaires du Caule au comté d'Eu, avait le secret de ces fours et pouvait les réussir". What was the situation in England? Where did the farmer-glassmakers get their knowledge from?

The Annealing Furnace (F4) is a so far unique example, for England, of a type which must have been widespread in France. It has two rectangular chambers, side by side, with a gap in the common wall evidently so that the hot gases from one chamber could pass to the other. The floors of both chambers were reddened, implying that fires were lit in both. Glass, sometimes large pieces, were found on the floors, and fragments of iron strips which may have been parts of frames or racks to stand items to be annealed or heated on. A sizable piece, nearly a whole side, of crucible, was found in the northern chamber, which may therefore have been used for potarching, if not potmaking.

It is of interest to compare this two-chamber furnace with the more primitive double furnace at Jamestown (Structures C and D). In his initial account, Harrington (1952, 18 and 45) inclined to regard one chamber as used for fritting, and the other as for annealing. But the smallness of chamber D did not appear to be capable of matching the probable output of glass to be annealed, and in a letter to me (17 October 1960), Harrington suggested that

the furnace, both chambers, was for annealing, even if fritting was at times carried out in one end. This idea is developed in his revised book (1972, p. 49); "by making alternate use of the paired annealing furnaces, the glassmaking operation could continue more-or-less uninterrupted. While one of the leers was being filled with the day's product, the other would be gradually cooling". This is attractive, and may well justify the arrangement of F4, with its two chambers side by side. (fig 30).

The normal form of working furnace in the Forest areas of northern Europe is the single-chamber rectangular, with a raised bench or siege for the pots on either side of a central fire-channel. This type is described by Theophilus in the 12th century, and every English glasshouse follows it until wings or other extensions were added in the late 16th century. Why this should be the Forest norm is not very clear. Elsewhere the normal furnace was circular and vertical in arrangement.

Perhaps the most familiar form of this is the type with three tiers -- the lowest for the fire, the next for working, and the highest for annealing. This is standard throughout "non-Forest" Europe, and in the Mediterranean area. It seems to have a very long ancestry. But there is another circular vertical type, with only two tiers, one for the fire, and that above it for working. Annealing and other processes were carried out in subsidiary furnaces. It was sometimes found convenient to combine such a furnace (join it on, laterally) with a second furnace, which might be rectangular. In such a case the fire might be contained in a trench on the lowest level, with openings through which the heat could reach the chambers above.

The three-tier type is often called Venetian; Strömberg calls it Alexandrian, and the authors of Dansk Glas Eastern. The two-tier type is sometimes known as Flemish; to Strömberg it is Roman, to Dansk Glas Western. None of this nomenclature seems entirely satisfactory, and Charleston (1978) plumps for the simple and convenient terms Southern and Northern, which will no doubt become standard. Pliny seems to be referring to the two-tier double furnace when he uses the phrase continuis fornacibus. Theophilus

describes it in the 12th century, and one is illustrated by Agricola (1556). One with two conjoined circular ovens appears in Kunckel (1679, 1756 edition, reproduced e.g. in Dansk Glas 1970, fig. 319; Charleston 1978, p. 27).

A good example not far in time from Knightons is that at Trestenshult, near Ryd in Småland, Sweden, which dates from 1620-1640. This was excavated in 1932-33 by H. Seitz and Edv. Strömberg; they reported it in Jorden Runt, IV, 1932, and it was reappraised in a wider context in Dansk Glas (1970). The plan at fig 31, and the remarks above, will make further description unnecessary. The form exemplified at Knightons (F4) has no underlying or continuous fire-tunnel, but consists merely of two chambers side by side, on the same level, and with communicating opening. There seems no reason however to doubt that this is a variant of the double Northern type, adapted for a specialised purpose.

What that purpose was is made clear in the admirable account of glassmaking in the great Encyclopédie, (1751 etc.) There are very well-known and frequently reproduced illustrations in the Encyclopédie showing the processes of making crown. One hardly ever reproduced, unaccountably, shows a glassworker carrying the finished crown sheet on a two-pronged fork and about to insert it into an annealing furnace, which has a horizontal slit at an appropriate low level clearly designed precisely for this purpose (fig 32). The slit appears to measure some 1.25 m by say 30 cm. The superstructure is cut off just above the slit for the purposes of the drawing, and its shape cannot be determined. There is of course no evidence at all for the superstructure at Knightons, or indeed for the slit. But the presence of crown in both chambers of F4 makes it certain that crown was annealed in it, and highly probable that we are dealing with a furnace made to take crown sheets, which would necessitate a commensurate opening. (The crown sheets at Knightons were about 33 inches, or 825 cm, across, or 30.5 old French pouces.)

Reliance on the Encyclopédie of the mid-18th century need not cause hesitation -- French glassmaking methods had a very long life, and medieval practices continued until after the Revolution.

The invention of this type of furnace can no doubt be pushed back to the early days of crown itself. The great problem with making crown was how to anneal it.

The commonly-accepted inventor of crown in Normandy, until recently, was Philippe de Caqueray, in 1330 (e.g. Le Vaillant de la Fieffe 1873). But recent research (Lafond 1969, p. 37) has discovered crown in 4 th century contexts in the Middle East (Gerasa and Samaria), and at Quasi el-Heir el-Gharbi before 750; the earliest occurrence in western Europe is stained-glass panels from the cathedral at Rouen (13th century) and from the castle there (1270-1280). This throws new light on the whole problem.

Why the horizontal furnace took root in the potash-Forest-glass regions of northern Europe, as against the vertical type which continued to be used by the soda-glass makers of the South, has never been obvious. But the answer may lie in the making of crown itself, for whose annealing the horizontal furnace is so much more appropriate and convenient than the upper tier of a vertical furnace, which was not designed for this. It is arguable that this variant arose in the Middle East with, or soon after, the invention of crown there, and accompanied crown when it began to be made in Europe. This could have happened either through the normal medieval Islamic contacts, or been accelerated by the Crusades. But crown-making seems to leap direct from the Middle East into the Forest area. The possibility has been suggested that glassmakers from the Armanaz region of Syria may have helped to establish the industry in Normandy (Engle 1973, 10-11).

Armanaz, seat of ancient glassmaking, was in the territory of the Fraisnels from the mid-12th century for nearly a century. The Fraisnels came from La Ferté-Frênel, Orne, where glassmaking was done since the Middle Ages (Barrelet 1953, 186). The Saint-Lô family had connections with the Fraisnels in Syria also. Crown was made in Syria since Roman times -- did it appear in Normandy in the 12/13th centuries via these families? (see Thorpe 1961, 79, 80, n1).

If this could be established it could illumine much that is obscure, and make an intriguing affiliation between Syria,

Normandy and Knightons. For it greatly strengthens the case for Knightons having been set up by people from Normandy, and not by a local English family.

The task now is to find other examples in England -- Knightons is unlikely really to be unique, or to be the first glasshouse to make crown.

Phases of Wealden Glass. G.H. Kenyon, in his great survey of the Wealden industry (Kenyon 1967, pp 100 ff), found it necessary to distinguish between glass made before Carré (1567) and glass made after that date. The distinction is a real one, and some such classification had to be made. "Early" (Kenyon's Type Y) glass is brittle, easily scratched, has no sharp fracture, and is very corrosible; it is generally pale or milky-green, and may be bubbly. "Late" (Type X), is hard, tough, has a sharp fracture, and suffers little or no corrosion; it is often transparent, and is usually dark green with blue or olive shades.

The reasons for this difference are still not entirely clear, but the chambered or winged furnaces (e.g. Vann, Rosedale Etc.), or the more precisely-designed and neatly-built types (e.g. Fernfold (Kenyon no. 25, p 185)) seem to have much to do with it. The batches were no doubt more predictable, materials chosen more carefully, were better prepared, and the firing perhaps better controlled. Analyses of the glass suggest a lower potash content in the Late glass.

The division seems to come, in fact, a few years before Carré, as Kenyon later admitted (Kenyon 1967, 17, largely influenced by Knightons itself) (see Engle 1977, 5), and appears in the early 1560s, or even in the late 1550s. Knightons has only a very small proportion of what might be called Late glass, and this may well be cullet, from a local source already working to higher standards, or may be aberrant results of local attempts to improve. The bulk of its glass is however, squarely Early, even if it is at the end of this phase. Kenyon's Transitional is better discarded -- the Early sites with some Late glass may best be accounted for on the model of Knightons. But in spite of the obscurity of the change-over date, Early and Late are still convenient terms, and have been retained in this paper.

The Composition of the Glass. At an early stage in the excavation (1966) samples were analysed by Mr. F. Hartley of the Analytical Laboratory at Pilkington Bros. Ltd., St Helens (by kind permission of the Research Director, Mr. W.J.R. Merren, through Mr. D.E. Hogan, then curator of the Pilkington Glass Museum). The results were:

	sample no, V 11514 -- Frit in glassy form	V 11516 -- glass	V 11518 -- crown glass
SiO_2	66.2% weight	74.8	56.9
CaO	6.8	0.9	15.7
Fe_2O_3	1.6	2.7	0.82
TiO_2	0.5	0.5	---
Al_2O_3	6.3	6.1	7.7
MgO	3.9	0.5	5.8
BaO	0.1	0.2	trace
Mn_3O_4	1.0	0.3	0.8
K_2O	11.4	11.8	10.0
Na_2O	2.3	1.9	1.7
SO_3	---	trace	0.5

In 1973, a further series of analyses was carried out, in the Department of Physics, University of Surrey, using the electron microprobe technique. This work was kindly initiated by Dr. A.G. Crocker, whose report follows: "The analysis was carried out by G.J. Pickford of the Physics Department, University of Surrey, as part of a final year undergraduate project. The technique employed was Electron Microprobe Analysis using facilities of the Structural Studies Unit, Department of Metallurgy and Materials Technology, under the direction of Dr. P.T. Goodhew. The procedure used was not capable of detecting elements of atomic number less than 11 (i.e. H,He,Li,Be,B,C,N,O,F and Ne). Note that this list contains O so that the amount of oxides present has to be deduced from the other elements detected. Na (atomic number 11) could only be detected with difficulty. Four samples were analysed quantitatively

A. Deep green very hard opaque vessel glass. (this was a lump -- ESW).

B. Good quality opaque vessel glass of metallic appearance. (from waste tip -- ESW).

C. Dark green very hard drip of waste

D. Window glass, partially transparent.

The results are given in the table.

Comments

1. The compositions of the four samples are similar, A and B being particularly close to each other. Sample D, the window glass, has rather more SiO_2, CaO and Al_2O_3 and rather less MgO and K_2O than the others.

2. The average composition is very close to Blunden's Wood except for Na_2O which seems to be very low at Knightons (as in Late Wealden glass; Kenyon p 39). The high Al_2O_3 content is similar to Blunden's but not the other Early Wealden glass.

3. Features which distinguish the Knighton's glass are rather high Fe_2O_3 and MgO concentrations.

4. Excluding the Blunden's analysis, the compositions tend to be similar to Early rather than Late Wealden glass.

5. The total alkali content is intermediate between that for Early and Late Wealden glass given by Kenyon.

6. Only the analyses given by Kenyon and Wood (Blunden's) have been used for comparison. Others may exist but it does appear that a far more thorough study of the compositions of these glasses is required. The spread in the results which have been reported is probably due in part to the use of different techniques by different workers. Electron probe micro-analysis is probably not the best method available at present, but comparative studies of different glasses using this technique would be valuable.

Table — Composition of Samples in wt %

	A	B	C	D
SiO_2	57.2	59.2	57.5	60.7
Fe_2O_3	2.6	3.1	1.1	2.1
CaO	14.3	14.4	16.2	19.3
MgO	8.4	9.0	8.1	4.5
K_2O	8.7	9.1	9.4	6.7
Al_2O_3	4.0	3.8	3.7	6.1
MnO_2	0.9	0.8	0.8	0.8
Cl	2.8	2.1	2.4	1.3
P	trace	trace	trace	trace
Na	trace	trace	trace	---
Ti	---	---	trace	---
Cr	---	---	---	trace
S	---	---	---	trace
Cu	---	---	---	trace

Total	98.9+	101.5+	99.2+	101.5+	"(report ends)

It will be seen that samples A, B and C are very similar in composition, but that D has higher silica, lime and alumina content, and less potash. The amounts of these differences are not however very significant, and are probably all within the tolerance of different batches of Early glass. The analysis of glass from Blunden's Wood referred to in Dr. Crocker's note (Wood 1965, p 67) is:

SiO_2	57%
TiO_2	0.08
Al_2O_3	4.78
Fe_2O_3	1.32
CaO	17.50
MgO	6.95
K_2O	9.00
Na_2O	3.40

Kenyon, in his comparative table of different sites (Kenyon 1967, p 39) only includes "main constituents", and excludes alumina. Yet the comparison of Blunden's Wood and Knightons seems to indicate that they were using the same or a similar source of sand, and the figure for alumina may therefore be significant. The figures for potash are practically the same for the two sites.

Turning now to Late glass, Kenyon (loc cit) gives the figures for Sidney Wood (no. 38), the high quality of whose Late glass is unquestioned. Here the silica (57.7%) is comparable, and the potash lower (4.4%). Sites not in Kenyon, which may help to fill out the picture, are Bagot's Park -- Early (Crossley 1967, p 72), Rosedale and Hutton -- Late (Crossley and Aberg 1972, p 151). Four samples from Bagots Park yielded averages of

Na_2O	2.8%
K_2O	10.5%

i.e. in the same region as Knightons and Blundens Wood.
The results for Rosedale and Hutton were:

	R	H
SiO_2	58.84%	58.98%
$Al_2O_3+TiO_2$	5.81	4.98
Fe_2O_3	1.57	1.51
MnO	0.30	0.37

CaO	20.15	24.59
MgO	3.25	2.28
Na_2O	3.54	1.84
K_2O	6.20	5.16

-- both with very high lime and comparable alumina -- indicating a similar sand source, and lower potash than Blundens Wood, Bagots Park or Knightons. The differences appear to be consistent as between Early and Late. Taking the picture as a whole, and with all due reservation, Knightons must, on these analyses, be classed as an Early site (pace Kenyon (1967 p 208) who classed it as Late, on evidence now seen to be insufficient). This is consistent with the other evidence.

It will be noticed that the iron oxide revealed by all these analyses is Fe_2O_3, ferric oxide. Flavell and Smale (1974, p 15) point out that the presence of this oxide results in a yellow-green glass, whereas ferrous oxide (FeO) gives blue-green. The ferric form is certainly normal in the Weald.

The Source of the Sand. Sand for glassmaking has to be fine, and as free from impurities (mostly iron oxide) as possible, as these make the glass green. Additives to decolorise the glass were sometimes used, such as manganese dioxide, but there is little evidence for its use in the Weald.

The analyses of the Knightons glass show a quite low iron content, and it is probable that all that was done was to select as visually white sand as possible. Such sand did not occur at the site itself, but convenient sources existed only two or three miles away at Hambledon and Ewhurst, and rather farther away at Puttenham, Haslemere, Hindhead, Petworth and Graffham (Thurrell et al 1968, p 142). There may well have been small sources in the Greensand or Wealden systems, now worked out. Other sources are recorded for glass made after the Forest phase of the industry, and some of these may have been used in the 16th century also, such as Selham (Higgs 1964, p 63). Wooldridge & Goldring (1953 p 173 and 228) pointed out the probability that sand exposures near Chiddingfold were also used.

One of the many small sources that must have been used over the centuries may have been lighted on by that shrewd observer John Aubrey, who said "In the Grott at Albury is here and there sand as white and fine, as the finest powdered white salt. Quare Mr. H... if it would not be fit to make Glasse with? the like in some places in Windsore forest". (Bodleian MS of his Perambulation of Surrey (largely written in 1673), folio 96 verso. It is in fact partly repeated in The Natural History and Antiquities of Surrey, vol IV, p 69 (reprinted 1975), but without the implied link with glassmaking which makes it of interest in the present context.)

Potash and Lime. It would have been interesting to know the tree-cover at the time of the life of the glasshouse. It is known that beech or oak billets were the usual fuel in the Forest industry, and that the ashes from these, together with ashes from burnt forest plants like bracken, were used as the source of potash and lime. But no way presented itself for checking this at Knightons. Pollen from any topsoil remaining beneath the furnaces (assuming they were built more or less on the surface -- in fact the topsoil was probably cleared from under the walls) would have been destroyed by the heat. And pollen from the cullet store would inevitably become mixed, and would not yield a reliable date. No pollen analysis was therefore attempted, and there is no evidence to show the vegetation cover in the mid-16th century. A certain amount of carbonised wood turned up, mostly in quite small fragments, all over the site, and probably has no significance for the glasshouse itself. However, a mass of dark woody material occurred in the cavity in the northern line of stones between F3 and F4. It is uncertain whether this represents a small fire, a post, or a tree forcing its way through the stones. This material was kindly examined by the Forest Products Research Laboratory (then of the Ministry of Technology), through Mr. J.D. Brazier. The samples were identified as English Oak (Quercus robur or Quercus petraea); but this determination is not conclusive for the tree-cover in the 16th century, nor for the fuel used in the glasshouse.

Flavell and Smale (1974, p 27) record the rather surprising fact that it takes half a ton of wood to produce one pound of potash. This meant that at least when glass manufacture was on a commercial scale, and coal was used for firing -- from the mid-17th century, -- flux manufacture was undertaken by specialists. Even in the Forest

period, and certainly in a new location, ashes from various plants were used, until the furnaces could produce enough (Godfrey 1975, p 158). More information is needed on this point.

Coloured Glass. The insignificant number of pieces of coloured glass at Knightons (red, blue, purple) - less than a dozen out of some 12000 pieces found -- points almost certainly to their importation with other cullet, and very probably to foreign origin. A few such pieces were also found at Blundens Wood (c 1330), and the same conclusions may be applied to these also. There is in fact remarkably little evidence for coloured glass having been made in the Weald at all. The well-known ruby glass in a small crucible from Chaleshurst (in Guildford Museum - Kenyon (1967, p 161), and that from Malham Ashfold (Kenyon op cit, p 190), may be regarded as experimental, and are certainly highly unusual.

Professor R.G. Newton, formerly Director of the British Glass Industry Research Association and lately Honorary Visiting Professor at the University of York, has kindly drawn my attention to recent work on this subject, in England and on the Continent (outlined in Newton 1980). It is now accepted that all the coloured glass used in England during the Middle Ages came from the continent (Knowles 1926). Makers of soda-glass, in the Mediterranean region, appear to have got their colours by the use of metallic additives (e.g. copper). But the sharply-growing demand for coloured glass by the cathedrals and great churches of France and elsewhere in the 12th and 13th centuries[1] led to a northward movement of glassmakers into the Forest areas of NW Europe, where the source of flux was not natron or barilla, but the ashes of timber and other forest plants, giving potash instead of soda. The tree normally used for fuel in these areas (e.g. in the Forêt de Lyons in Normandy) was beech. Beechwood contains manganese and iron, and sand contains iron. The iron gave a green colour in reduced conditions of firing, and yellow when the firing was oxidising, and the manganese could be manipulated to yield a variety of colours.

---

(1) Some 80 cathedrals and 500 churches of near cathedral size were started in France alone in the century from 1170 to 1270 (Cowen 1979, 12)

Variation of the oxygen flow across the mouth of the crucibles (i.e. changing the atmosphere in the furnace), when beech ash is used as the flux, can produce a range of colours, from bright blue when the atmosphere was fully reducing, through green and amber, to brownish purple when the atmosphere was fully oxidising (work by Frau Sellner at Erlangen-Nürnberg University). Hints as to the use of this method (actually by altering the period of melting) occur in Theophilus. (Newton 1978).

When the glassmakers reached England, and settled in the Weald (presumably by the late 13th, certainly by the early 14th century), the timber immediately available to them on the clay lands appears to have been oak and not beech. Oak contains iron, but not manganese, so the production of "coloured" glass was not possible without the use of additives, for which there is no good evidence, except at Malham Ashfold.

I have rechecked, on the ground, the present tree-cover of the clay parts of the Wealden glass parishes (some are entirely on the Wealden clays, but the northern ones, e.g. Hambledon, Dunsfold and Alfold, are partly on sands). Beech grows freely on the North Downs (chalk), and on the greensand (Wooldridge and Goldring 1953, pp 136-7), as may be well seen at e.g. north of Shere, and at Ewhurst and north of Vann, but only in limited areas on the Weald clays, and those areas lie south of all but two glasshouses. Elsewhere the tree-cover is, at a rough estimate, 95% oak, with occasional birch, chestnut, ash and sycamore, and other trees; beech hardly occurs. It seems highly unlikely that oak has so totally replaced beech on the clay since the 16th century, and indeed Wooldridge and Goldring (1953, pp 134-5) say that the oak forest has been continuous during post-glacial times. This question is being further studied by Professor Willis (Department of Botany, University of Sheffield).

Kenyon (1967), refers to the use of beech (p.36), and quotes documentary evidence for Idehurst (p 45-49); and Godfrey (1974) also refers to beech (p 5 and 48; on p 160-1 she mentions the manganese content of beech ash). But, except for Idehurst, this adds up to very little. The only wood from Knightons to be identified (see p 47) proved to be oak, but the dating of this piece is not certain.

The edicts of 1614 and 1615 (see p 172) were presumably intended to apply to oak and not beech, as being the timber most appropriate to and required for shipbuilding and house construction.

Thus the evidence for the exclusive use of oak by most of the Wealden glasshouses seems overwhelming; but no convincing reason can be suggested why the glassmakers, many of whom were of continental origin, did not obtain beechwood from the nearest points on e.g. the greensand, and thus meet at least some of the market demand for coloured glass; this is a problem which will certainly require further study. (see Newton 1980, p 178). Unless economics accounts for this, perhaps a contributory factor may have been the large increase in the use of grisaille, painted on "white" (green) glass, from the second half of the 13th century, whether or not accompanied by painted medallions etc. of pot-metal; before then windows were predominantly of pot-metal, either painted or left clear. This change could have materially reduced the demand for coloured glasses, apart from the slowing-down of church-building itself in the 14th century.

The Distilling Apparatus. The presence of fragments of alembic at Knightons (collecting-channels, spouts) adds to the quite short list of finds of these vessels (Moorhouse 1972, p 101) -- Selborne and Pontefract priories; The More, Rickmansworth; Bramber Castle; 8 Castlegate, Nottingham. Distorted pieces at Knightons strongly suggest cullet of local origin, which again is a valuable addition to knowledge.

The Knightons glass also includes cucurbits, which, Moorhouse points out, are very rare in archaeological contexts (op cit p 102). Bagots Park (Early) and Buckholt (Late) seem in fact to be the only other glasshouse where these vessels can actually be shown to be made. The smaller pieces of this form were probably receivers. A receiver has now been reported from Rosedale (Crossley and Aberg 1972, fig 61, 31). See Moorhouse p 88 for a description of all these terms, and fig 20.

Distilling-apparatus of this type, in glass and pottery, was used until the 18th century. It was used in the stillhouse for the preparation of flavours, essences and medicinal remedies, and in monasteries for liqueurs. It was also used in alchemy.

In medieval times monasteries might have alchemical laboratories,[1] and until well into the 17th century private experimenters had laboratories in their houses.

This makes the widely-quoted verses from Thomas Charnock's Breviary of Naturall Philosophy (1557), contained in Ashmole (1652) of startling relevance here. They are accessibly reprinted in Kenyon 1967, p 83, but it will be convenient to repeat them here. Charnock writes:

"As for Glassemakers they be scant in this land,
Yet one there is as I doe understand:
And in Sussex is now his habitacion,
At Chiddingfold he workes of this Occupacion:
To go to him it is necessary and meete,
Or send a servant that is discreete:
And desire him in most humble wise
To blow thee a Glasse after thy devise;
It were worth many an Arme or a Legg,
He could shape it like to an egge;
To open and to close as close as a haire,
If thou have such a one thou needest not feare.
Yet if thou hadst a number in to store,
It is the better, for Store is no sore."

Thomas Charnock was born about 1524 in the Isle of Thanet. He met two alchemists: William Bird, last Prior of Bath, who had a phial of red elixir at the Dissolution, and hid it in a wall of Bath Abbey -- their meeting took place when Charnock was about 28 years old, say in 1552; and James S...., priest, who lived in the Close at Salisbury, about 1554. These two bequeathed their secrets (including the formula for the Philosopher's Stone) to Charnock, who must have been an apt pupil, before 1552. Charnock carried on their work. A serious accident, with fire, took place in his laboratory in 1555, but he is recorded as working in his laboratory at Camadge in

---

(1) The basis of the at first sight puzzling connection between medieval Christianity and alchemy is suggested by modern psychologists -- e.g. by Jung in Psychology and Alchemy (1953); a useful summary of his views is in Yolande Jacobi: The Psychology of C.G. Jung (London, RKP, 1942; 7th ed 1968, pp 142-3)

Somerset from 1562 until his death in 1581. He was buried at Otterhampton.[1]

Charnock's poem must therefore relate to the years 1552 (at least) or 1554 to 1557, which is exactly contemporary with the presumed date of Knightons. It is certainly not impossible (and very tempting to speculate) that Knightons is the glasshouse referred to by Charnock. It seems to be one of the very few glasshouses working in the Weald in the 1550s; and the only one which can indisputably be shown to be producing distilling apparatus at the precise time. It could of course have continued to supply Charnock and other alchemists after 1557; the poem clearly implies that the glasshouse was in active operation when it was written. It no doubt supplied distilling equipment for ordinary medical and domestic purposes as well.

If Charnock is to be relied on, and that he means Chiddingfold to be taken literally (and hence "Sussex" is a mistake), there are only a few candidates in this parish making Early glass. Broomfield Hanger (Kenyon's no 2 -- 1967 p 159) may be ruled out, as being too early in the 16th century; Upper Chaleshurst (no 3), a Peytowe house (Lower Chaleshurst, no 4, although put forward by Kenyon (p 83, note) must be ruled out as being a Late site); Fromes Copse (no 5); Gostrode II, no 6; Hazelbridge Hanger, no 7, too early, (probably 14th century); Prestwick Manor, no 10, ?too early; Redwood, no 11. But Kenyon cannot point to any distilling glassware from any of these sites.

If Sussex is not a mistake but Chiddingfold is, the Early sites in Sussex are -- in Kirdford parish, Crouchland, no 12 -- this did produce "rods and tubes of many shapes and thicknesses" (Kenyon p 171), and is ascribed to the end of the Early period -- so a serious contender; Hog Wood, no 15, probably 14th century; Little Slifehurst, no 18; Wephurst, no 21, probably 14th century. Wisborough Green parish, Malham Ashfold, no 29, ?c 1500. There are two other Early sites in Surrey, in Hambledon parish -- Blundens Wood, no 33, 14th century, and Gunter's Wood, no 34.

---

(1) For brief biographies of Charnock see DNB, and Anthony Wood: Athenae Oxonienses, II, 1692, col 492. There is much of interest about Charnock in the Ashmole MSS in the Bodleian Library, Oxford, particularly MSS nos. 962 and 1411.

So, with the just possible exception of Crouchland (although tube alone seems a flimsy argument for this site), Knightons is the only site in the area to have yielded distilling glassware in all its range of component forms, and that, moreover, in substantial quantities, making local manufacture certain. This is of course not conclusive proof that Charnock was actually writing about Knightons; but the distinct possibility is there.

Kenyon's remark (p 90) that Early glassmakers did not produce the quality of glass required for retorts, must in the light of the Knightons evidence, be challenged. Indeed, the quality of Weald-made specialised glassware is indicated, rather ruefully, by Charnock himself in the "Preface of the Author" to the poem quoted above:

"Goe forth little Booke in volume but small,
Yet hast thou in thee that is not in them All,
For satisfying the mindes of the Students in this Arte,
Then art thou worth as many Bookes, as will lye in a Cart:
Glad may he be that hath thee in his keeping,
For he may find through diligent seeking,
All things in thee which shall be necessary,
As Vessells and Instruments belonging to Alchimy;
Which would set many a Mans heart on fire,
To have the same knowledge they have so great desire.
And no mervaile though they be glad and faine,
For they have spent many a pound in vaine;
In making of Vessells of many divers sorts,
And have brought them out of many strange Ports:
Because they did not well understand,
That all things we need we have in England."

Certainly the Knightons pieces are Early.
It is an interesting speculation why an alchemist had to be so careful, "humble and discreet", when placing his orders for glass-ware. Was it merely because the glassmaster happened to be touchy, or to stand on his dignity as a gentilhomme? It must have been more than that. Presumably the references to discretion etc. are not there solely for stylistic reasons either. These qualities may then have been required (a) so as not to give away secrets of

the alchemists more than was strictly necessary; and (b) so as not to draw undue attention -- alchemists not only regarded themselves as a secret confraternity, but were frowned on by the Church. It throws an interesting sidelight on the glassmakers that they were willing in these circumstances to make vessels for alchemists at all! There is the further relevant fact that the vessel used by the alchemist for his work, and the actual glass of which it was made, both held symbolical meanings for the alchemist, and were therefore regarded by him with reverence and awe (cf C.G. Jung: Collected Works, particularly vol 13, Alchemical Studies, p 197).

The Cullet Problem,- the local product. The perennial problem posed by cullet-- what categories were the result of breakages or failures of products of the glasshouse, and what was brought in from elsewhere -- will probably never be fully solved. But at Knightons we can go a long way towards a solution. Here we have two valuable sources of evidence -- not found on all sites -- the glass on the floor of the annealing furnace (F4), and the contents of the waste tip.

(Waste tips are uncommon: that at Jamestown (Harrington 1972, 19) did not include glass vessel or window, only "furnace refuse".)

The cullet store itself can be interpreted in the light of these two sources. On this basis it may be safely accepted that the "imported" cullet (largely as exchange for new crown window, but perhaps also from other sources such as inns, apothecaries and specialised dealers) included at least:
the coloured and painted glass, the fine decorated glass, the roundels, the cut-offs, the marked-out and shaped pieces, the muff, and the cames. Conversely, the products of the glasshouse included: crown, flasks and bottles, drinking-vessels, alembics, urinals and other medical glassware, hourglasses, smoothers; moulded ribbed and wrythen patterns are also local. Doubtful pieces, which could be either, include milled based beakers, the square moulded bottle (if it is one);some of the vessel feet look exotic.

Harrington (1952, p 29, and 1972, 32) quotes Merret's list of the types of vessel which were made from "common green" glass:

"In domestick Affairs it makes drinking Vessels, infinite in Fasion, Colour, Largness
Bottles and Vessels to keep Wine, Beer, Spirits, Oyls, Powders
Dishes to keep and to serve Sweetmeats
Glasses to measure Time (= hour glasses)
Sleek-stones for Linnen (= linen smoothers)
Windows to keep us warm and dry, and to admit Light into our Dwellings
Tubes and Syphons and other experimental Equipment."

Merret (1662) is translating Neri (1612), which brings us back to the Forest period of glassmaking. This list is a remarkable reflection of the results of the actual excavation of the Knightons glasshouse, which clearly stands comparison with any other.

The figures on page M48 indicate how small a proportion of the total cullet was in fact extraneous. It might even be said that, if those who delivered new crown to the glaziers did not return with waste which the glaziers wished to get rid of, Knightons could have been imperturbably self-sufficient without it.

The few Late pieces were not confined to the cullet store, but turned up all over the site, including in F4, and the possibility must be faced that some of the products of Knightons were of Late quality.

<u>The Crucibles</u>. (see page M26). The crucibles raise some interesting questions. In fabric and size they seem to be normal for the Weald. The range of thickness is wide (1.1 to 2.8 cm), and this range is occupied by two quite distinct types, thin-walled and thick-walled. With the example of Blundens Wood before me, I was at first inclined to see the pots as either bucket or barrel-shaped. But analysis showed that in fact the bucket shape was confined to the thick type, and the thin type had straight walls incurving towards the rim in the last few centimetres; the barrel was rare, and may be accidental. A good comparison is Chambon's (1959, fig 24, right bottom), where he shows the development of wall-forms for Lorraine; his 14th - 18th century types are very similar to the Knightons form, and this may be another hint at the French origin of the glasshouse.

A feature of interest is the pinched-in rim, which occurs on most examples found, and may be taken as characteristic (fig 26 , p 38). Indeed, it appears that each glasshouse had its own rim-form -- e.g. the hammer-head at Blundens Wood (Wood 1965, 69), or the heavily inturned rim at Woodhouse Farm (Kenyon 1967, 55). These are, so to speak, signatures. And they greatly reinforce the view that the crucibles were made at each glasshouse, by one specialised potter, who was either one of the team, or came in to make batches of pots. These could have been fired in the main furnace at slack times. Kenyon suggests (1967, p 53) that there may have been one crucible-maker for this district; but the highly individual and local rimforms appear to militate against this view. Perhaps both situations obtained, some glasshouses having a man on the staff who could make pots, others not.

Three pots with anomalous rims were found, none in furnace contexts. These were clumsy, heavy and squashy, and quite different from the usual pinched-off type. One can only speculate about the presence of these. If they dated to the beginnings of the glasshouse, they might have been brought in then, or be made by someone who was feeling his way (if indeed he was the same man who made the "Knightons" form). No answer can be given, but their scarcity hints that they were not acceptable as the regular form.

While on this point, the difference between the pots at the extreme ends of the thickness range is very striking; but this is not in itself a reason for thinking there were two men at work. There may be a date difference, or it may be just the whim of one man.

Grooving or scratching occurs on a few pots, both thick and thin. (They may be single grooves, pairs, or three; one groove with scalloped line below; or crossed lines forming curvilinear lozenges). It is easy to explain away one groove, or even two, as the accidental slipping of a potter's tool; but the other types demand acceptance of a deliberate decoration. Kenyon (1967, 215) indeed accepts this for Buckholt.

It is unfortunately not possible to arrange the crucible types or sizes in a date sequence, nor to see a pattern of use. Thick and thin crucibles come from all furnaces, and some seem to have been

used for fritting. The thin pot in F4 had Early glass in it; the thin one in F3 broke while fritting. The thick bases seem to contain Late glass. But there is not enough evidence to harden on this as a sequence -- it is in fact not possible to say which type was used for what process, nor why one type was chosen. They may have both been used contemporaneously and indiscriminately, although Kenyon (1967, 55) seems to be leaning towards Bridgwater's suggestion that thick pots are late.

Crucibles were normally made by hand-moulding, and the distinctiveness of the rims also bears this out. Knightons produces no evidence that any were glazed, although glass spill on them is not uncommon. Many pieces of pot are fresh, clean and apparently unused. These are probably wasters, or failures in firing (another indication of local manufacture). Imperfect knitting of the lumps or coils might well leave bubbles, and make for weaknesses in the fabric.

There is documentary evidence for pot-making at the glasshouse. Godfrey (1975, 190) refers to the wages of a potmaker at Wollaton, and the Knole accounts contain an item under February 1586: "ii lode pot clay for makyng XII pots" (Kenyon 1965, 53, quoting T. Barrett-Lennard: Glass-making at Knole, The Antiquary, 41, 1905). Godfrey (p 143) says the pots "were made of the best fireclay available". The clay from which these pots were made has been analysed at Pilkington's Analytical Laboratory, St. Helens. The results are:

sample	V 11515	V 11517	(1.9.66)
SiO_2	72.6%	74.9	
Al_2O_3	18.6	17.3	
Fe_2O_3	2.2	1.7	
TiO_2	0.8	0.7	
CaO	1.8	1.4	
MgO	0.9	0.7	
Na_2O	trace	0.2	
K_2O	2.3	2.6	
L.o.I.	0.7	0.3	

--- very similar compositions.

The clay on which the site stands was also analysed, and showed contents of:

sample V 11519	(1.9.66)
SiO_2	54.3%
Al_2O_3	24.3
Fe_2O_3	6.9
TiO_2	1.0
ZrO_2	trace
CaO	0.3
MgO	0.8
K_2O	2.6
Na_2O	0.2
L.o.I.	9.5

-- very different.

It is thus quite clear that the pots were not made from the local clay, although it has quite good refractory properties.

A similar result was obtained from analyses of the pot and clay at Blundens Wood (Wood 1965, p 71). Here the iron content of the local clay was 5.92%, and of the pots 2.26%. The iron oxide content was virtually identical with that of Knightons clay, but the rest of the Blundens Wood analysis is not.

Another piece of crucible was examined at the University Chemical Laboratory, Cambridge, by Dr. David R. Cousins, as part of a joint experiment with Dr. G.P. Moss at Queen Mary College, London. Dr. Cousins reported (in letter to ESW 11th September 1969): "We have just run the Mössbauer spectrum of a crucible sherd from Knightons (labelled Knightons (16C)). This is part of our policy of covering as wide a variety of pottery types as possible from Surrey, and this was an example of pottery heated to a very high temperature. ... Dr. Moss is studying the X-ray fluorescence spectra of pottery sherds with exactly the same aims as our study of the Mössbauer spectra. Dr. Moss and I agreed that it would be a good idea to study exactly the same sherds to see how information derived from the two techniques compared. Since the Knightons sample was one of the sherds he was studying, we have run a spectrum of the same sherd.

The result is rather negative. The sherd contains even less iron than any we have examined to date (over 100 sherds). There is even less iron than in a fragment of pure white claylining from a kiln at Cheam. The quantity of iron is too small to enable any meaningful results to be obtained from the spectrum, although if we get time to run the spectrum at liquid nitrogen temperatures we may obtain a little more information. All we can say at the moment is that what little iron is present is there as Fe^{2+} in an octahedral environment, i.e. it is <u>not</u> present as the oxide. This means that not only should the clay source be relatively iron free, but that any iron in it will not be in the form of accessory minerals (e.g. siderite, hydrated iron oxides etc.) but will probably be substituting for Al^{3+} in one of the clay minerals. Dr. Moss' method, which yields a trace element analysis, will probably prove more useful than Mössbauer spectroscopy in this particular case."
It so happened that Dr. Moss was unable to continue his side of the experiment, and made no report.

We have not finally arrived at being able to pin-point the cource of the iron-free clay, but the indications are beginning to converge.

Charleston (1961 p 7) quotes Merrett, that in his day (1662) the clay for crucibles came from "Purbeck in the Isle of Wight (sic), the very same which make Tobacco Pipes." But, Merrett says, crucibles for "Green Glass are made of Non-such clay, mixed with another clay brought from Worcestershire, which bears the fire better than that of Nonsuch, but both together make the best pots". If this statement may be projected back a century, it gives a valuable clue. The Worcestershire source no doubt includes the clays of the Stourbridge area, well-known then and later for their suitability for crucibles. They were undoubtedly transported over long distances.

The Old Mine fireclay, white, from Stourbridge, was analysed by the Geological Survey (1920) (Lab no 611), and found to contain 1.04 % iron oxide, a lower figure than in the Knightons crucibles. The "Nonsuch Fire-earth", white variety (Lab no 659), gave a Fe_2O_3 content of 1.98%, but the silica is much higher, and the alumina lower, than at Knightons. A blend of the two, as Merrett indicates, may be the answer.

We can go a little further: there is an immediately apparent resemblance to the clay used for the white Surrey (Cheam) wares, which begin about 1300, and continue into the 17th century. Much effort has been devoted to identifying the source of this white clay. Holling (1969, p 19), in respect of white ware from Ash, has been able to pinpoint it to a small outcrop of the Reading Beds in Farnham Castle Park. These beds run in a long narrow line from west of Farnham along the north of the Chalk through Epsom and Sutton and beyond. The Farnham Castle clay has been worked out, but no doubt there was a line of workable outcrops, with local variations, including Nonsuch. If Farnham Castle clay was used, then sand was added, for greater strength, as the Farnham clay is very sand-free (per Roger Young, Guildford School of Art).

Dr. Cousins (see above) wrote to me on 1 October 1969 to say "I have just been examining a sample of clay from the clay-pits at Nonsuch which I baked at 1200°C a few years ago. I was struck by the similarity in appearance between this sample and the sample of the crucible from Knightons". He goes on: "We have used this approach (Mössbauer spectroscopy) on 'Cheam-ware; and preliminary results indicate that two sources of clay were used. We have located the source of one, and are fairly certain about the other -- it only remains to run the spectra to confirm this. The temperature of firing of the kiln was about 950°C."

This figure may incidentally throw an unexpected light on the question of where the crucibles were made. Even if the clay came from the Farnham-Nonsuch band, the pottery kilns were unable to sustain heat of the order required for crucibles; the crucible-makers thus had to use the glass furnaces. It remains of course also that crucibles are inconvenient to transport, and that it is more practicable to make them on the spot to meet the local requirements.

<u>The Pottery</u>. The paucity of pottery found at Knightons is puzzling. Only seven pots are represented in all, of which three -- the plain buff bowl, the green-glaze and saltglaze -- were from the cullet store, and can thus be firmly linked to the period of operation of the glasshouse. Two others -- the pinky-buff gritty,

and the black ware with lead glaze -- are at home in the 16th century, and may reasonably be considered as contemporary with the first three (although the assemblage does not lend itself to fine dating). The remaining two -- the yellow bowl and the willow-pattern blue and white -- may have been left by the canal builders or users.

This is in sharp contrast to the situation at other sites. At Blunden's Wood (Wood 1965 p 75) -- an early 14th century glasshouse -- 158 sherds came to light, representing 9 vessels, including a jug, a pitcher, bowls, plates, storage pots (although one may be a crucible). This assemblage, all closely datable to the period of the glasshouse, betokens cooking and eating on the spot. Even larger assemblages were excavated at Bagot's Park (Crossley 1967, p 75), where sherds contemporary with the glasshouse -- site 4, early 16th century -- represented cups, jug and flask. At Rosedale (Crossley and Aberg 1972, p 152) a wide variety of jars, jugs, dishes, pans and bowls was found.

These are all recently excavated sites, and can probably be taken as representative. This raises sharply the question "where did the Knightons glassworkers live?" There is no trace of any occupation-site, temporary or permanent, in the vicinity of the site. Mr. R.J. Charleston has kindly said (personal communication 18.3.75) that in his view the working of Forest glasshouses was likely to be seasonal, with a break each year possibly of as much as several months. During this time the furnaces would be rebuilt or repaired, supplies got in, and crucibles made. A similar concept underlies Kenyon's account of the "primarily yeoman" 16th century glassmaking families in the Weald, the Peytowes and the Strudwicks (Kenyon 1967, pp 117-120).

Yet, unless the family farm was close at hand, the glassmakers must either have lived on the site while the seasonal work was going on, or must at least have taken meals there. In the Swedish glasshouses, it was customary until well into the present century for the glass makers to live in or next to the glasshouse (in housing provided by the firm), or even to sleep round the furnaces (Anderbjörk 1966, p. 41). St. Gobain (1775-82) had ranges of tenements for the workers (Polak 1975, 42 and fig 12). Coming nearer home, Logan (1972, p 185) records two rows of workers' houses, at the Dumbarton Glass Works (c 1777 - c 1850) -- the others lived in lodgings.

Blundens Wood, Bagots Park and Rosedale fit this pattern of a certain amount of living on the spot. Yet Knightons does not, and the reason for this is not easy to find. The nature of the excavation makes it unlikely that pottery on the site would be missed. This is one of the unsolved enigmas of the site.

Mr. Holling has suggested to me that the workers may have had a separate hut or shelter outside the site, where they could rest and take their meals. This, if it existed (and it has not unnaturally not been located), would account for the virtual absence of pottery on the site itself.

The master himself, unless he were a local yeoman, presumably lived in a separate house not far from the glasshouse. The nearest old house is Old Knightons, a quarter of a mile away; this is both unpretentious and of suitable size and type. But, in spite of research kindly carried out by Miss. G.M.A. Beck (Guildford Muniment Room), no record can be found of the date of the building. Mr. John Baker has kindly examined the house from the architectural point of view. Old Knightons is a 3-bay timber-framed house with a later added bay. The principal posts have no cowls, and the framing is in equal rectangles. Mr. Baker assigns a date of about 1630 to this house, and thinks it extremely unlikely that it could antedate 1600, if indeed it goes back that far. No solution can therefore be offered to the problem of where the master or workers lived.

Archaeomagnetic Dating. In view of the interest of Knightons, Dr. Martin J. Aitken, FSA, of the Research Laboratory for Archaeology and the History of Art, Oxford, kindly agreed to take samples from the furnaces for archaeomagnetic measurement (for this method see Aitken 1970 a & b; Aitken and Hawley 1971; and Aitken 1975). Mr.Nicholas Hawley and Mrs. Joan Huxtable visited the site on 13 October 1969, and took several samples of burnt clay from the floors of each of the four furnaces. It was hoped to reveal differences in the measurements, which might point to a time-sequence for the structures, as well as establishing a date-bracket for the glasshouse as a whole.

Mr. Hawley (who carried out the measurements) reported later that satisfactory numbers of samples had been taken from furnaces 2 and 4,

both of which seemed eminently suitable for the purpose. A smaller number of samples were also taken from furnaces 1 and 3, although F3 was not sufficiently well fired to give reliable results (see page M36).

In June 1971 Dr. Aitken provided a list of all Post-Roman sites (those conveying "complete confidence" and "reasonable confidence") measured by the Laboratory. Furnaces 2 and 4 at Knightons came within these categories. (It was hoped to publish this list, with comments, in Archaeometry, but this has not yet been possible. In advance of this, I am grateful to Dr. Aitken for commenting to me on the Knightons measurements).

The measurements were: (D=remanent Declination; I= remanent Angle of Dip)

Furnace 2, 25 samples, D= $12.3^{o}E \pm 2.4^{o}$, I = $66.2^{o} \pm 1.4^{o}$

Furnace 4, 19 samples, D= $15.2^{o}E \pm 1.6^{o}$, I = $68.2^{o} \pm 0.5^{o}$

The error limits quoted are at the 68% level of confidence, and represent the standard error on the value as derived from the observed scatter of the individual measurements. The unstable "viscous" component was removed from each sample by heating and cooling in zero magnetic field prior to measurement. Some measurements were made on the F1 samples; the results did not appear significantly different from those from F2 and F4. It is thus not possible to say whether there is any considerable time-difference between F1 and the other furnaces.

Knightons is shown in the list referred to above with a time- bracket of 1500-1600. This wide bracket can be narrowed down by reference to the study made in connection with the glasshouse at Bagots Park (Aitken and Hawley in Crossley 1967). The rate of change in the Angle of Dip does not follow any known laws, and the actual rate during the 16th century can only be inferred from other archaeomagnetic measurements. The kiln at Potterton (Ant J XLVI, 1966, 255) has a date of close to 1500 on archaeological evidence, and a magnetic dip of 61.4^{o}. It so happens that three early scientists carried out direct observations on a suspended magnetised needle, Norman in 1576, Gilbert in 1600, and Ridley in 1613. Their measurements can be lumped together into a composite Angle of Dip in London of 72° for 1593. These figures imply a rate of change of 1° every ten years during the 16th century. On this basis a date of c 1535 ± 35

was proposed for Bagots Park (whose angle of dip was 65.5°), which accords well with the other evidence for that site.

Applying this rough rule to Knightons suggests a date in the region of 1550; allowance for the possibility of the remanent Angle of Dip being one or two degrees less than the true Angle would make the date one or two decades later. This is in striking agreement with the evidence of the coin (see page 32) and, if taken as the starting-point of a reasonable bracket, closely reflects the evidence of the glass itself. (page 44).

Published References. Interim notes on Knightons (by ESW) have appeared in the Surrey Archaeological Society's Annual Reports for 1967 and 1968; and Bulletin nos. 33 (September 1967), 60 (December 1969) and 102 (November 1973). Also in Post-Medieval Archaeology 1 (1967) 118-9; 4 (1970) 186; 8 (1974) 132-4; and Journal of Glass Studies, IX (1967), 149-50 (letter).

The site is listed in Kenyon (1967, p 208) as no. 42. This note was written in the early days of investigation, and its conclusions are not final. There are also references in Crossley 1967, p 61; Crossley 1972, p 427; Godfrey 1975, p 16 (n 4) -- this note contains inaccuracies, and has unfortunately been followed by Engle (1977, p 3); and Moorhouse 1972.

An illustrated article by F. Holling; Made in Chiddingfold, 1351 (in Cranfold Life III, 6, June 1967) refers to the Knightons excavations (photographs by Allan Batchelor).

Knightons is mentioned by Colin Platt in Medieval England (1978) as one of the new glasshouses run by Frenchmen, "with a markedly more sophisticated technology", "able to capitalize on consumer preferences", which formed part of "the impetus which converted window glass from the luxury it remained in the late sixteenth century to the necessity it had become by the seventeenth". (p 242). There is a bare mention of Knightons in Harden (1978, p 19) the site being later than the subject of his paper (which deals fully with Blundens Wood). Charleston (1978) 23 and 39 also mentions both sites. Vose (1980, 137) briefly describes the site, with plan; and on page 160 refers to the importance of the waste tip. She also deals with Blundens Wood in this book.